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

Second Progress Technical Report
(Feb. 2006 - Apr. 2006)

Contract No. (116/2005)

Prepared by

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Submitted to

Badia Research & Development Center / Jordan

And

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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 second of a series of progress reports required by RSS for the second year of the project, and covers the period (Feb. to Apr. 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 (Oct. 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		
Land Preparation	X	X											
Plantation		X	X	X	X	X	X	X					
Soil Sampling & Analysis	X					X			X	X			
Plant Sampling & Analysis						X			X	X			
Evaluation and Reporting				X			X				X	X	X

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. Naser Budier: B.Sc. in Agricultural Science / Soil, Water and Environment. (Role: follow-up field-pilot experiments with NCARTT staff, perform physical and chemical analysis and participate in preparing progress and final technical reports).

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:

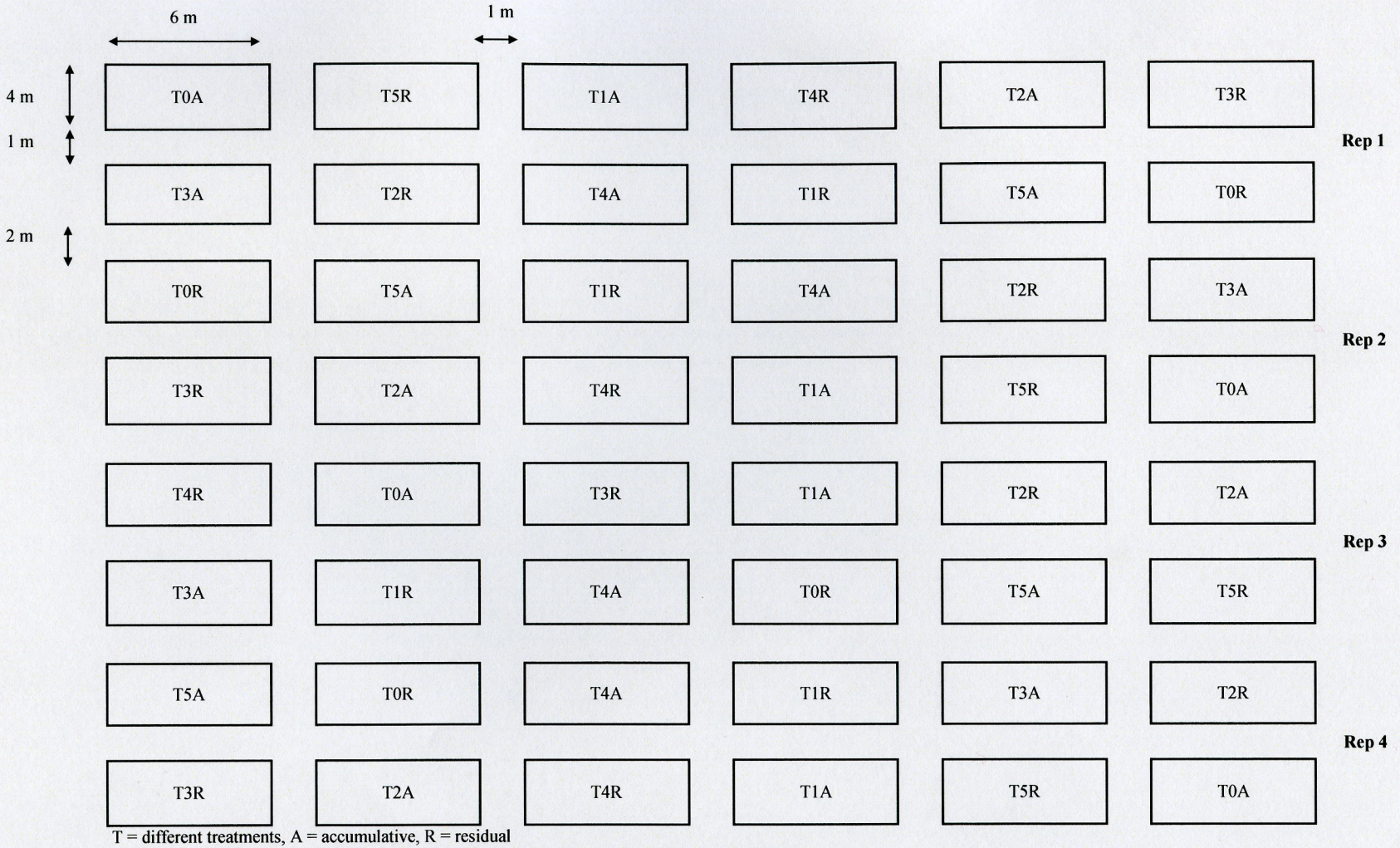
As mentioned earlier, field experiments location was identified at Ramtha research station/ NCARTT. The site is located 70 km to the north of Amman and 5 km away from Wadi Hassan treatment plant (where bio-solids were obtained), 32°30 north latitude and 35°59 east longitude with an altitude of 590 m above sea level (figure(1)). The climate in the area is characterized by cold winter and hot summer with an average annual rainfall of (221 mm) for the period of (1998-2006), 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 Plant Sampling and Analysis:

Plant "barley" samples were taken randomly from all plots in three replications for chemical analysis and plots in one replication for microbiological analysis (Figure (2) shows the layout of the experiment). A total of 36 samples were chemically analyzed and 12 samples were microbiologically analyzed. In order to carry out chemical analysis, samples were dried at 65 C° for 48 hrs, then ground to a fine powder using a laboratory mill with 0.5 mm sieve, the milled products were mixed thoroughly and kept in glass jars. Samples were analyzed for total nitrogen, protein content, nitrate, total phosphorus, total potassium, total sodium, total magnesium, boron, and trace metals. Samples for microbiological analysis were directly moved to the labs to carry out the required analysis (Salmonella spp., TFCC, *E. coli*). Figure (3) shows plant sampling and preparation of samples.



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

Figure (2): Experimental layout.

Figure (3): Plant sampling and samples preparation.

2.3.1 Plant Chemical Analysis at Tillering Stage

Table (2) shows chemical analysis results of barley at tillering stage for the different treatments. Macronutrients results show that, in general, plots with accumulative bio-solids application have higher total nitrogen, protein, phosphorus, sodium and potassium levels than those with no bio-solids accumulative application (plots that did not receive bio-solids application at the beginning of the second growing season). Maximum measured levels were obtained at accumulative bio-solids application rate of (8ton/ha).

Micronutrients levels in plant were not significantly affected with bio-solids application. Relatively low levels of zinc, nickel, lead and cupper were determined although the concentrations of zinc and cupper increased slightly with increasing bio-solids application rate. However, lead concentrations show an increase with accumulative application of bio-solids, the concentration at maximum bio-solids accumulative application rate was about eight times that of the control case.

2.3.2 Plant Microbiological analysis at Tillering Stage

Table(3) shows microbiological analysis of barley at tillering stage, results of analysis for TFCC, *E.coli* and Salmonella spp. show that these species were not detected in all plant samples.

Table(2): Chemical analysis of barley at tillering stage *.

Treatment**	TN (%)	Protien (%)	P (%)	Ca (%)	Na (%)	K (%)	Mg (%)	NO3 (mg/kg DW)	Pb (mg/kg DW)	Zn (mg/kg DW)	Cu (mg/kg DW)	Ni (mg/kg DW)	B (mg/kg DW)
T0A	1.73	10.10	0.24	0.26	0.13	2.08	0.17	66.33	0.10	46.72	6.64	0.51	17.69
T0R	1.55	9.04	0.24	0.25	0.14	2.16	0.17	74.67	0.12	41.82	7.14	0.30	11.80
T1A	1.67	9.75	0.25	0.20	0.13	2.19	0.17	67.67	0.51	49.06	8.09	0.98	12.90
T1R	1.65	9.61	0.24	0.23	0.13	2.08	0.17	60.67	0.30	52.68	6.57	0.35	12.71
T2A	1.78	10.39	0.24	0.23	0.13	2.24	0.18	61.00	0.17	50.08	7.71	0.23	10.11
T2R	1.65	9.63	0.27	0.28	0.14	2.22	0.17	62.33	0.33	39.53	7.44	0.33	8.54
T3A	2.10	12.25	0.27	0.26	0.20	2.55	0.19	54.33	0.50	56.31	7.50	0.48	11.55
T3R	1.53	8.92	0.25	0.26	0.12	2.17	0.18	48.33	0.28	47.63	6.57	0.40	10.30
T4A	2.23	13.02	0.29	0.23	0.25	2.78	0.20	43.33	0.79	47.43	6.98	0.58	18.70
T4R	1.73	10.08	0.25	0.23	0.11	2.00	0.18	52.67	0.68	56.69	6.85	0.45	9.19
T5A	2.04	11.90	0.24	0.23	0.16	2.46	0.19	55.00	0.62	36.44	6.69	0.46	14.85
T5R	1.61	9.36	0.24	0.22	0.12	1.86	0.16	42.00	0.49	46.20	5.72	0.36	6.87

(*): Average of (3) samples.

(**):T0: control,T1: 2ton/ha,T2: 4ton/ha,T3: 6ton/ha,T4: 8ton/ha,T5: chemical fertilizer, A: accumulative and R: residual.

Table(3): Microbiological analysis of barley at tillering stage*.

Treatment**	TFCC (MPN/g)	*E. coli* (MPN/g)	Salmonella spp. (Presence or absence /100g)
T0A	<0.03	<0.03	N.D.
T0R	<0.03	<0.03	N.D.
T1A	<0.03	<0.03	N.D.
T1R	<0.03	<0.03	N.D.
T2A	<0.03	<0.03	N.D.
T2R	<0.03	<0.03	N.D.
T3A	<0.03	<0.03	N.D.
T3R	<0.03	<0.03	N.D.
T4A	<0.03	<0.03	N.D.
T4R	<0.03	<0.03	N.D.
T5A	<0.03	<0.03	N.D.
T5R	<0.03	<0.03	N.D.

(*): Results for one sample.
(**): T0: control,T1: 2 ton/ha,T2: 4 ton/ha,T3: 6 ton/ha,T4: 8 ton/ha,T5: chemical fertilizer, A: accumulative and R: residual.
N.D.: Not Detected.

2.4 Soil Sampling and Analysis:

Soil samples at a depth of (0-15cm) were collected randomly from all plots in three replications for chemical analysis and plots in one replication for microbiological analysis. For chemical analysis, samples were air-dried at NCARTT Ramtha station labs then transferred to RSS labs in clean labeled plastic bags where they were sieved at (2mm) sieve size. Samples were then analyzed for electrical conductivity (EC), organic matter (OM), pH, available P, available K, available Na, available Mg, available Ca and trace metals. Samples for microbiological analysis were collected in clean labeled plastic bags then transferred to RSS laboratories to carry out the required analysis (Salmonella spp. and TFCC). Figure(4) shows soil samples preparation for analysis.

2.4.1 Soil Chemical Analysis

Table(4) shows chemical analysis results for soil during the second growing season, results shows that pH , EC, magnesium and calcium values were not significantly affected by bio-solids application. On the other hand, nitrogen, potassium and phosphorus contents increased with accumulative bio-solids application and results were more than that of the control plots. Maximum values of nitrogen, potassium and phosphorus in soil were found at accumulative bio-solids application rate of (8ton/ha). Organic matter values were not highly affected with accumulative bio-solids addition.

Figure (4): Soil samples preparation.

Micronutrients concentrations in soil at different treatments show slight differences for most of the analyzed elements even for accumulative plots, this is mainly attributed to the relatively low levels in bio-solids. However, some results of these elements (chromium, nickel and zinc) show increase for plots with accumulative bio-solids application over the residual plots and the control.

2.4.2 Soil Microbiological Analysis

Table (5) shows soil microbiological analysis during the second growing season, results of analysis for TFCC and Salmonella spp. show that these species were not detected in all soil samples.

2.5 Supplemental Irrigation

Two successive supplemental irrigations were carried out during March 2006 because of the shortage in rainfall which had a cumulative value of (150mm) during the growing season (2005/2006). The total irrigated water amount is about ($60m^3$), equivalent to an average of (40mm).

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. In addition, four plant and four soil samples were analyzed at NCARTT laboratories for the same chemical analysis carried out at RSS laboratories.

Table(4): Chemical analysis of soil during the second growing season *.

Treatment**	pH (SU)	EC (ds/cm)	P (mg/kg)	TN (mg/kg)	Ca (mg/kg)	Mg (mg/kg)	Na (mg/kg)	K (mg/kg)	OM (%)
T0A	8.2	0.39	13.6	925.7	8318.5	710.7	112.7	598.9	2.2
T0R	8.2	0.38	14.3	910.8	8153.5	785.2	111.3	558.6	2.1
T1A	8.2	0.44	17.8	1069.3	8249.5	696.7	124.4	699.4	2.5
T1R	8.2	0.39	16.3	1043.5	8300.0	790.9	120.6	676.3	2.4
T2A	8.3	0.42	17.8	1068.1	8000.7	848.3	132.6	706.0	2.4
T2R	8.3	0.40	16.3	1030.0	8067.9	795.0	122.3	666.8	2.2
T3A	8.2	0.40	22.6	1189.9	8013.9	789.0	113.6	724.8	2.5
T3R	8.2	0.40	20.4	1115.7	8097.9	773.7	98.2	718.0	2.2
T4A	8.2	0.40	25.8	1193.7	8023.8	835.8	121.9	757.5	2.4
T4R	8.3	0.37	19.4	1114.9	8041.1	809.0	116.1	684.0	2.3
T5A	8.3	0.40	20.5	1035.5	8080.5	808.7	117.7	637.4	2.2
T5R	8.3	0.38	17.7	1027.5	7824.7	854.8	128.3	632.4	2.1

(*): Average of (3) samples.

(**):T0: control,T1 :2 ton/ha,T2: 4 ton/ha,T3: 6 ton/ha,T4: 8 ton/ha,T5: chemical fertilizer, A: accumulative and R: residual.

Table(4): Cont., Chemical analysis of soil during the second growing season *.

Treatment**	As (mg/kg)	Cd (mg/kg)	Cr (mg/kg)	Cu (mg/kg)	Pb (mg/kg)	Hg (mg/kg)	Mo (mg/kg)	Ni (mg/kg)	Se (mg/kg)	Zn (mg/kg)	B (mg/kg)
T0A	4.85	0.76	22.35	11.75	6.75	2.58	1.17	19.04	0.54	11.19	7.90
T0R	4.66	0.82	24.33	12.23	6.75	3.08	1.28	19.65	0.47	13.93	6.24
T1A	5.82	0.89	35.33	12.00	7.52	3.23	1.63	40.27	0.63	17.11	4.00
T1R	3.78	0.70	33.84	10.82	6.23	1.81	1.41	27.38	0.48	14.38	3.65
T2A	5.70	0.85	25.90	13.10	7.40	2.93	2.56	21.65	0.77	11.14	4.48
T2R	4.71	0.70	21.30	9.81	5.88	1.53	1.23	19.21	0.55	7.68	3.63
T3A	5.70	0.85	25.22	11.49	7.20	2.66	1.32	20.95	0.98	15.07	5.22
T3R	5.30	0.91	25.51	11.14	7.07	2.04	1.72	24.17	1.29	9.15	4.96
T4A	5.42	0.85	35.25	11.08	6.77	2.30	1.11	22.04	1.12	9.51	4.11
T4R	4.98	0.80	34.30	11.10	6.13	1.70	1.47	26.23	1.03	9.26	4.32
T5A	6.32	0.91	40.16	11.42	7.53	2.07	1.89	28.32	1.25	8.13	3.72
T5R	5.96	0.82	27.87	10.60	5.89	2.18	1.49	24.17	1.36	8.17	4.10

(*): Average of (3) samples.

(**):T0: control,T1 :2 ton/ha,T2: 4 ton/ha,T3: 6 ton/ha,T4: 8 ton/ha,T5: chemical fertilizer, A: accumulative and R: residual.

Table(5): Microbiological analysis of soil during the second growing season *.

Treatment**	TFCC (MPN/g)	Salmonella spp. (Presence or absence /25g)
T0A	<0.3	N.D.
T0R	<0.3	N.D.
T1A	<0.3	N.D.
T1R	<0.3	N.D.
T2A	<0.3	N.D.
T2R	<0.3	N.D.
T3A	<0.3	N.D.
T3R	<0.3	N.D.
T4A	<0.3	N.D.
T4R	<0.3	N.D.
T5A	<0.3	N.D.
T5R	<0.3	N.D.

(*): Test value for one sample.
(**):T0: control,T1: 2 ton/ha,T2: 4 ton/ha,T3: 6 ton/ha,T4: 8 ton/ha,T5: chemical fertilizer, A: accumulative and R: residual.
N.D.: Not Detected.

2.7 Other Activities

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

With regard to the modification of the Jordanian Standard No.(JS: 1145/1996), the *ad hoc* committee prepared and approved a modified version of the standard taking into consideration the major findings of this research project. This proposed standard was presented and discussed throughout several meetings with the National Domestic Wastewater Management (NDWM) Committee (a committee headed by the secretary general of WAJ/MWI and formulated from decision makers at different governmental and research institutions). The proposed standard was slightly modified and approved by NDWM committee. In April, 2006 WAJ sent the standard to the Jordan Institution of Standards and Metrology JISM for final approval and dissemination.

3. 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.

4. PROJECTIONS

Referring to the project execution plan (Table 1), the following activities will be conducted throughout the coming few months:

(A): Plant Harveting:

Barley will be harvested by the end of May /2006.

(B):Crop Measurements:

A (1.0 m^2) area in each plot will be sampled randomly. Plant will be manually harvested from the sampling area. Total biological yield (Kg/ha) will be recorded as the total weight of the above-ground parts (grain and shoot). The harvested samples will be threshed, cleaned then the grains will be weighed to determine the grain yield (Kg/ha).

(C): Plant Analysis:

Further plant sampling and analysis will be conducted at the harvesting stage, and will be analyzed for total nitrogen, protein, total phosphorus, total potassium, trace metals in addition to some microbial analysis (Salmonella spp., TFCC and *E.coli*).

(D): Soil Analysis:

Upon harvesting, composite soil samples will be collected at a depth of (0-15cm) from each plot. These composite samples will be analyzed for pH, EC, CEC, organic matter, mineral nitrogen (NH_4 and NO_3), available phosphorus, exchangeable potassium, sodium, micronutrients and trace metals, in addition to some microbial analysis (Salmonella spp. and TFCC).

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ANNEX (1)

Photos Taken During the Period Covered by This Report


إستخدام الحمأة لتحسين خصوبة التربة وانتاجية
المحاصيل الزراعية في الأردن
Bio-solids Application for Improving Soil Fertility
and Crop Production in Jordan
With the Support of
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