Bio-solids Application for Improving Soil Fertility and Crop Production in Jordan

First Progress Technical Report
(Nov. 2005 - Jan. 2006)

Contract No. (116/2005)

Prepared by

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Submitted to

Badia Research & Development Center / Jordan

And

International Arid Lands Consortium /
University of Arizona
U.S.A.

January/2006

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1. INTRODUCTION

Wastewater management is a continuing problem in many countries in the world. The problem is relatively more acute in Jordan because of the need to conserve and reuse water resources. The recent changes in regulations concerning municipal wastewater management in the country had resulted in significant increase in reclaimed water as well as bio-solids quantities. Although reclaimed water reuse plans have been set since the eighties of the last century, still there are no definite policies and solid regulations for utilizing generated bio-solids for beneficial usages. As a result, accumulated quantities at treatment plants is being dealt with in an uncontrolled manner that may cause negative impacts on public health and the environment.

The majority of municipal wastewater treatment plants MWTPs in Jordan are of secondary type, achieving nutrient and pathogen reduction utilizing conventional and modified activated sludge processes that generate relatively huge amounts of bio-solids. Bio-solids generated at MWTPs are usually thickened , dewatered using drying beds, then disposed of at adjacent dumping sites and landfills, while anaerobic lagoons are occasionally de-sludged for operational purposes, and bio-solids are inadequately stored in nearby areas . In other words, none of bio-solids are currently being reused or recycled . Obviously, these current practices cannot be continued indefinitely. Adverse impacts include potential operational problems such as leachate management (especially in rainy seasons) and gas hazards. Key stakeholders in Jordan are seeking sustainable methods of treating and recycling bio-solids in ways that minimize potential risks to the public and environment. Guidelines for bio-solids land application, currently the most widely–employed reuse options in many countries, need to be developed under Jordanian arid and semi-arid conditions.

This project is aiming at investigating the feasibility of utilizing bio-solids for improving soil fertility and crop production in Jordan. The specific measurable objectives are:

- To evaluate impacts of bio-solids application on soil properties and crop yield and quality based on field-pilot experiments.
- To recommend appropriate bio-solids application procedures and rates that are suitable to local conditions.
- To work through a collaborative model with the concerned governmental organizations and academic institutions.

In October 2004 the United States Agency for International Development USAID (Washington & Jordan/ Water Resources & Environment Office- Jordan), and through a cooperative agreement with the International Arid Lands Consortium IALC/ University of Arizona represented by the Badia Research & Development Center BRDC / Jordan, approved a request by the Royal Scientific Society RSS of Jordan to contribute in financing this project. A one-year contract was signed by BRDC and RSS in November 2004. Upon the end of the contract, both parties mutually agreed to extend the work for another year starting Nov. 2005, and another one-year contract was signed by both parties (contract No. 116/2005).

This report is the first of a series of progress reports required by RSS for the second year of the project, and covers the period (Nov. 2005 to Jan. 2006). The report summarizes different activities and tasks executed throughout this time period as well as projections for the anticipated subsequent activities.

2. PROGRAMMED & EXECUTED ACTIVITIES

Table (1) below shows the schedule for implementing different activities for the second year duration of the project (Nov. 2005-Oct. 2006). Following is a description of the activities executed throughout the period covered by this report.

2.1 Mobilization:

Based on the project's term of reference, RSS is conducting the project in close cooperation with the National Center for Agricultural Research and Technology Transfer NCARTT. NCARTT is a local research center involved in applied research activities in the agricultural field. Both parties signed a Memorandum of Understanding MoU upon which NCARTT is offering a piece of land as a research site within the premises of a research station in the northern part of Jordan (in Ramtha city).

Table (1): Implementation schedule for the project (Oct. 2005 – Oct. 2006).

Activity	Month												
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.
Bio-solids Sampling & Analysis	X		X		X		X		X		X		
Land Preparation	X	X											
Plantation		X	X	X	X	X	X	X					
Soil Sampling & Analysis	X								X	X			
Plant Sampling & Analysis						X			X	X			
Evaluation and Reporting				X			X				X	X	X

The project team had been formulated. The following staff are directly involved in different activities since the commencement of the second year of the project:

1. Dr. Bassam Hayek: PhD in Chemical Engineering. Director of the Environmental Research Center ERC / RSS. (Role: provide overall guidance, coordinate with various parties, and act as a contact person with IALC).
2. Eng. Wa'el Suleiman: M.Sc. in Water & Environmental Engineering. Researcher at ERC / RSS. (Role: supervise different activities, and participate in preparing progress and final technical reports).
3. Eng. Asma Alsheraideh: M.Sc. in Civil Engineering / Water Resources & Environment. Researcher at ERC / RSS. (Role: follow-up day-to-day work, and participate in preparing progress and final technical reports).
4. Dr. Nisreen Al-Humoud: PhD in Microbiology. Researcher at ERC / RSS. (Role: perform and supervise microbial analysis).
5. Naser Budier: B.Sc. in Agricultural Science / Soil, Water and Environment. (Role: perform and supervise physical and chemical analysis).

In addition, Eng. Loai Al-Quraan and Eng. Said El-Zuriqi, researchers at NCARTT Ramtha station follow up field-pilot experiments with RSS staff.

The *ad hoc* committee that was formed during the first year of the project continue its meetings. It comprises representatives of different stakeholders including governmental and non-governmental organizations as well as academic institutions. The committee meet regularly to follow-up and discuss different aspects and up-dated results of various activities, and to firm-up suggestions and recommendations. The following list shows names of the *ad hoc* committee members:

1. Dr. Manar Fayyad: Director of the Water and Environment Research and Study Center, University of Jordan.
2. Dr. Sa'ad Al-Ayyash: Badia Research and Development Center BRDC.
3. Dr. Ziad Al-Ghazawi: Jordan University of Science and Technology.
4. Eng. Saleh Malkawi: Water Authority of Jordan WAJ / Ministry of Water and Irrigation MWI.
5. Eng. Khalil Jamjoum: National Center for Agricultural Research and Technology Transfer NCARTT / Ministry of Agriculture.
6. Eng. Husni Hamdan: Ministry of Environment.
7. Eng. Ahmad Ulimat: Directorate of Water Quality, WAJ / MWI.
8. Dr. Bassam Hayek: Director of ERC / RSS.
9. Eng. Wa'el Suleiman: ERC / RSS.
10. Eng. Asma Alsheraideh: ERC / RSS.

2.2 Location:

As mentioned earlier, field experiments location was identified at Ramtha research station/ NCARTT. The site is located 70 km to the north of Amman and 5 km away from Wadi Hassan treatment plant (where bio-solids were obtained), 32°30 north latitude and 35°59 east longitude with an altitude of 590 m above sea level (figure(1)). The climate in the area is characterized by cold winter and hot summer with an average annual rainfall of (232 mm) for the period of (1998-2004), and the average temperature ranges from (5 °C) in January to (35 °C) in August. Generally, rainfall

starts in early November and ends in early April. Maximum rainfall occurs during January-February.

Figure (1): Map of Jordan showing the research site.

2.3 Land Preparation and Plantation:

Two shallow cultivations (10-12 cm depth) perpendicular to each other were carried out using chisel plow (duck foot model). The experiments have been established during the first year of the project in Factorial Randomized Completely Block Design (FRCBD) with four replications. Experiment plots of 4m X 6m were established. Field layout of the experiments is shown in figure (2).

The treatments have been designed to study two factors. The first is the bio-solids different application rates, the second is the accumulative and residual effects of different application rates. Dewatered bio-solids were obtained from Wadi Hassan treatment plant. Six different treatments, zero sludge application as a control, 2, 4, 6 and 8 T/ha in addition to one chemical fertilizer treatment (di-ammonium phosphate DAP) that represents the recommended fertilizer rate, were applied manually to certain sub-plots, these are designated as accumulative sub-plots and signed by (A) letters. The other sub-plots were left without any bio-solids application, these are designated as residual sub-plots and signed by (R) letters. Bio-solids were incorporated uniformly with soil to a depth of (8 cm). Barley was sowed using sowing machinery with a seeding rate of 100 kg/ha. Figure (3) shows the experimental site after one month of seeding.

2.4 Bio-solids Sampling and Analysis:

Seven dewatered bio-solids composite samples were collected from different drying beds at Wadi Hassan treatment plant to be analyzed. Table (2) shows analysis results of physical, chemical and microbial properties for the seven samples.

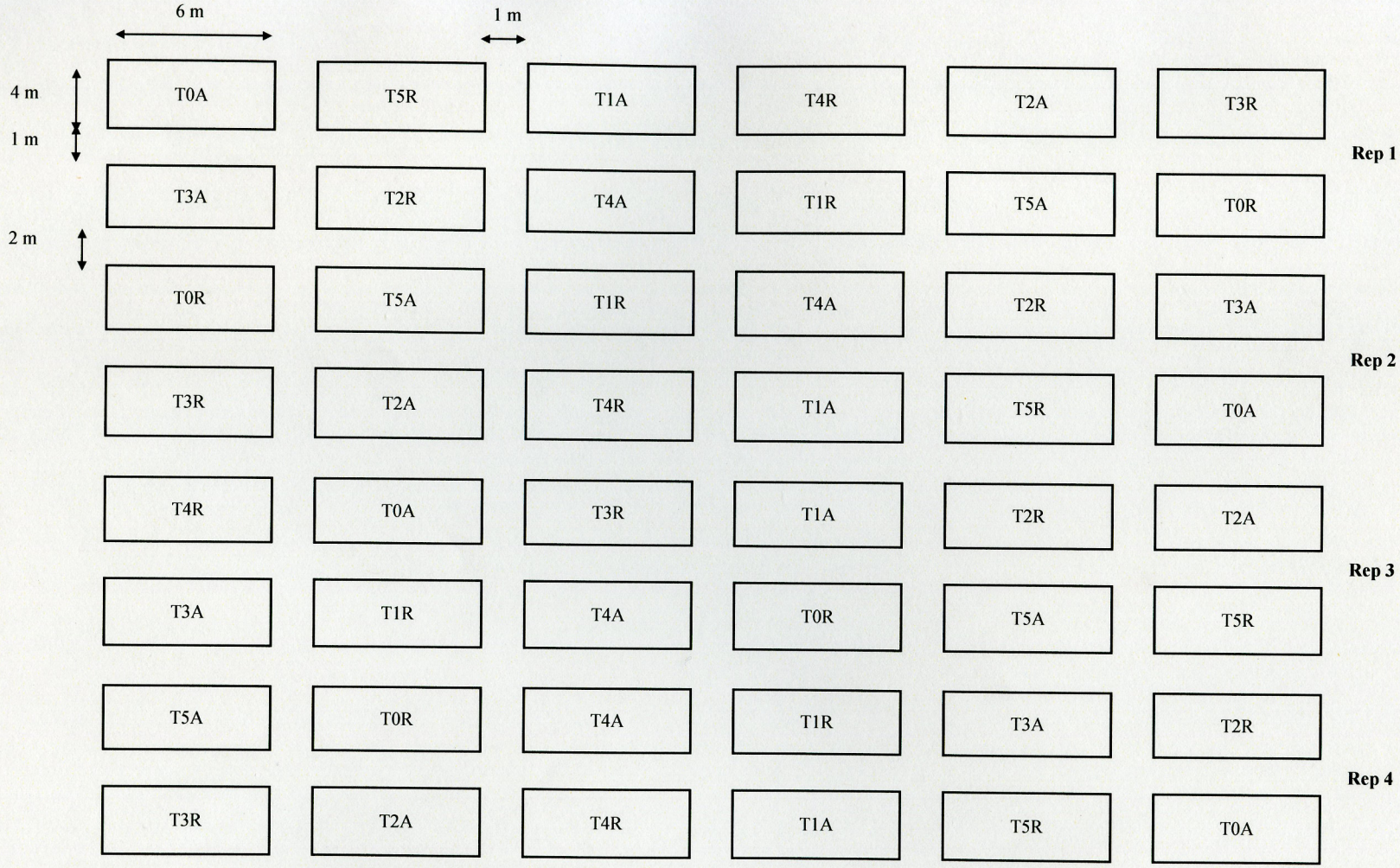
As can be noticed from the table, levels of trace metals in the seven samples are relatively low when compared to the requirements of the US EPA Rule 503 and the Jordanian Standard (1145/1996) for utilizing bio-solids for agricultural land application. However, fecal coliform levels are exceeding the limit (1000 MPN/gm), hence these bio-solids could be classified as Class (B) according to the US EPA regulations.

Bio-solids samples were analyzed following the "Standard Methods for the Examination of Water & Wastewater", Online, 2004, APHA, AWWA. Other analytical methods were also applied, especially those of the US EPA.

2.5 Soil Sampling and Analysis:

In order to collect data about the soil quality at the experimental site prior bio-solids application for the second year, twelve composite soil samples were collected at depths of 0-15 cm and 15-30 cm. Samples were analyzed in accordance to the Soil Science Society of America (1996) for general physical, chemical and microbial characteristics, results are shown in table (3).

The preliminary analyses show that the soil is alkaline, pH ranges between 7.9-8.1, with relatively low organic matter content, while trace elements levels are within normal low range. Table (3) shows also slight changes in Organic Matter, Electrical Conductivity EC, Cations Exchange Capacity CEC, macro-nutrients and some micro-nutrients concentrations when compared to soil baseline data carried out at the beginning of the first growing season.



T = different treatments, A = accumulative, R = residual

Figure (2): Experimental layout

Table (2): Results of bio-solids analysis at Wadi Hassan WWTP.

Parameter	Unit	S1	S2	S3	S4	S5	S6	S7	Average	JS: 1145/1996	US EPA	
											Ceiling Conc.*	Poll. Conc.**
TS	%	90	91	90	91	91	92	91	91	-	-	-
TVS of TS	%	66	65	66	66	67	65	66	66	-	-	-
T.kj.N	%	5.8	5.7	5.8	5.6	5.7	5.7	5.6	5.7	-	-	-
NH4-N	%	0.040	0.042	0.045	0.043	0.056	0.064	0.054	0.049	-	-	-
T-P	%	0.34	0.39	0.34	0.48	0.46	0.35	0.39	0.38	-	-	-
K	mg/kg D.W.	3088	3485	4245	2111	3253	2439	1234	2836	-	-	-
As	mg/kg D.W.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	< 75	< 75	< 41
Cd	mg/kg D.W.	2.00	2.04	1.81	2.13	1.86	1.73	1.30	1.83	< 85	< 85	< 39
Cr	mg/kg D.W.	21.3	27.4	18.1	16.3	20.6	21.9	12.4	19.7	< 3000	-	-
Cu	mg/kg D.W.	103.1	103.6	94.8	78.9	101.0	100.5	74.5	93.8	< 4300	< 4300	< 1500
Pb	mg/kg D.W.	41.2	41.8	37.2	41.8	38.9	38.4	28.1	38.2	< 840	< 840	< 300
Hg	mg/kg D.W.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	< 57	< 57	< 17
Mo	mg/kg D.W.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	< 75	< 75	-
Ni	mg/kg D.W.	28.4	31.6	27.3	34.2	28.3	29.1	21.3	28.6	< 420	< 420	< 420
Se	mg/kg D.W.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	< 100	< 100	< 36
Zn	mg/kg D.W.	744	741	680	576	722	716	547	675	< 7500	< 7500	< 2800
Co	mg/kg D.W.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	< 150	-	-
Salmonella	MPN/4 gm	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	< 3/4 gm	< 3/4 gm	
TFCC	MPN/gm	>1.10E+03	>1.10E+03	>1.10E+03	>1.10E+03	>1.10E+03	>1.10E+03	>1.10E+03	>1.10E+03	$< 1 X 10^3$	$< 1 X 10^3$	
Nem. Eggs	Egg/gm	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	< 1/4 gm	< 1/4 gm	

D.W. : Dry Weight.
N.D. : Not Detected.
*: Maximum concentration of each pollutant that bio-solids can contain and still be land applied. Limits are applied as maximum, never to be exceeded values.
** : Land applier has no land application requirements relative to pollutants for bio-solids meeting these limits.

Table (3): Soil quality at the experimental site prior to application / second year.

Parameter	Unit	To		T1		T2		T3		T4		T5	
		0-15 cm	0-15 cm	0-15 cm	0-15 cm	0-15 cm	0-15 cm	0-15 cm	0-15 cm	0-15 cm	0-15 cm	0-15 cm	0-15 cm
pH 1:1	SU	8.1	8.0	8.0	8.0	8.0	8.0	8.0	8.1	8.0	8.1	7.9	8.0
EC 1:1	dS/m	0.696	0.526	0.493	0.552	0.547	0.622	0.660	0.642	0.681	0.594	0.618	0.644
CEC	cmol/kg	38	39	43	37	36	37	37	37	38	37	38	33
Organic matter	%	1.95	1.86	2.01	2.02	2.19	2.09	2.03	2.02	2.18	2.53	2.39	2.11
T.kj.N	mg/kg D.W	867	866	1013	969	1021	1017	1016	961	981	933	972	944
NH4-N	mg/kg D.W	22.0	30.5	20.7	25.8	25.2	26.9	25.8	20.7	32.8	29.0	35.0	37.7
NO3-N	mg/kg D.W	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
available-P	mg/kg D.W	8.7	8.0	13.6	12.9	9.7	12.1	12.6	14.7	14.2	12.8	13.8	38.2
available-K	mg/kg D.W	44	46	52	42	42	42	36	26	32	36	26	28
exchangeable-Na	cmol/kg D.W	64.0	49.6	56.5	62.6	85.0	70.0	69.6	76.5	82.6	87.8	90.0	100.0
exchangeable -Mg	cmol/kg D.W	8162	8236	8003	7880	8081	7721	7842	7687	7899	7859	7828	7553
exchangeable -Ca	cmol/kg D.W	8477	8440	8547	8406	8498	8244	8171	8061	8115	8172	8164	8052
As	mg/kg D.W	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Cd	mg/kg D.W	0.835	0.470	0.574	0.625	0.490	0.500	0.428	0.506	0.522	0.733	0.481	0.481
Cr	mg/kg D.W	20.30	21.20	23.10	23.00	20.60	21.10	18.20	23.40	22.34	N.D.	7.73	7.30
Cu	mg/kg D.W	8.35	2.56	2.30	2.20	1.93	3.28	1.90	4.28	2.24	23.62	8.46	39.70
Pb	mg/kg D.W	6.00	6.30	6.63	7.14	5.68	6.30	5.01	6.58	6.21	14.65	9.51	8.71
Hg	mg/kg D.W	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Mo	mg/kg D.W	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Ni	mg/kg D.W	21.10	21.00	22.70	22.35	20.31	21.50	19.43	23.42	21.92	48.40	19.33	19.33
Se	mg/kg D.W	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Zn	mg/kg D.W	6.53	8.20	7.62	6.49	5.83	6.36	6.21	8.46	6.84	57.4	21.1	21.0
Co	mg/kg D.W	35.0	33.42	29.80	30.50	26.60	30.50	25.50	34.46	27.14	31.30	28.73	30.50
Salmonella	cell/gm	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
TFCC	MNP/gm	0.23	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Nem. Eggs	cell/gm	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

D.W. : Dry Weight.
N.D. : Not Detected

Figure (3): The experimental site after one month of seeding.

2.6 Quality Assurance Schemes:

Quality control schemes were followed so as to ensure a high degree of confidence of the analyses results. Those include, but not limited to, the following: analysis of duplicate and spiked samples (not less than 10%), analysis of external samples (certified reference materials); internal and external calibration of analytical instruments.

2.7 Other Activities

- **Modification of the Jordanian Standard No.(1145/1996):**

A sub-committee from the project *ad hoc* Committee was formed in order to modify the current Jordanian standard No.(1145/1996) for bio-solids reuse in agriculture. The sub-committee held it's meetings in a weekly or bi-weekly basis during the period Aug.-Nov. 2005. The modified version of the standard is now in the process of accreditation by official parties.

- **Scientific Workshop and Seminar :**

A workshop on risk assessment of bio-solids used for agricultural purposes was held at RSS during the period Dec. 13-15,2005. Among different activities of the workshop, researchers from University of Arizona presented their experiences in

reusing bio-solids for planting some crops such as cotton and barley among other beneficial usages. Representatives from different stakeholders including governmental and none-governmental organizations as well as academic institutions and the private sector participated in the workshop in addition to representatives of international donors.

A scientific seminar was also held for successive two days after the end of workshop to discuss modifying the Jordanian standard for bio-solids reuse in agriculture (No. 1145/1996). Many institutions participated in the process including Jordan Institution for Standards and Metrology (JISM), Ministry of Water and Irrigation (MWI) and Ministry of Environment in addition to some academic institutions.

- **A Field Survey on Bio-solids Management Practices in Jordan:**

A field survey was carried out by representatives of RSS and WAJ during the period Aug.–Nov. 2005 aiming at investigating and assessing current management practices of sludge and bio-solids in Jordan including treatment, handling, testing, disposal and application. Nineteen MWTPs operated or supervised by WAJ were involved in the survey. A technical report as well as a guide will be prepared showing main results.

2.8 *Ad hoc* Committee meetings:

The *ad hoc* committee held a meeting on Dec. 1st, 2005. Different aspects were discussed, among these are results of the field survey carried out by RSS and WAJ, and the issue of modifying the current Jordanian standard No.(1145/1996) for bio-solids reuse in agriculture.

3. INTERNATIONAL VISITS

Dr. Akrum Tamimi, representative of IALC/University of Arizona, visited RSS during Oct. and Dec. 2005 to discuss different aspects of the project with the research team at RSS. Among these are the preparation of scientific papers and technical articles, and the preparation for the scientific workshop and seminar.

4. ADMINISTRATIVE ACTIVITIES

Management of this project is the responsibility of ERC/RSS. A project leader, and researchers specialized in different fields are directly involved in all activities related to the project. RSS is conducting this project in close cooperation with NCARTT through a memorandum of understanding signed by both agencies.

5. PROJECTIONS

Referring to the project execution plan (Table 1), the following activities will be conducted throughout the coming three months (Feb.-Apr. 2006) when the second progress report will be issued:

(A): Crop Measurements:

Some crop measurements will be conducted, among these are the following: number of plants, number of tillers per plant, dry weight, and number of fertile tillers per plant.

(B): Plant Sampling and Analysis:

Plants at tillering stage will be sampled and analyzed for chemical and microbiological properties.

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ANNEX (1)

Photos Taken During the Second Growing Season