AG:NECP/BAH/501/KUW
Technical Report

FAO/NEAR EAST COOPERATIVE PROGRAMME

RESEARCH AND DEMONSTRATION ON PROTECTED VEGETABLE PRODUCTION

B A H R A I N

THE STUDY AND IMPROVEMENT OF SOIL PRODUCTIVITY UNDER PLASTIC TUNNELS AND OPEN FIELD CONDITIONS

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

ROME, 1983

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THE STUDY AND IMPROVEMENT OF SOIL PRODUCTIVITY UNDER PLASTIC TUNNELS AND OPEN FIELD CONDITIONS

Report prepared for
the Government of Bahrain
by
the Food and Agriculture Organization of the United Nations

based on the work of

S.A. Amer
FAO Soil Fertility Specialist

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ABSTRACT

This report covers activities of the Fertility and Management Expert during his assignment (November 1979 to January 1983) with the project Research and Demonstration on Protected Vegetable Production in Bahrain. The results are presented in the form of guidelines for the technical staff of the Directorate of Agriculture for future research. The studies were implemented under high plastic tunnels, in the open field, under low tunnels in the regular growing season (September to May) and in the summer season of 1982. The vegetable crops under experiment were cucumber, determinate and indeterminate tomato, peppers, eggplant, squash and okra. The studies involved evaluation of the potential fertility of soils under the plastic tunnels at Budaya, and of 47 sites for future expansion in protected vegetable production in Bahrain at the farmers' level. Assessment of the quality of the irrigation waters as well as management of hydroponics were included in the study. Ideal formulas of nutrient solutions for growing tomato and cucumber including maximum, optimum and minimum concentrations of nutrients are given. Detailed tables of experimental data and analysis of variance tables, are also contained in the report.

Recommendations cover soil management practices, quality of irrigation water, mulching and irrigation under plastic tunnels and use of organic, mineral and foliar fertilizers and fertilization. Other subjects discussed are sterilization, blossom end rot of tomato fruits, modification of micro-climate during summer, cucumber varietal response to fertilization and rates of mineral fertilization for vegetables under the drip irrigation system, as well as extension to farmers' fields.

The Food and Agriculture Organization is greatly indebted to all those who assisted in the implementation of the project by providing information, advice and facilities.

TABLE OF CONTENTS

LIST OF TABLES

1. INTRODUCTION

1.1 BACKGROUND

The main purpose of the project 'Research and Demonstration on Protected Vegetable Product in Bahrain' NECP/BAH/501/KUW, was to introduce new vegetable production practices through the use of economically feasible protection techniques against the adverse climatic conditions which prevail in the country and to improve soil fertility and plant nutritional practices.

The long-term objectives of the project were to assist the Government of Bahrain to achieve better use of the country's natural resources of land and water for increased production of important vegetable crops to achieve a maximum degree of self-sufficiency; and to explore investment opportunities in the field of intensive vegetable production.

More specifically, the project was to:

- test simple single and double-span plastic tunnels, equipped with cooling, ventilation and supplementary heating systems, for the production of important year-round vegetable crops such as tomato, cucumber, peppers, eggplant and squash;

- test new irrigation techniques with emphasis on suitable drip irrigation systems in conjunction with plastic mulching of various types;

- test and introduce new cultivars of important vegetable crops adapted to the new systems of production, with emphasis on virus, heat and salt tolerant cultivars;

- initiate a research programme to deal with the immense nutritional problems resulting from poor soil fertility and poor quality irrigation water;

- establish adequate training facilities, for local trainees in the operation, supervision and management of new cultural practices, in intensive protected cropping of vegetables;

- demonstrate to farmers and advise them on the use of new cultural techniques recommended by the project.

The two-expert project became operational in May 1979, when the Project Manager/Production Horticulturist, arrived.

The Soil Fertility Specialist was on post from 2 November 1979 to 31 December 1982. Three consultants were provided (consultant in environmental horticulture, March 1980; an entomologist, March 1981; a horticulturist, October 1980 and February 1981).

This report concerns the activities of the Soil Fertility Specialist.

1.2 ASSIGNMENT OF THE SOIL FERTILITY SPECIALIST

The Soil Fertility Specialist was required to:

(a) study and determine fertility problems in Bahrain in relation to the use of brackishwater on different crops;

(b) initiate a research programme for the improvement of soil fertility by the use of organic matter, soil amendments and chemical fertilizers by foliar or soil application on different vegetable crops.

The Specialist's counterpart officers were Mr Nabeel S. Al-Hamdan to April 1980, his replacement Mr Ahmad El-Saad to October 1981, who was followed by Ms Ahlam M. El-Tamiemi to December 1982. Further assistance was provided by Mr Gaafer Hussain, Field Technician, Mr Ali Haroun, Agriculture Extension Officer (farmer's field experiment), and by Mr Sayed M. El-Qourashi (soil and water sampling from farmers' fields). Personnel of the Soil and Water Laboratory also assisted with soil water and plant analyses.

1.2.1 Programme

Three plans of work for the study and improvement of soil fertility in Bahrain were proposed by the expert: in December 1979 for the 1979/80 agricultural season; in August 1980 for the 1980/81 season; and in August 1981 for the 1981/82 season. A summer production and research programme for 1982 was jointly prepared with the Project Manager in April 1982. The work plans were seasonal because the assignment of the expert was for one year and was renewed annually. All proposed plans of work were technically cleared by FAO headquarters Rome.

Implementation of the first plan of work, for the 1979/80 season, started on 20 November 1979, and subsequent plans of work were also implemented as scheduled. The experiments, observational trials and the studies implemented were those agreed upon with government officials. They were chosen according to the available facilities, counterparts and local technical staff and considering the on-going studies by the FAO 'Regional Project for Land and Water Use in the Near East Region and North Africa' REM/71/306. The results of the studies, observational trials and experiments of the first two agricultural seasons 1979/80 and 1980/81 were reported in detail in two technical documents (Appendix 5, items 4, 12) and are summarized here.

The work was organized as follows.

Research under high plastic tunnels. Research covered the following investigations, observational trials and studies:

- investigation on mulching for improving soil productivity and management for cucumber production;

- observational trial on the effect of irrigation regime on indeterminate tomato production;

- comparative study of soil and foliar application of mineral fertilizers and their effects on yield of indeterminate tomato and cucumber;
- yield response of indeterminate tomato to foliar application of micronutrients;
- yield response of indeterminate tomato to addition of NPK fertilizers;
- differential response of some varieties of cucumber to fertilization;
- a study on blossom end rot of tomato.

Research in the open field. This work was limited to vegetable crops which are grown under cover, and included the following investigations, observational trials and studies:

- improving productivity of a light soil by organic matter addition;
- yield response of squash to various nitrogen carriers;
- soil and foliar application of superphosphate or urea on okra yield;
- soil and foliar application of a compound mineral fertilizer on trellised indeterminate tomato;
- assessment of addition necessary of NPK fertilizers to indeterminate and determinate tomatoes, eggplant, bell pepper and long pepper grown on light soil;
- demonstration of a fertility trial in a farmer's field on organic and inorganic fertilizer use.

Research under low plastic tunnel conditions. This involved three experiments on yield response of determinate tomato, bell pepper and long pepper to addition of NPK fertilizers.

Summer trials. Fertility trials under plastic tunnels and shade houses in summer on tomato, cucumber and peppers were carried out in 1982, as well as a trial on yield response of okra in the open field to NPK fertilizers.

Soil and irrigation water studies. These studies covered:

- evaluation of the potential fertility of the plastic tunnel soil site at Budaya;
- evaluation of potential fertility of some vegetable farms in Bahrain for protected vegetable production;
- assessment of the quality of irrigation waters in Bahrain.

Formulation of hydroponic nutrient solution. Trials in hydroponics covered proper concentrations of nutrient solutions, i.e., maximum, minimum and optimum ranges of elements in nutrient solutions. Some formulas were reached.

1.2.2 Soil and Water Laboratory

Attempts were made to organize the newly built laboratory, and some essential soil tests were conducted on a routine basis. Guidelines on soil and water analyses were prepared in Arabic, in line with the available facilities, for the laboratory assistants. Analysis of soil and water samples was also undertaken, and a laboratory technician, Mr A. Nabi Ahmed Habib, was trained in this work. The laboratory is now operating smoothly, with one qualified officer in charge, two technicians and one labourer. It is equipped with most of the required apparatus and chemicals, some of which came through the FAO Regional Project REM/71/306. Some more equipment is needed, and spare parts for soil and water analysis work. The laboratory needs to be enlarged to cover also analysis on fertilizers and plant materials. The Soil Fertility Specialist offered advice and his technical expertise to all the laboratory personnel when requested or when deemed essential.

1.2.3 Overseas visits

In April 1981, the Specialist accompanied by technical assistant Mr A. Nabi Ahmed, visited Kuwait, the United Arab Emirates and Qatar, to observe protected vegetable projects run by government and private farmers. Meetings were held with the personnel, to discuss the various activities and means of solving common problems.

The 12th International Congress of Soil Science, New Delhi, India, 8 to 16 February 1982, was attended by Mr Jaffer H. Ahmed, the Deputy Director of Agriculture, and by the Soil Fertility Specialist. The theme of the Congress was 'Managing Soil Resources to Meet the Challenges to Mankind'.

1.2.4 Training

Direct training on research planning and implementation, experimental observations and data recording was imparted to the soil fertility counterparts and personnel of the research and development section. Field assistant Mr Jaafar Hussein was given on-the-job training on cultural practices in the nursery, in plastic tunnels, shade houses and in the open field. The expert also lectured on field sampling for fertility soil testing, interpretation of soil results, essential plant nutrients, soil and plant fertilization,hydroponics and nutrient solution to project personnel and extension officers. Extension officers and farmers received indirect training through their visits to the experimental sites in the plastic tunnels and in the open field.

1.2.5 Education and extension

Participation in preparing guidelines for agricultural education for high schools in Bahrain (with Directorate of Agriculture and Ministry of Education), was a further activity.

Two extension notes were issued in Arabic, on soil sampling for soil testing and on fertilizing vegetable crops in the open field under the flood irrigation system.

The expert also acted as a focal point for the first World Food Day celebrated on 16 October 1981.

1.3 CLIMATE, SOIL AND WATER RESOURCES AND CROPS

1.3.1 Climate

Bahrain has an arid climate modified by maritime influences. There are two seasons during the year, winter (November-April) and summer (May-October).

The main characteristics of the climate are high summer temperatures, mild winters, high relative humidity, irregular scant rainfall mostly in winter and persistent winds prevailing from the northwest. Appendix 1 contains details (1980-82). Summarized information is given below.

Temperature and rainfall

	Winter	Summer
Mean daily maximum temperature	20-29 °C	32-38 °C
Mean daily minimum temperature	14-22 °C	25-31 °C
Mean daily maximum humidity	82-88 %	82-90 %
Mean daily minimum humidity	42-60 %	40-48 %

Annual rainfall: 20-233 mm, annual average 70 mm.

Rainfall usually comes from thunder showers and squalls which can cause floods on agriculture areas particularly where drainage is imperfect. Blights spread after rainfall and cause considerable damage to tomatoes.

Evaporation rates range from 2 mm per day in winter to approximately 7 mm per day in summer. The number of sunshine hours throughout the year is relatively very high, with an annual average of almost 10 hours. Consequently, shade to protect vegetables against hot sun is essential especially during summer. Dust storms are frequent, particularly from May to October, and last for some days (2-6 days). The northerly (Shamal) wind is the predominant wind with a speed of 10-12 knots and windbreaks are needed for cropping practices. Most farmers use dry date palm fronds as windbreaks as well as for shading material.

1.3.2 Soil resources

Geologically, Bahrain is a shallow elongated dome characterized by Eocene and Neocene rocks which are partly covered by Quaternary sediments and a complex of pliestocene deposits. The dominant rocks are calcic limestones and dolomites with subsidiary marls and shales.

The soils of Bahrain in general are saline, gypsiferous and calcareous. Soil profiles depths are limited by the presence of petrocalcic or lithic contact at variant depths. Soil structure in most cases is poorly defined. The soils have a hyperthermic temperature regime.

Many of the solonchaks soils of Bahrain belong to the Aridosol order, Orthids suborder and Calciorthids great group. The sandy soils are Entisols coming into the great group of Torripsamments as Torrifluvents Other pedologically underdeveloped soils are considered Torriorthents.

1.3.3 Water resources

The main source of groundwater in Bahrain comes from three aquifers, regionally called Alat, Khobar and Um-ErRadhuma (traditionally termed A, B, and C aquifers) originating in Saudi Arabia and extending beneath the sea. These aquifers have been derived from the Eocene-Paleocene aquifer system.

Information on these aquifers is given below.

Aquifer	Thickness	Total dissolved salts	Productivity
A Alat	80 m	2 000 ppm	Low
B Khobar	40-55 m	2 000 - 5 000 ppm	Good
C Um-ErRadhuma	350-500 m	8 000 ppm and above	

Most of the irrigation water in Bahrain comes from the Khobar aquifer.

The quantity of extracted water has been estimated to be 160 million m^3 per year. Of this quantity, 75% is used at present for agriculture; the number of wells (including drilled wells) is estimated to be 2 000. Optimum water conservation is under consideration by the State. There are plans for the reuse of drainage water and treated sewage effluent for irrigation.

1.3.4 Crops

The agricultural land in Bahrain was estimated to be 6 000 ha but the actual cultivated land amounts to 3 700 ha. This is confined to the northern part of the main island with narrow strips extending down the west and east coasts. Within this area water is available for irrigation. The average farm size is 4.3 ha, the range being 0.5 to 20 ha and above. Although most farms in Bahrain are very small, land use is very complex as farmers grow a wide range of crops.

Date palms remain the largest crop, followed by alfalfa and vegetable crops. Tomato, cabbage, cauliflower, raddish, lettuce, eggplant, peppers, onion, celery, beet and carrots predominate in the winter months. In summer melons, various cucurbits and okra are mainly grown. A few crops are under cultivation, and include papaya, lime, mango, grapes, figs, guava, sapota, pomegranate and almonds. People appreciate ornamental plants and there is a future for expanding production.

1.4 FERTILITY EXPERIMENTS 1982/83 AGRICULTURAL SEASON

The following experiments and demonstration trials under low and high tunnels and in the open field are ongoing in the 1982/83 season.

1. Yield response of tomato to increasing rates of potassium application under plastic tunnel conditions.

2. Effect of split application of superphosphate on tomato and cucumber yields under plastic tunnel conditions.

3. Yield response of cucumber to potassium application in the presence of different base mineral fertilizers under plastic tunnel conditions.

4. Effect of split application of slow release fertilizer on yield of long red cayenne peppers under plastic tunnel conditions.

5. Effect of split application of urea on the yield of squash and bell peppers under plastic tunnel conditions.

6. Effect of split application of potassium on the yield of eggplant under plastic tunnel conditions.

7. Effect of increasing rates of superphosphate on the yield of long green peppers under plastic tunnel conditions.

8. Comparative study on soil and foliar application of a complete mineral fertilizer on yield of round purple eggplant under plastic tunnel conditions.

9. Yield response of tomato (determinate and indeterminate), eggplant, long green peppers, lettuce, cabbage, cauliflower and onion to increasing rates of NPK fertilizers under drip irrigation and open field conditions.

2. RESULTS AND CONCLUSIONS

Tables 1-100 contain experimental data; variance tables of the experiments are given in Table 101-113.

2.1 RESEARCH UNDER HIGH PLASTIC TUNNEL CONDITIONS

All experiments involving high plastic tunnels were carried out at the project site at Budaya, under tunnels equipped with two extractor fans on one side for ventilation. In some cases, there were also Kool-cell perforated pads operative only from April till October. The tunnels measured 30 x 8 x 3 m (height). The drip irrigation system with precoiled microtubes was used at a discharge rate of 0.5 gal/h.

The brackish Budaya water was used for irrigation (Table 1). The pH value lies within the normal range usually encountered for irrigation waters. Sodium and chloride can be toxic to some sensitive crops since their concentrations are above 10 meq/litre; however, the sodium toxicity in Bahrain is often modified and reduced due to the abundance of calcium carbonates and the gypsum present in the soils. There is also a seasonal variation in the salinity of the irrigation water. A steady increase is noticed in the salt content of the irrigation water, but the water quality class remains the same at C4-S2 (very high salinity water with medium sodium content). Most of the vegetable crops are tolerant to semi-tolerant to boron, and are not expected to be affected by the boron level of the water. Plant analysis for boron should however be carried out in the future.

In general, the soils of the experimental sites are light in texture (loamy sand to sandy loam), and low in organic matter content. They are calcareous and contain considerable amounts of gypsum which increase with depth. They are also slightly to moderately saline and alkaline in reaction. There is a compact cemented layer below 60 cm from the surface. There is variation in soil properties under each tunnel due to the continuous addition of the locally named 'sweet sand' (Table 2). The addition of sweet sand is continually required to increase the effective soil depth and to compensate for the subsidence of the soils due to the dissolution of gypsum present in the soil. Analysis indicates that the transported sweet sand is very low in organic matter content and in both available phosphorus and potassium. It has considerable amounts of calcium carbonate and sulphates, magnesium chlorides and carbonates and sodium chlorides. No harm is expected from its sodium chloride content since the sand has to be leached before cultivation and calcium is present in abundant quantities.

2.1.1 Effect of mulching on improvement of soil productivity and management for cucumber production

Mulching conserves water, reduces the upward capillary movement of soil water and cuts down the amount of salts that accumulates in the soil. These advantages are expected to be reflected on yield and salt movement in soil.

An experiment was conducted in the 1981/82 agricultural season to study the mulching effect on yield of cucumber and on salt movement in the soil. Cucumber variety Femdan, which the project proved to be one of the outstanding varieties, was direct seeded on 15 October 1980. The plant density was 3 plants/m^2. Two irrigation regimes were used, irrigation for two hours or for three hours once every other day at the rate of 0.5 gal/h. Three mulching treatments were used: without mulch (control), with black polyethylene mulch, and with translucent mulch. Each mulching treatment was replicated twice under each irrigation regime.

Harvesting started on 17 December 1982 and lasted for 60 days, during which time 14 harvests were collected at an average rate of one harvest every 4.5 days.

The effect of polyethylene mulching on yield of cucumber is indicated in Tables 3 and 4 for the two irrigation regimes. Data revealed an increase in yield due to mulching, but this increase was not statistically significant. Data showed that irrigation for three hours at a rate of 0.5 gal/h once every two days in winter increased the yield slightly over that of the two hours irrigation at the same rate and frequency (Table 5). It was noticed that black polyethylene mulch controlled weed growth better than the translucent mulch. Data showed that polyethylene mulching reduced the soil salinity at the surface (0-30 cm) soil (Table 6). It considerably increased bicarbonates and decreased sulphates in the surface soil. It also decreased soluble calcium and magnesium in the surface soil. Sodium adsorption ratio considerably increased under black polyethylene mulching. No change in sodium adsorption ratio was noticed under translucent mulching. No noticeable change was noted in soil pH due to mulching treatments.

2.1.2 Observational trial on the effect of irrigation regime on indeterminate tomato production

Since the brackishwater of Budaya (C4-S2 class), is used for irrigation it may be advisable to add more water at each irrigation than regularly applied in order to leach any salt which may accumulate near the surface. Two irrigation regimes were compared to study their effect on yield of tomato and salt accumulation under plastic tunnel conditions.

Tomato variety Floradel was seeded on 3 September 1980 in Jeffy 7 pots in the nursery, and the seedlings were transplanted on 3 October 1980 in the plastic tunnel. Two treatments were used: irrigation for either two or three hours at the rate of 0.5 gal/h once every other day in winter, or once every day in summer. Each treatment was replicated three times.

Harvesting started on 31 December 1980 and lasted until 28 April 1981. During the period, 29 harvests were collected.

A study of the effect of the irrigation regime on the yield of tomato (Table 7) showed an increase in yield under the two-hour treatment, but it was not statistically significant. The effect of the irrigation regime on some soil characteristics is indicated in Table 8. Continuous leaching tends to lower soil pH, to reduce salinity and available soil phosphorus in the surface 0-30 cm layer and intensifies the injury of nematodes.

2.1.3 Comparative study of soil and foliar applications of mineral fertilizers and their effect on yield under plastic tunnel conditions

The soils of Bahrain are commonly calcareous with a high content of salts and alkaline pH values. Soil application of fertilizers is subjected to loss and alterations which will reduce nutrient utilization by plant roots. Foliar spraying the plants with the needed fertilizers can increase the nutrient utilization by the plants. This practice can be used after the soil application of an organic fertilizer and the first dose of soil applied mineral fertilizers. A study was conducted on tomato in one season, and on cucumber in another season.

2.1.3.1 Effect on yield of indeterminate tomato

Tomato variety Floradel was seeded on 3 September 1980 in Jeffy 7 pots in the nursery, and the seedlings were transplanted on 3 October 1980. A basal treatment of the organobiological fertilizer, "Confuna",was added at 1.5 kg/m^2, and thoroughly mixed with the soil. Six treatments of fertilization were trireplicated in a completely randomized block design. The treatments were:

1. Foliar spraying once a week with N and K.

2. Foliar spraying once a week with N and K + 6 micronutrients.

3. Foliar spraying once a week with N and K + soil application of the micronutrients.

4. Soil application of N and K once every two weeks.

5. Soil application of N and K once every two weeks + soil application of the micronutrients.

6. Soil application of N and K once every two weeks + foliar spray once a week with the micronutrients.

Phosphate was soil applied in two doses at the early stage of plant growth. The rate of addition of N-P_2O_5 -K_2O was 200-400-400 kg/ha. Urea 46% N, treble superphosphate 46% P_2O_5, and potassium sulphate 48% K_2O were used to supply NPK respectively. The concentration of the urea in the foliar spraying solution was 0.1%, whereas that of potassium sulphate was 0.2%. Micronutrient elements were either once side dressed at the rate of 1.4 g manganese sulphate, 2.8 g ferrous sulphate, 0.4 g zinc sulphate, 0.18 g copper sulphate, 0.28 g boric acid and 0.002 g sodium molybdate per plant, or foliar sprayed once a week at concentrations of 20, 24, 4, 2, 2 and 0.06 ppm for Mn, Fe, Zn, Cu, B and Mo respectively.

Soil properties of surface and subsurface layers of the experimental site are indicated in Table 9. The soil is loamy sand in texture from the surface to a depth of 60 cm. This shows that it is light in texture throughout the root zone. It is alkaline in reaction, calcareous, extremely low in organic matter. It contains little gypsum in the surface 0-30 cm layer, and has medium gypsum content in the sub-surface layer. Soil salinity is low, resulting from the periodic leaching with Budaya irrigation water immediately before transplanting. Olsen's chemical test value for available P is very high at the surface (0-30 cm), and high at the subsurface (30-60 cm) layer. The soil is low in chemically determined available K.

Harvesting started on 31 December 1980, and lasted for four months. In all, 29 harvests were collected, at an average rate of one harvest every 4.1 days.

The comparative effect of soil and foliar application of mineral fertilizers on the yield of indeterminate tomato under plastic tunnel conditions is indicated in Table 10. Data revealed that soil application of these nutrients in these mineral compounds gave slightly higher yields than foliar spraying. This slight increase was significant. Yield data did not reveal the necessity of micronutrient addition in the mineral form to the soil.

2.1.3.2 Effect on yield of cucumber

The mineral compound fertilizer of 15-30-15 ratios for $N-P_2O_5-K_2O$ which also contains Fe, Mg, Mn, Cu, Zn, B and Mo in chelated forms at concentrations of 0.13%, 0.8%, 0.2%, 0.06%, 0.06%, 0.04% and 0.009% respectively, appeared to be good in nutrient concentration ratios. It was applied at various rates with two methods of application, soil and foliar, in order to study the effect of increasing the rate of application on yield and to select the most suitable method of application.

Cucumber variety Femdan was direct seeded on 15 October 1981 in a high plastic tunnel. A basal treatment of locally produced poultry manure was added at the rate of 2 kg/m^2, and thoroughly mixed with the soil. Treble superphosphate 46% P_2O_5 was side-dressed twice at two week intervals from seeding, at the rate of 13 g/plant, and with 20 g of the slow release fertilizer 18-11-11 with longevity of 3-4 months added once at seeding. The mineral compound fertilizer 15-30-15 was used as the continuous supplemental fertilizer in six treatments, namely either:

S1 - 2 g soil applied per plant once a week

S2 - 2 g soil applied per plant twice a week

S3 - 2 g soil applied per plant three times a week

or:

F1 - foliar spraying the plant twice a week with 0.25% solution

F2 - foliar spraying the plant twice a week with 0.5% solution

F3 - foliar spraying the plant twice a week with 1.0% solution.

Each fertilization treatment had four replications in a completely randomized block design.

The site soil was similar in almost every character to that mentioned in the previous experiment. Harvesting started on 7 December 1981 and lasted for 60 days. During the period, 14 harvests were collected (average rate: one harvest every 4.5 days). Yield data of cucumber are indicated in Table 11. Data were statistically analysed. Significant yield increases due to increased rate of the fertilizer were noted (Table 12). The pattern of response to fertilizer rate was different whether it was soil or foliar applied, i.e., significant interaction effect between rate and method of application of the fertilizer was noticed. There was no significant difference in yield between soil or foliar mean application of the fertilizer. Increasing the rate of the soil application from 2 to 4 g/plant/week, or from foliar spraying with 0.25% solution twice a week to 0.5% solution, led to significant yield increases. Increasing the soil application rate of the fertilizer from 2 to 6 g/plant/week steadily increased the yield significantly. No significant difference in yield was noted when the plants were foliar sprayed twice a week with 0.5% or 1% solution, but differences in yield were significant between 0.25% or 0.5% solution.

The influence of the method and rate of application of the fertilizer on nutrient concentration in young mature leaves of cucumber is indicated in Table 13. Data illustrate that foliar application of the fertilizer at any rate resulted in noticeable increase in P concentration in plant tissue. It also led to sharp increases in Mn and Fe concentrations at the highest application rate (F3). Soil application of the fertilizer had no clear trend on concentrations of nutrients in leaf tissue. Data also indicate that all nutrients occur at a wide intermediate range of concentration commonly found in plant tissue of cucumber on a dry weight basis, but certainly above the low range of concentrations.

2.1.4 Yield response of indeterminate tomato varieties to foliar application of micronutrients

Micronutrient disorder is a common problem in the light textured calcareous soils which represent most of the cultivated soils in Bahrain. Lime-induced chloris is common. Plants also vary considerably in their tolerance to micronutrient disorders.

Indeterminate tomato varieties grown under plastic tunnel conditions were used to examine their response to various balances of micronutrients. Six micronutrient elements, Mn, Fe, Zn and Cu in sulphate forms, B in boric acid form and Mo in ammonium molybdate form, were tested. These carriers were dissolved in Budaya brackishwater and were applied at a rate of litre/plant once a week. Three varieties of tomato were used:

1. Floradel, to examine the effect of omitting one micronutrient from the solution that contained Mn, Fe, Zn, Cu, B and Mo at the concentrations of 10, 12, 2, 1, 1, 0.03 mg/litre respectively;

2. Beef Steak, to test the addition of a complete micronutrient solution and of doubling the concentration of one micronutrient once in each treatment;

3. Gross Lisse, to examine the addition of a complete micronutrient solution and of halving the concentration of one micronutrient once in each treatment.

The treatments were as follows:

Floradel

1. Mn, Fe, Zn, Cu, B and Mo
2. Fe, Zn, Cu, B and Mo (-Mn)
3. Mn, Zn, Cu, B and Mo (-Fe)
4. Mn, Fe, Cu, B and Mo (-Zn)
5. Mn, Fe, Zn, B and Mo (-Cu)
6. Mn, Fe, Zn, Cu and Mo (-B)
7. Mn, Fe, Zn, Cu and B (-Mo)
8. Control (brackishwater only)

Beef Steak

9. Mn, Fe, Zn, Cu, B and Mo
10. 2Mn, Fe, Zn, Cu, B and Mo
11. Mn, 2Fe, Zn, Cu, B and Mo
12. Mn, Fe, 2Zn, Cu, B and Mo
13. Mn, Fe, Zn, 2Cu, B and Mo
14. Mn, Fe, Zn, Cu, 2B and Mo
15. Mn, Fe, Zn, Cu, B and 2Mo
16. Control (brackishwater only)

Gross Lisse

17. Mn, Fe, Zn, Cu, B and Mo
18. 1/2Mn, Fe, Zn, Cu, B and Mo
19. Mn, 1/2Zn, Fe, Cu, B and Mo
20. Mn, Fe, Zn, 1/2Cu, B and Mo
21. Mn, 1/2Fe, Zn, Cu, B and Mo
22. Mn, Fe, Zn, Cu, 1/2B and Mo
23. Mn, Fe, Zn, Cu, B and 1/2Mo
24. Control (brackishwater only)

All treatments were implemented in a completely randomized block design with four replications for Floradel or Gross Lisse, whereas Beef Steak had three replications. The organic fertilizer Confuna was rotavated in the surface soil at a rate of 1 kg/m^2. The tomato plants were transplanted on 20 November 1979, 30 cm apart on rows 40 cm apart. Each plant was side-dressed twice with 15 g of treble superphosphate 46% P_2O_5 at two week intervals from transplanting. One kilogramme of calcium nitrate 15.5% N and one kilogramme of potassium nitrate 13.5% N and 46% K_2O, and 200 g of magnesium sulphate 10% mg were dissolved weekly, in Budaya brackishwater and supplied through the drip lines via the fertilization tank. Soil properties of surface and subsurface layers of the experimental site are indicated in Table 14. The soil is sandy loam in texture, calcareous and very low in organic matter content throughout the root zone. There is a compact layer 55 cm from the surface. Gypsum is minimum near the surface and there is only little after 45 cm from surface. The soil is alkaline or basic in reaction and moderately saline. It contains considerable sodium chlorides, calcium and magnesium carbonates, calcium sulphates and magnesium chlorides.

Harvesting started on 12 February 1980 and lasted for three months. In the period, 20 harvests were collected at an average rate of one harvest every 4-5 days.

Yield data were statistically analysed; the yield of the three tomato varieties as affected by foliar application of the micronutrients treatments is indicated in Tables 15, 16, and 17. There were some variations in yield between the different treatments, but the effect of the various treatments was not significant. The absence of a clear trend in the treatment may be due to the variability in yield encountered among the different replications and the improper sterilization of the soil before transplanting, since Nemagon was the only nematocide available and it was not good enough to treat the soil badly infected with nematodes. Also, there was variability in the ionic composition of the saturation extract of the surface soil in the different plots (Table 18). This contributed to the variations in yield between the replications.

2.1.5 Yield response of indeterminate tomato to increasing rates and ratios of N, P and K

High rates of phosphorus are essential in Bahrain calcareous light textured soils not only to replenish their levels but also to build up their phosphorus reservoirs. Nitrogen and potassium in abundant quantities are also needed to meet the high demands of the fast growing vegetable crops under plastic tunnel conditions. This study was conducted under plastic tunnels on tomato for two seasons.

2.1.5.1 Summer experiment 1980 season

Three varieties of tomato - N-69, Tuckcross-K and Tuckcross-O - were transplanted on 8 March 1980 in a plastic tunnel equipped with fan ventilation only without a cooling pad, 40% net shading and white paint made by Dr C. Olympios, FAO consultant in environmental horticulture, from a mixture of 50% white plastic emulsion paint. The soil inside the greenhouse was excavated in strips from some sites to a depth of 30 cm, and was lined with plastic sheets and filled with transported sand in a trial to reduce damage caused by nematodes.

Five selective mineral fertilizer treatments were conducted for each variety in altered and non-altered (original) surface soil, as shown below.

TOMATO - NPK TREATMENTS - SUMMER SEASON 1980

Treatment No.	Rate (kg/ha) N	Rate (kg/ha) P_2O_5	Rate (kg/ha) K_2O	Ratio
1	200	400	200	1:2:1
2	400	400	200	2:2:1
3	200	600	200	1:3:1
4	200	400	400	1:2:2
5	200	200	200	1:1:1

Treble superphosphate 46% P_2O_5 was split side-dressed into two doses and was applied once every two weeks from transplanting to supply the phosphate. Calcium nitrate 15.5% N and potassium sulphate 48% K_2O were soil applied into 12 split doses once a week. A basal treatment of micronutrients was soil applied before transplanting to all fertilizer treatments at the rate of 1 kg B/ha, 1 kg Mo/ha, 2 kg Zn/ha, 3 kg Mn/ha, 3 kg Cu/ha and 6 kg Fe/ha. Micronutrients were added in the form of boric acid ammonium molybdate, zinc sulphate, manganeous sulphate, copper sulphate and ferrous sulphate.

The characteristics of original and transported experimental soil media are indicated in Table 19. The two media are similar in the light texture (loamy sand), percent saturation and pH. Although the original medium is low in organic matter content, it contains seven times more organic matter than the transported medium. The salinity and calcium carbonates in the original medium are higher than in the transported medium. Gypsum is 22 times higher in the transported medium than in the original medium. The subsurface soil is more saline and somewhat heavier in texture than the surface soil (sandy loam).

During harvesting, from 3 May to 15 June 1980, 14 harvests were collected at an average rate of one harvest every three days.

The effect on yield of changing the soil medium, and increasing rates of N, P and K for Tuckcross-K, Tuckcross-O and N-69, are indicated in Table 20. In general, average yield was very low because plants suffered from the high temperature even after fan ventilation, white paint and 40% shading. Cracking of fruits was also abundant due to excessive heat inside the plastic tunnel. The variety Tuckcross-O gave the highest average yield, followed by N-69 and by Tuckcross-K with the lowest average yield. Treatments 4 and 5 in variety N-69 started with sick seedlings and their plants died soon and for this reason only three treatments for this variety are indicated in Table 20 (c). Slight apparent differences were noted in the average yield between the three treatments of N-69. Changing the media did not have any significant effect on the yield since slight differences were noted in the average yield of the original and transported soil. Treatments 3 and 4 gave the highest yields for the two varieties of Tuckcross. This shows that a ratio of 1-3-1 or 1-2-2 for N-P_2O_5 -K_2O respectively is good for tomato in these calcareous loamy sand soils provided that phosphatic fertilizers are added at the early stages of plant growth, and nitrogenous and potash fertilizers are split applied at frequent intervals during the whole period of plant growth.

2.1.5.2 Winter experiment 1981/82 season

Floradel tomato was seeded on 3 September 1980 in Jeffy 7 pots in the nursery, and the seedlings were transplanted on 2 October 1980 in the plastic tunnel. Irrigation given was three hours every other day. A basal treatment of Cofuna was added at the rate of 1.5 kg/m^2, and thoroughly mixed with the soil. Six selective treatments were trireplicated in a completely randomized block design:

TOMATO - NPK TREATMENTS WINTER SEASON 1981/82

Treatment No.	N	P_2O_5	K_2O	Ratio
1	200	200	200	1:1:1
2	200	400	200	1:2:1
3	400	200	200	2:1:1
4	200	200	400	1:1:2
5	200	600	200	1:3:1
6	200	400	400	1:2:2

A basal treatment of 50-100-50 from each treatment was soil applied at transplanting. Treble superphosphate 46% P_2O_5 was split side-dressed into two doses added at 2 week intervals from transplanting. Calcium nitrate 15.5% N and potassium sulphate 48% K_2O were split side-dressed once every week.

Soil properties of surface and subsurface layers of the experimental site are indicated in Table 21. The soil is loamy sand in texture from surface to 60 cm depth. This shows that it is light in texture throughout the root zone. It is alkaline in reaction, calcareous, extremely low in organic matter and contains little gypsum. Salinity is low due to periodic leaching with Budaya irrigation water just before transplanting. Olsen's chemical test value for available P is very high. The soil is low in chemically determined available K.

During harvesting, from 13 December 1980 to 28 April 1981, 29 harvests were collected, at an average rate of one harvest every 4.1 days.

The effect of increasing rates and different ratios of N, P and K on the yield of tomato under plastic tunnels is indicated in Table 22. Data were statistically analysed, and the effect of the treatments was significant. It was found that treatments 200-200-400, 200-400-400 and 200-600-200 significantly outyielded those of 200-200-200; 200-400-200 and 400-200-200 kg/ha. This illustrates the higher requirements of tomato grown in the calcareous loamy sand soil under plastic tunnel conditions, for both phosphorus and potassium as against nitrogen. The addition of phosphorus at 400 kg P_2O_5/ha did not increase the yield significantly, but did at the 600 kg P_2O_5/ha level. Although Olsen's chemical test value of available P is high in this soil, tomato responded to the highest addition of P. This may be attributed to the high fixation capacity of this soil to P as it contains 13.8% $CaCO_3$. When P was added at the highest rate, some was still immediately available to the plant after satisfying the fixation capacity of this soil. Soil solution is very low in potassium and the soil is also low in chemically determined available K (ammonium acetate extractable K is 50 ppm or below).

The yield of tomato ranged from 2.66-3.6 kg/plant. Since the plastic tunnel accommodates 720 plants, the yield ranges between 1.92-2.59 t per 240 m^2 tunnel.

2.1.6 Differential response of some varieties of cucumber to fertilization

On 28 October 1980, 14 varieties of cucumber were seeded in a high plastic tunnel,30 x 5 x 3 m (height), with neither fans nor cooling pad. Ventilation was through two opposite doors, placed at the front and back of the tunnel. Irrigation was for two hours every other day. A basal treatment of poultry manure was added at the rate of 1.5 kg/m^2 and thoroughly mixed with the soil. Another basal treatment of 7.9 kg treble superphoshpate and 14 kg of 18-11-11 slow release fertilizer with longevity of 3-4 months, was applied for the tunnel. All cultural practices were regularly carried out except that minimal insecticide or fungicide treatments were used, and mechanical control was practised. The foliar compound fertilizer 15N-30 P_2O_5-15K_2O, which also contains Fe, Mg, Mn, Cu, Zn, B and Mo in chelated forms at the concentrations of 0.13%, 0.8%, 0.2%, 0.06%, 0.06%, 0.04% and 0.009% respectively, was side-dressed twice a week at a rate of 2.0 g/plant for two months. It was intended to check this continuous feed method and to study its effect on the yield of the various varieties of cucumber.

Soil properties of surface and subsurface layers of the site are indicated in Table 23. The soil is loamy sand in texture from the surface till 60 cm depth. It is alkaline in reaction, calcareous, extremely low in organic matter and contains only little gypsum. It is of medium salinity. Olsen's chemical test value for available P is high. The soil contains a medium amount of chemically determined available K.

During harvesting,from 14 December 1980 to 7 February 1981, 14 harvests were collected at an average rate of one harvest every 3.9 days.

The yield averages of the 14 cucumber varieties are shown is descending order in Table 24. Feminex proved to be the highest yielding variety, and Fertila the lowest. The average yield for all varieties ranged between 4.4 and 2.6 kg/plant. The average yield values in kg/tunnel or t/donum are also indicated in the Table.

2.1.7 Study on blossom end rot of tomato

Blossom end rot was noticed in one of the plastic tunnels used for tomato production. Although this tunnel had many varieties, this phenomenon was noticed only in one variety, Big Set.

To ensure that the plants were adequately supplied with Ca and Mg, leaf tissue was immediately collected from Big Set. Similar tissue from another variety free from this phenomenon was also collected and both were ashed and analysed for total Ca and Mg. Soil samples from the site were collected and analysed for the ions soluble in the water saturation extract of the soil (Table 25). The levels of calcium and magnesium are suitable for production of tomato since calcium constitutes 50% or more of the total soluble salts, and magnesium represents 14% or more of the total soluble salts. It has been suggested by many authors that levels of 15% Ca and 5% Mg of the total soluble salts are suitable for tomato production. Either calcium or magnesium constituted more than 2% of the ash in both blossom end rotted plants and those which are not injured. Sufficiency ranges for calcium and magnesium in plant leaves have been previously reported by many authors to be 0.9-1.8% and 0.5-1.0% respectively.

Injured plants were also sprayed with $CaCl_2$ solution twice a week for four weeks to see if this would correct the phenomenon. No response was obtained.

It was concluded that the blossom end rot is a varietal susceptibility, and that its exact cause was not due to any Ca or Mg deficiencies or unavailabilities in the soil under study. It should also be noted that this soil also contains appreciable amounts of calcium carbonate (13%). Care should be taken to ensure that plants are not water-stressed.

2.2 RESEARCH IN THE OPEN FIELD

All experiments discussed below with the exception of the demonstrative trial on a farmer's field, were conducted in the open field at the Eastern Experimental Farm at Budaya. The drip irrigation system with precoiled microtubes was used at a discharge rate of 0.5 gal/h. Budaya brackish irrigation water was used for three hours daily.

The soils of the experimental site are generally light in texture (sandy loam). There is a very hard white limestone layer 45 cm below from the surface. The soils are calcareous, low in organic matter content, alkaline in reaction and contain a considerable amount of gypsum. They are highly saline at the surface and the salinity decreases with depth. Some variations in salt content, gypsum, calcium carbonate and organic matter were noted at the various experimental sites.

2.2.1 Effect of organic fertilizer application to a light soil on tomato yield

The soils of Bahrain commonly have low organic matter content, low water-holding capacity, light texture, poor structure and low reservoir of nutrients needed for proper plant growth. Build up of the organic matter in soils will improve their physical and nutritional properties. Organic materials vary in their ameliorating effect due to their different sources and rates.

An experiment was conducted to evaluate the effect of different organic materials added at various rates in improving soil productivity, and their immediate effects on yield of tomato.

Floradel variety was seeded on 3 September 1980 in Jeffy 7 pots in the nursery, and the seedlings were transplanted on 5 October 1980 in the open field. Twelve treatments involving four rates (0, 1, 2 and 3 kg/m^2), and three types of organic fertilizers (Confuna, cow manure and poultry manure), were tetrareplicated in a split plot design. Iron angles 2 m in length were inserted into the soil 2 m apart and were used for trellising the tomato plants. The organic fertilizers were placed in furrow 10 cm deep under the drip lines with rates according to treatments, and the nematocide D.D. Fumigant was soil drenched at the rate of 25 ml/m^2. The furrows were covered with soil and left for two weeks. Mineral fertilizers were added at the rate of 150-300-150 kg/ha for N-P_2O_5-K_2O respectively. The fertilizer materials were urea 46% N, treble superphosphate 46% P_2O_5 and potassium sulphate 48% K_2O. Nitrogen and potassium were split soil applied into frequent doses once every two weeks, whereas phosphorus was divided into two doses applied at the early stages of plant growth after transplanting.

Soil properties of surface and subsurface layers of the experimental site are indicated in Table 26. The soil is sandy loam in texture throughout the root zone. The effective soil depth is only 45 cm. The soil is alkaline in reaction, calcareous, extremely low in organic matter and contains little gypsum. The salinity is high. Olsen's chemical test value for available P is high. The soil is high in chemically determined available K.

Some properties of the organic fertilizers which were used are indicated in Table 27. The properties indicated are those for which laboratory facilities were available at the time the analysis was done. Locally produced cow manure is neutral in reaction, whereas both poultry manure and Cofuna are slightly alkaline. The amount of salts in cow manure and poultry manure is extremely high whereas that of Confuna is low. This suggests that if cow and poultry manure are soil applied at high rates, the soil should be irrigated several times after their addition to reduce their salt effect. If they are used as potting mixes, they should be washed several times before seeding. Locally produced cow manure contains more organic matter than locally produced poultry manure.

During harvesting (11 January 1981 to 12 March 1981), 27 harvests were collected, at an average rate of one harvest every 4.4 days.

Tomato yield as affected by type and rate of organic fertilizers is indicated in Table 28. Yield data were statistically analysed. The effects of the rate and the interaction between type and rate were significant. There was no significant difference in yield between the three organic fertilizers applied, which shows that locally produced organic manures are equally as good as imported Confuna. There was a significant steady increase in yield with the increase in the rate of organic fertilizer addition regardless of the organic fertilizer type. The average increases in yield over the control were 25%, 55% and 76% when the rates were 1,2 and 3 kg/m^2 respectively. Differences in yield were insignificant when either cow manure or poultry was added at the rate of 1 kg/m^2, whereas when the rate was increased to 2 or 3 kg/m^2, cow manure proved to be better in increasing yield than poultry manure. This effect may be attributed to the higher organic matter content of the locally produced cow manure than of poultry manure (Table 27).

The average yield of tomato ranged between 1.83-3.21 kg/plant. Since the distance between the adjacent two drip lines in the Eastern farm is 1.5 m and 50 cm between the successive precoiled micro-tubes, then there will be 1 333 plants/donum. The yield ranged between 2.4-4.3 t/donum. This yield could be raised to 4.8-8.6 t/donum by doubling the number of drip lines - this can be done as the drip lines are at present too widely spaced.

2.2.2 Comparative effect of various forms and rates of nitrogen on the yield of squash

Urea 46% N is in common use in Bahrain as a nitrogenous fertilizer. Under prevailing agronomic practices, micro-climatic conditions and soil alkalinity, there will be considerable loss of nitrogen by volatization and leaching. Creation of localized pH effects at the rhizosphere is also expected. Nitrogen is present in various forms in the nitrogenous fertilizers and it will be necessary to compare these forms in order to find that with the best effect on yield. Rates of addition may also contribute to the effectiveness of such forms.

Zapallo Squash (Black Zucchini) was seeded on 9 March 1980. Three nitrogen sources were used: urea 46% N (Amide-N), calcium nitrate 15.5% N (NO_3-N), and ammonium sulphate 20% N (NH_4-N). Each source was added at three rates: 50, 100 and 150 kg N/ha. The total number of treatments was nine. Each treatment was tetrareplicated in a complete randomized block design. Each plot had 16 plants, 40 cm apart and in rows 140 cm apart. Nitrogenous fertilizers were split side-dressed into 3-doses. To all nitrogen treatments, superphosphate at a rate of 200 kg P_2O_5/ha was added in two doses (one before planting and one after the fifth true leaf). Potassium sulphate was also added to all treatments at the rate of 150 kg K_2O/ha in three doses. A basal application of cow manure preceded all treatments.

The soil characteristics of the experimental site are indicated in Table 29. The soil is sandy loam in texture, highly saline, calcareous and alkaline in reaction. It contains little gypsum in the surface 0-30 cm layer, which noticeably increases to a medium amount in the subsurface 30-45 cm layer. The soil is also low in organic matter content which further decreases with depth.

During harvesting (26 April to 17 May 1980), 7 harvests were collected at an average rate of one harvest every three days. Yield data were collected (Table 30), and the effect of nitrogen source and rate on the yield of squash is indicated in Table 31. Data were statistically analysed and differences among average effect of either rates or sources were insignificant. There was a significant interaction effect between the source and rate of nitrogen. At the least nitrogen rate 50 kg N/ha, urea, ammonium sulphate or calcium nitrate were similar in their effect on the yield. At 100 kg N/ha, calcium nitrate has a better effect on yield than either urea or ammonium sulphate. At 150 kg N/ha, urea was better in its effect on yield than either ammonium sulphate or calcium nitrate.

Although the interaction effect was significant, no conclusions can be drawn from this experiment due to the severe moisture stress and bad infection with the cucurbitaceae fruit fly (*Dacus* spp) which led to the termination of the experiment before its due time and the low yield.

2.2.3 Comparative study of soil and foliar application of phosphorus or nitrogen on okra yield

Fertilizers are usually added in different ways. Each placement method affects the efficiency of utilization of a specific fertilizer. In Bahrain, the soils are mostly light in texture, calcareous with high content of salts and alkaline pH value. Addition of fertilizers to such soils is subjected to loss and alteration which will reduce their utilization by plant roots. To minimize the salt accumulation in soil and economize the water use, sprinkler irrigation may be used, and in this case foliar spraying of the plants with the needed fertilizers is essential. Trials on superphosphate and urea rates combined with methods of applications were therefore carried out on okra in two experiments.

2.2.3.1 Soil and foliar application of phosphates

Okra, Clemson Spineless, was seeded on 13 March 1980. Three rates of phosphates were used: R1 (100 kg P_2O_5), R2 (200 kg P_2O_5/ha) and R3 (300 kg P_2O_5/ha). Triple superphosphate 46% P_2O_5 was used to supply the phosphate. Four methods of application were tested for each rate:

- S1 - soil applied in two equal doses;
- S2 - soil applied in three equal doses;
- S3 - soil applied in four equal doses;
- F - foliar-sprayed four times

In the foliar spray treatment, the quantity of triple superphosphate w dissolved in 8 litres of the brackish irrigation water of Budaya. The same quantity of the fertilizer was used to foliar spray the 16 plants in the experimental plot. The range of concentrations of superphosphate varied fr 0.35% to 1.7%.

There were 12 treatments: S1R1, S1R2, S1R3, S2R1, S2R2, S2R3, S3R1, S3 S3R3, FR1, FR2, FR3.

The treatments were replicated four times in a completely randomized b design. Plants were 45 cm apart in rows 120 cm apart. To all phosphate tr ments, urea at the rate of 150 kg N/ha and potassium sulphate at a rate of 150 kg K_2O/ha were split added to the soil in four doses.

Soil characteristics of the experimental site are indicated in Table 3. Data indicate that the experimental site is similar in soil description to that mentioned in experiment 2.2.2.

Harvesting lasted from 30 April 1980 to the end of July, but data were evaluated only until the 30 June harvest. Harvesting was once every two days.

Yield data are contained in Table 33, and the effects of rate and methc of application of superphosphate on the yield of okra are indicated in Table 34. Differences between average effect of either rates or methods of application were insignificant. There was a significant interaction effect between phosphorus rates and methods of application.

At the lowest phosphorus rate 100 kg P_2O_5/ha, soil split application in two doses at the early stages of plant growth gave a better positive significant increase in yield than any of the other treatments. This illustrates than okra plants grown on such soil require considerable phosphorus at the early stages of plant growth since this fertilization treatment supplied the highest amount of phosphorus.

At 200 kg P_2O_5/ha, all soil application treatments or foliar applicatio were similar in their effect on yield. This may indicate that at this rate, the amounts of phosphorus applied at the early stages of plant growth by the various methods are enough to satisfy the plant's requirements.

At 300 kg P_2O_5/ha, foliar application had a better effect on yield than the soil application treatments. This may be attributed to more phosphorus fixation by soil at this high application rate, and foliar spraying was enough to satisfy the plants' requirements.

2.2.3.2 Soil and foliar application of urea

Okra, Clemson Spineless, was seeded on 13 March 1980. Two rates of urea were used, R1 (100 kg N/ha) and R2 (200 Kg N/ha). Three methods of application were tested for each rate:

- S1 - soil applied in two equal doses;
- S2 - soil applied in four equal doses;
- F - foliar-sprayed four times.

In the foliar spray treatment, the amount of urea of each treatment was dissolved in 8 litres of the Budaya brackish irrigation water and was used to foliar spray the 16 plants of the experimental plot. The concentration of urea ranged between 0.35% and 1% for the 100 and 200 kg N/ha respectively.

The six treatments - S1R1, S1R2, S2R1, S2R2, FR1 and FR2 - were replicated four times in a completely randomized block design. Plants were 45 cm apart in rows 120 cm apart. To all nitrogen treatments, superphosphate at the rate of 200 kg P_2O_5/ha was split added to the soil into two equal doses at the early stages of plant growth. Potassium sulphate at a rate of 100 kg K_2O_5/ha was split added to the soil into four doses. Data on the soil characteristics revealed similarity to the soil description in experiment 2.3.1 with one exception, gypsum content, which is low in both surface and subsurface layers of the soil (Table 35).

Harvesting started on 30 April 1980 and lasted until the end of July, but data were evaluated only up to the harvest of 30 June. Harvesting was once every two days.

Yield data are given in Table 36, and the effects of rate and method of application of urea on the yield of okra are indicated in Table 37. Data were statistically analysed, and showed that the effect of the rates or methods of application of urea on yield was not significant. This indicates that splitting the urea into two or four doses at the rates used had the same effect on okra yield as foliar spraying it at concentrations of 0.35% and 1.0%. There was scorching on the leaves of the plants which were foliar sprayed particularly at the 1% concentration, but this scorching did not affect the yield.

2.2.4 Comparative study of soil and foliar application of chemical fertilizers on trellised tomato in the open field

Tomato variety Floradel was seeded on 5 September 1980 in Jeffy pots in the nursery, and the seedlings were transplanted on 6 October 1980. A basal treatment of poultry manure was placed in furrows under the drip lines at the rate of 2 kg/m^2, and the nematocide D.D. Fumigant was soil drenched at the rate of 25 ml/m^2. The furrows were covered with soil and were left for two weeks. The same six treatments used in experiment 2.1.3.1 were tetrareplicated in a completely randomized block design. The rate of addition of N-P_2O_5-K_2O was 150-300-150 kg/ha respectively. Urea, triple superphosphate and potassium sulphate were used to supply N,P and K. Phosphate was soil applied into two doses at the early stages of plant growth, whereas N and K were either split soil applied once every two weeks, or foliar sprayed once a week. The concentration of urea or potassium sulphate in the foliar spray was 0.1%. Micronutrient elements were either side dressed at the rate of 1.4 g manganous sulphate, 2.8 g ferrous sulphate, 0.4 g zinc sulphate, 0.18 g copper sulphate, 0.28 g boric acid and 0.002 g sodium molybdate per plant, or foliar sprayed once a week at a concentration of 20, 24, 4, 2, 2 and 0.06 ppm for Mn, Fe, Zn, Cu, B and Mo respectively.

Soil properties of the experimental site are indicated in Table 38. The site soil is sandy loam in texture throughout the root zone, highly saline, alkaline in reaction, calcareous, extremely low in organic matter and contains little gypsum. Olsen's chemical test value for available P is high. The soil is also high in chemically determined available K (ammonium acetate extractable K).

During harvesting, (11 January to 12 May 1981), 27 harvests were collected.

The comparative effect of soil and foliar application of mineral fertilizers on the yield of tomato in the open field is indicated in Table 39. Data were statistically analysed. The slight differences in yield between treatments were not significant, indicating that soil or foliar application of N, K, Mn, Fe, Zn, Cu, Mo and B has the same effect on yield of trellised tomatoes in the open field. The yield ranged from 1.7-2.16 kg/plant, or 2.27-2.88 t/donum. By doubling the number of drip lines, yield could be raised to 4.54-5.76 t/donum; drip lines are too widely spaced at present. The treatment in which N and K was soil applied and the six micronutrients in a mineral form were foliar sprayed, gave the highest yield.

2.2.5 Assessment of addition necessary of NPK fertilizers to vegetable crops grown on light textured soil

Very few fertilizer trials have been carried out in Bahrain to assess response to added micronutrients to a specific crop or soil. Yield response to fertilizers in a certain soil under a specific system of irrigation and microclimatic conditions is essential for guidance in fertilizers recommendations. The current investigation dealt with response of squash, determinate tomatoes, trellised indeterminate tomatoes, eggplants and bell and long peppers, for a number of agricultural seasons in Budaya calcareous sandy loam soil under drip irrigation system.

2.2.5.1 Yield response of squash

Zapallo Squash (Black Zucchini) was seeded in the field on 10 March 1980. Eight fertilizer treatments were replicated four times in a completely randomized block design. Each plot had 16 plants, 40 cm apart in rows 120 cm apart. Urea was used to supply the nitrogen at two rates, 50 and 100 kg N/ha. It was soil split added into three doses. Triple superphosphate was used to supply the phosphorus at rates of 100 and 200 kg P_2O_5/ha. It was added in two doses, one before planting and one after the fifth true leaf. Potassium sulphate was used to supply the potassium at rates of 50 and 100 kg K_2O/ha. It was soil split added into three doses.

The soil at the site (Table 40), is highly saline, alkaline in reaction, calcareous and contains a little gypsum which noticeably increases with depth to medium content. The soil is low in organic matter content which further decreases with depth.

During harvesting from 26 April to 17 May 1980, 7 harvests were collected at an average rate of one harvest every three days.

Yield data were statistically analysed; the effect of adding N, P and/or K on squash yield is indicated in Table 41. Addition of fertilizers led to significant increases in yield. Differences between treatments which had two nutrients and those which had three nutrients were insignificant. Differences between treatments which had the three nutrients in any combination and the control which did not receive any mineral fertilizer were highly significant. This may indicate that squash yield response in such soil is a function of interaction effect between the added NPK nutrients. Increasing rates of either N, P or K led to insignificant effects on yield increases. This might have been due to the high salt content of the high doses or the severe moisture stress which occurred at the early stages of the experiment, due to the failure in power supply operating the irrigation pump and the absence of a standby electrical generator.

Treatments which gave the highest yield were 50-200-50 or 50-100-100 for $N-P_2O_5-K_2O$ respectively. It should be noted that bad infection with the cucurbitaceae fruit fly and the severe moisture stress led to relatively low yield and the termination of the experiment before time as harvesting should have lasted for at least two months.

2.2.5.2 Yield response of determinate tomato

(a) 1980/81 season

VFN-8 is a popular nematode resistant and virus free determinate variety of tomato commonly grown in the farmers' fields. Farmers grow it under furrow irrigation and it was thought to grow it under drip irrigation for comparison. It was seeded on 10 September 1980 in the nursery, and the seedlings were transplanted on 15 October 1980. An observational trial of eight nonreplicated treatments, i.e. O, N, P, K, NP, NK, PK and NPK, was conducted in the field. The rates used were 150 kg N/ha, 300 kg P_2O_5/ha and 150 kg K_2O/ha. Fertilizer materials were urea 46% N, treble superphosphate 46% P_2O_5 and potassium sulphate 48% K_2O. All treatments received a basal treatment of poultry manure at the rate of 2 kg/m^2 which was placed in the furrows under the driplines, and the nematocide D.D. Fumigant was soil drenched at the rate of 25 ml/m^2. Fertilizers were split side dressed at the early stages of plant growth, and foliar sprayed at later stages once a week.

The soil at the experimental site is sandy loam in texture, alkaline in reaction, calcareous, extremely low in organic matter and contains little gypsum (Table 42). The salinity is generally high but it is more at surface than subsurface. The soil is high in both chemically determined available P and K.

Harvesting (11 January to 11 April 1981), covered 19 harvests at an average rate of one harvest every 4.7 days.

Yield data as affected by mineral fertilizers are indicated in Table 43. The yield ranged between 1.63 and 3.67 t/donum. Tomato grown in Budaya sandy loam soil responded to added NPK. The highest response was for added N alone or in combination with P and/or K. The yield increase over control was 100%, 117%, 113% and 126% for the addition of N, NP, NK and NPK respectively. There was a slight response to P and/or K addition, which may be attributed to the high levels of sufficiency of these two nutrients in the site. The yield increase over the control was only 30%, 21% and 25% for the P, K and PK addition respectively.

(b) 1981/82 season

Tomato variety VFN-8 was seeded on 8 September 1981 in the nursery, and the seedlings were transplanted on 13 October 1981 in the open field. A basal treatment of poultry manure was added at the rate of 2 kg/m^2 in the furrows under the driplines, and the nematocide D.D. Fumigant was soil drenched at the rate of 25 ml/m^2. The standard FAO eight-plot design was used, with the following treatments:

STANDARD FAO EIGHT-PLOT DESIGN AND TREATMENTS

Treatment No.	Rate in kg/ha N	Rate in kg/ha P_2O_5	Rate in kg/ha K_2O
1	0	0	0
2	0	150	150
3	150	150	150
4	300	150	150
5	150	0	150
6	150	300	150
7	150	150	0
8	150	150	300

All treatments were tetrareplicated in a completely randomized block design. The soil characteristics of the experimental site were similar to those indicated in Table 42.

During harvesting (1 January to 18 April 1982), 19 harvests were collected at an average of one harvest every 4.7 days.

Yield data as affected by mineral fertilizers are indicated in Tables 44 and 45. The yield ranged between 6.01 and 9.53 t/donum. Increases over the control, where no mineral fertilizer was added, are indicated in Table 45. Data revealed that tomato grown in Budaya sandy loam soil responded to added NPK. N application at 150 kg N/ha resulted in 33.7% yield increase. When N rate was doubled, the relative increase was 57.4%. The yield increase due to phosphate response at the level of 150 kg P_2O_5/ha was 12.1%. When P rate was doubled, the yield increase was 22.1%. The yield increase due to potassium response at the level of 150 kg K_2O/ha was 7.8%. When K rate was doubled, the yield increase was 13.3%. This indicates that the highest response was to nitrogen, followed by response to phosphorus, the least response being to potassium. Doubling the rate of addition of N, P or K doubled the relative yield increase of determinate VFN-8 tomato. The slight responses to phosphorus or potassium may be attributed to the high levels of sufficiency of these two nutrients in the site soil.

2.2.5.3 Yield response of indeterminate trellised tomato

(a) 1980/81 season

Indeterminate tomato was grown in the open field after being trellised to compare relative performance and response with tomato, grown under plastic tunnels.

Floradel variety was seeded on 6 September 1980 in Jeffy pots in the nursery, and the seedlings were transplanted on 6 October 1980 in the open field. Eight treatments which are the factorial combination of NPK (0 "without application", N, P, K, NP, NK, PK, NPK), were tetrareplicated in a completely randomized block design experiment. The rates used were 150 kg N/ha, 300 kg P_2O_5/ha and 150 kg K_2O/ha. Urea, triple superphosphate and potassium sulphate were used to supply the nitrogen, phosphorus and potassium respectively. All treatments received a basal treatment of poultry manure at the rate of 2 kg/m^2 which was placed in the furrows under the drip lines, and the nematocide D.D. Fumigant was soil drenched at the rate of 25 ml/m^2. Nitrogen and potassium were split soil applied into frequent doses once every two weeks, whereas phosphorus was divided into two doses applied at the early stages of plant growth.

The soil at the site is sandy loam in texture through the root zone, alkaline in reaction, calcareous, extremely low in organic matter and contains only a small amount of gypsum. The salinity was generally high but it was more at surface than subsurface. Olsen's chemical test value for available P was high at surface and decreased with depth. The soil is also high in chemically determined available K at the surface, which decreases with depth to low contents (Table 46).

During harvesting (11 January to 12 May 1981), 27 harvests were collected.

The effect of mineral fertilizer treatments on yield of trellised tomatoes in the open field is indicated in Tables 47 and 48. Data were statistically analysed. The response to added potassium either alone or in combination with either nitrogen or phosphorus was negligible. This is probable since the content of chemically determined available K is high in this Budaya calcareous sandy loam soil. The response to added phosphorus either alone or in combination with potassium was significant and led to a yield increase of 10% over control, although the chemical test for soil available P indicated sufficiency. The response to added N alone or in combination with either P or K was significant and led to a yield increase range of 24-27%. The response to N combined with both P and K addition led to a yield increase of 50%. This indicates that the first limiting factor in the fertility of this soil is N, and its addition led to about 25% increase in yield. This increase in tomato yield can be doubled if accompanied by P and K addition regardless of their chemical sufficiency levels in the soil. This also shows that sufficiency levels are relative and are affected among other factors, by the crop which is grown in the soil and microclimatic conditions. Tomato yield ranged from 1.74 to 2.61 kg/plant, or 2.32 to 3.48 t/donum. This yield can be doubled if the number of driplines is doubled,which can easily be done as the present distance between the current driplines is too wide for trellised tomatoes.

(b) 1981/82 season

Tomato variety Floradel was seeded on 9 September 1981 in the nursery, and the seedlings were transplanted on 15 October 1981 in the open field. A basal treatment of poultry manure was added at the rate of 2 kg/m^2 in the furrows under the driplines, and the nematocide D.D. Fumigant was soil drenched at the rate of 25 ml/m^2. The standard FAO eight-plot design (see experiment 2.2.5.2b) was followed. All treatments were replicated five times in a completely randomized block design. The soil characteristics of the experimental site were similar to those indicated in Table 46.

During harvesting (18 January to 29 May 1982), 24 harvests were collected at an average of one harvest every 5.4 days.

Yield data as affected by mineral fertilizers are indicated in Tables 49 and 50. Data showed that trellised indeterminate tomato grown in Budaya sandy loam soil responded to added N, P and K fertilizers. N application at 150 kg N/ha resulted in 30% yield increase. When N rate was doubled, the relative increase was 42.8%. The yield increase due to phosphate response at the level of 150 kg P_2O_5/ha was 15.3%. When P rate was doubled, the yield increase was 23.2%. The yield increase due to potassium response at the level of 150 kg K_2O/ha was 12.4%. When K rate was doubled, the yield increase was 17.8%. The highest response was to nitrogen, followed by phosphorus, with the least response to potassium. Doubling the rate of addition of N, P or K led to relative increases in yield of about 50% more than those obtained at the 150 kg/ha rate. This shows that indeterminate tomato responds less to higher rates of nitrogen than determinate tomato grown on the same soil. The slight responses to phosphorus or potassium may be attributed to the high levels of sufficiency of these two nutrients in the site soil.

Yields ranged between 3.5-4.6 t/donum. Yields can be easily doubled by doubling the number of drip lines, which are now spaced too far apart.

2.2.5.4 Yield response of eggplant

Black Beauty is a popular variety of eggplant, commonly grown in the farmers' fields under furrow irrigation. For comparison, an experiment using drip irrigation was conducted. Black Beauty was seeded on 4 October 1980 in the nursery and the seedlings were transplanted on 10 November 1980. An observational trial of five nonreplicated treatments, i.e., O, N, P, NP and NPK, was performed in the field. The nutrients rates used were 150 kg N/ha, 300 kg P_2O_5/ha and 150 K_2O/ha. Fertilizer materials were urea 46% N, treble superphosphate 46% P_2O_5 and potassium sulphate 48% K_2O. All treatments received a basal treatment of poultry manure at the rate of 2 kg/m^2 which was placed in the furrows under the driplines, and the nematocide D.D. Fumigant was soil drenched at the rate of 25 ml/m^2. Fertilizers were side dressed at the early stages of plant growth, and foliar sprayed at later stages once a week.

The soil at the site is sandy loam in texture, alkaline in reaction, calcareous, extremely low in organic matter and contains little gypsum. The salinity is generally high but more at surface than subsurface. The soil is high in both chemically determined available P and K (Table 51).

During harvesting, from 26 January to 17 May 1981, 14 harvests were collected, at an average rate of one harvest every 7.9 days.

Yield data as affected by mineral fertilizers are indicated in Table 52. The yield ranged between 1.25 and 2.17 t/donum. Eggplant grown in Budaya sandy loam soil responded to added N and P. The highest response was for added N alone or in combination with P. The yield increase over the control was 64%, 73% and 73% for N, NP and NPK respectively. There was a response to P addition alone which amounted to 30% increase in yield over the control. There was no response to added potassium, indicating the sufficiency of chemically determined available K in this soil to satisfy the requirements of eggplant. The yield per donum can be doubled easily by doubling the number of drip lines which are at present spaced too far apart.

2.2.5.5 Yield response of peppers

(a) Bell peppers

Bell pepper variety Yolo Wonder was seeded on 7 September 1981 in the nursery, and the seedlings were transplanted on 15 October 1981 in the open field. A basal treatment of poultry manure was added at the rate of 2 kg/m^2 in the furrows under the driplines, and the nematocide D.D. Fumigant was soil drenched at the rate of 25 ml/m^2. The standard FAO eight plot design (see 2.2.5.2b) was followed. All treatments were tetrareplicated in a completely randomized block design.

The soil characteristics of the experimental site are similar to those indicated in Table 51.

During harvesting (26 December 1981 to 7 June 1982), 20 harvests were collected with an average rate of one harvest every 8 days.

Yield data as affected by mineral fertilizers are indicated in Tables 53 and 54. The yield ranged between 0.65-1.25 kg/plant or 0.87-1.67 t/donum. The yield can be doubled by doubling the number of driplines, which are spaced too widely for peppers.

Data revealed that bell pepper grown in Budaya sandy loam soil responded to NPK fertilizers. N application at 150 kg N/ha resulted in 31.6% yield increase. When N rate was doubled, the relative increase was 34.3%. The yield increase due to phosphate response at the level of 150 kg P_2O_5/ha was 16.7%. When P rate was doubled the yield increase was 18.2%. The yield increase due to potassium response at the level of 150 kg K_2O/ha was 7.8%. No more response to K was noted when the K rate was doubled. This indicates that the highest response was to nitrogen, followed by phosphorus with the least response to potassium. Doubling the rate of addition of N or P led to slightly more increases than that which occurred at the 150 kg/ha level. The slight responses to phosphorus or potassium may be attributed to the high levels of sufficiency of these two nutrients in the site soil.

(b) Long peppers

Long green pepper variety Anaheim-M was seeded on 7 September 1981 in the nursery, and the seedlings were transplanted on 16 October 1981 in the open field. The same basal treatment of organic manure, nematocide application, treatments and experimental design used for the preceding experiment on bell pepper were followed. The site soil is also similar to the characteristics of the soil of the bell pepper experiment.

During harvestings, from 26 December 1981 to 7 June 1982, 20 harvests were collected at an average rate of one harvest every 8 days.

Yield data as affected by mineral fertilizers are indicated in Tables 55 and 56. The yield ranged between 0.67-0.93 kg/plant, or 0.89-1.24 t/donum. The yield can be easily doubled by doubling the number of driplines which are spaced too wide for peppers.

Data revealed that long peppers grown in Budaya sandy loam soil responded to NPK fertilizers. N application at 150 kg N/ha resulted in 24.1% yield increase. When N rate was doubled, the relative increase was 25.9%. The yield due to phosphate response at the level of 150 kg P_2O_5/ha was 10.3%. When P rate was doubled the relative increase was 11.1%. The yield increase due to potassium response at the level of 150 kg K_2O/ha was 3.7%. No more yield response to potassium was noted when K rate was doubled. This indicates that the highest response was to nitrogen, followed by phosphorus and with a negligible response to potassium. Doubling the rate of addition of N, P or K had no effect on yield increase. This illustrates that application of the nitrogenous fertilizer at the rate of 150 kg N/ha to Budaya sandy loam soil is sufficient for obtaining a good yield of Anaheim-M long green pepper. The slight response to phosphorus at the rate of 150 kg P_2O_5/ha and the negligible response to potassium at the same rate may be attribdted to the high levels of sufficiency of these two nutrients in the site soil.

2.2.6 Demonstration of a fertility trial on organic and inorganic fertilizer use in a farmer's field

A fertility trial in a farmer's field (Mr Ahmad Sarhaan) at Sanad was conducted to demonstrate to a Bahraini farmer improvements in organic and inorganic fertilizer use. VFN-8 determinate variety of tomato was seeded on 25 August 1981 in the farmer's nursery, and transplanted on 1 October 1981 in the field. Seedlings were planted 50 cm apart in furrows 15 m long x 35 cm wide. Each furrow represented one treatment. Flood irrigation was used. Irrigation water was applied at transplanting twice a day for four days, then daily till the first flower, later once every two days till the beginning of the fruit set, and daily at fruit setting. The irrigation water had 3 000 ppm total dissolved salts. Nine fertilizers treatments were applied.

1. The farmer's method in which he puts poultry manure in the furrow at the rate of 5 kg/furrow, covers with sweet sand, irrigates once a day for 5 days, harrows the soil, transplants, covers the plants with date palm fronds for 4 days and then removes covers. He places 3.5 kg of the compound mineral fertilizer 15-15-15 "known as nitrofoska" 10 days after transplanting at the rate of 500 g/furrow once every 5 days for 35 days. He again adds poultry

manure at the rate of 7.5 kg/furrow and covers it with sweet sand. He stops fertilization for three weeks, then continues at the rate of 0.5 kg of the mineral compound fertilizer or 2.0 kg poultry manure once every 3 days on alternative basis till the start of harvesting, and again once every 5 days with 0.5 kg of the compound fertilizer till the completion of harvesting. In summary, the farmer's procedure is organic fertilization at the rate of 1 kg/m^2 added in five split doses, and mineral fertilization with the compound mineral fertilizer 15-15-15 at the rate of 15 kg/furrow added into 30 split doses.

2. Poultry manure only, at the rate of 1 kg/m^2, in five split doses applied as previously described in the farmer's method.

3. Poultry manure only at the rate of 1 kg/m^2 added once before transplanting.

4. Poultry manure once before transplanting at the rate of 1 kg/m^2 + farmer's method of the mineral fertilizer 15-15-15 at the rate of 15 kg/furrow added in 30 split doses.

5. Poultry manure at the rate of 1 kg/m^2 added once before transplanting + 15-15-15 mineral fertilizer applied the farmer's way in rate and method of application + side dressing of triple superphosphate at the rate of 3 kg/furrow added in three split doses within three weeks from transplanting.

6. Poultry manure at the rate of 1 kg/m^2 added once before transplanting + 15-15-15 mineral fertilizer at the rate of 1.5 kg/furrow once every two weeks + side dressing of triple superphosphate at 3 kg/furrow added in three split doses within three weeks from transplanting.

7. Poultry manure at the rate of 1 kg/m^2 added once before transplanting + 15-15-15 mineral fertilizer at the rate of 0.75 kg/furrow added once every two weeks + side dressing of triple superphosphate at 1.5 kg/furrow added in two split doses within two weeks from transplanting.

8. Poultry manure at the rate of 2 kg/m^2 added once before transplanting + 15-15-15 mineral fertilizer at the rate of 1.5 kg/furrow added once every two weeks + side dressing of triple superphosphate at the rate of 3 kg/furrow added in three split doses within three weeks from transplanting.

9. Poultry manure at the rate of 2 kg/m^2 added once before transplanting + 15-15-15 mineral fertilizer at the rate of 3 kg/furrow once added three days after transplanting + side dressing of triple superphosphate at the rate of 3 kg/furrow in three split doses added within three weeks from transplanting + foliar spraying 0.2% solution of 15-30-15 mineral fertilizer once every 5 days.

The site soil is sandy loam in texture throughout the root zone. It is alkaline in reaction, calcareous, low in organic matter and contains very little gypsum. The salinity is high (EC_e = 30 mmhos cm^{-1}). Olsen's chemical test value of available P is high, whereas ammonium acetate extractable K (termed chemically determined available K) is very low.

Harvesting lasted until 22 May 1982. The yield data of the different treatments are shown in a descending order in Table 57, which also indicates relative increases over the farmer's method of fertilization. Data revealed that increasing the rate of organic fertilizer addition from 1 kg/m^2 to 2 kg/m^2, and adding it once at transplanting + triple superphosphate at the rate of 200 g/m^2 at transplanting + split application of the compound mineral fertilizer 15-15-15 once every two weeks at the rate of 100 g/m^2, gave the highest yield of tomato which amounted to 11.8 kg/m^2 and a relative increase over the farmer's method of fertilization of 84.71%.

In the absence of any mineral fertilization, application of poultry manure at 1 kg/m^2 into five split doses had a better effect on yield of determinate tomato grown in a sandy loam soil than adding it once before transplanting under flood irrigation system. In the presence of the mineral fertilizer 15-15-15, application of poultry manure at 1 kg/m^2 once before transplanting had better effect on yield of tomato than applying it in five split doses. The yield increase due to the addition of triple superphosphate at the rate of 3 kg/furrow (200 kg/donum) within three weeks from transplanting, regardless of the sufficiency level of chemically determined available P, was 35.56%.

2.3 RESEARCH UNDER LOW TUNNEL CONDITIONS

All experiments discussed here were conducted in the Eastern Farm at Budaya under low tunnels 40 x 1.1 x 0.9 m (height), covered with plastic during winter, and with 50% black net shading during early summer. The drip irrigation system with precoiled microtubes was used at a discharge rate of 0.5 gal/h for 3 h daily. Budaya brackishwater was used for irrigation. These experiments dealt with yield response of determinate tomatoes, bell peppers and long green peppers to NPK fertilizers in Budaya calcareous sandy loam soil. All experiments also had a basal treatment of poultry manure at the rate of 2 kg/m^2 in furrows under the driplines, and the nematocide D.D. Fumigant was soil drenched at the rate of 25 ml/m^2. The standard FAO eight plot design (see 2.2.1.3), was followed. All treatments were tetrareplicated in a completely randomized block design. Urea 46% N was added to supply the nitrogen, triple superphosphate 46% P_2O_5 was used to supply the phosphorus, and potassium sulphate 48% K_2O was used to supply the potassium.

2.3.1 Yield response of determinate tomato under cover

Tomato variety VFN-8 was seeded on 8 September 1981 in the nursery, and the seedlings were transplanted on 13 October 1981. The soil characteristics of the experimental site were similar to those indicated in Table 42.

Harvesting was from 3 January 1982 to 3 June 1982, and 25 harvests were collected at an average rate of one harvest every 6 days.

Yield data as affected by mineral fertilizers are indicated in Tables 58 and 59. The yield ranged between 7.09 and 10.92 t/donum. Increases over control, where no mineral fertilizer was added, are indicated in Table 59. Data revealed that tomato grown in Budaya sandy loam soil under covers responded to NPK fertilizers. Nitrogen application at 150 kg N/ha resulted in 25.8% yield increase. When N rate was doubled, the relative increase was 50%. The yield increase due to phosphate response at the level of 150 kg P_2O_5/ha was 9.8%. When P rate was doubled, the yield increase was 19.7%. The yield increase due to potassium response at the level of 150 kg K_2O/ha was 14.1%. When K rate was doubled, the yield increase was 22.4%. This indicated that tomatoes under low covers responded less to nitrogen, more to potassium and less to phosphorous than in the open field. Data also revealed that the highest response was to nitrogen, followed by response to potassium with the least response to phosphorus. Doubling the rate of addition of N or P doubled the relative yield increase, whereas doubling the rate of K addition led to more relative yield increase of 58.9%. Covering determinate type of tomato variety VFN-8 in the open field, with plastic in winter and shade net in early summer over low tunnels, led to an overall average yield increase of 11.6%.

2.3.2 Yield response of bell pepper under cover

Bell pepper variety Yolo Wonder was seeded on 7 September 1981 in the nursery, and the seedlings were transplanted on 15 October 1981. The soil characteristics of the experimental site were similar to those indicated in Table 51.

During harvesting (26 December 1981 to 7 June 1982), 20 harvests were collected at an average of one harvest every 8 days.

Yield data as affected by mineral fertilizers are indicated in Tables 60 and 61. The yield ranged between 1.573 and 3.213 t donum. Increases over control are indicated in Table 61. Data revealed that bell pepper grown in Budaya sandy loam soil under cover responded to NPK application. Nitrogen application at 150 kg N/ha resulted in 68% yield increase. When N rate was doubled, the relative increase was 93%. The yield increase due to phosphate response at the level of 150 kg P_2O_5/ha was 26.3%. When P rate was doubled, the yield increase was 30.5%. The yield increase due to potassium response at the level of 150 kg K_2O/ha was 35.5%. No more response to potassium was noted when the K rate was doubled. Data revealed that the highest response was to nitrogen, followed by potassium, with the least response to phosphorus. Doubling the rate of addition of N or P led to more relative yield increases of 25% and 4.2% respectively. This indicates that bell pepper under low covers responded more to nitrogen, phosphorus and potassium than in the open field. Covering the bell pepper Yolo Wonder variety in the open field with plastic in winter, and shade net in early summer over low tunnels, led to an average yield increase of 82.6%.

2.3.3 Yield response of long green pepper under cover

Long green pepper variety Anahiem-M was seeded on 7 September 1981 in the nursery, and the seedlings were transplanted on 16 October 1981. The soil characteristics of the experimental site were similar to those indicated in Table 51.

During harvesting, from 26 December 1981 to 7 June 1982, 20 harvests were collected at an average rate of one harvest every 8 days.

Yield data as affected by mineral fertilizers are indicated in Tables 62 and 63. The yield ranged between 1.28 and 2.12 t/donum. Increases over control are indicated in Table 63. Data revealed that long green pepper grown in Budaya sandy loam soil under cover responded to N-, P-, and K-fertilizers. Nitrogen application at 150 kg N/ha resulted in 29.8% yield increase. When N rate was doubled, the relative increase in yield was 33.5%. The yield increase due to phosphate response at the level of 150 kg P_2O_5/ha was 21.6%. The yield increase due to potassium response at the level of 150 kg K_2O/ha was 8.8%. Data revealed that the highest response was to nitrogen, followed by response to phosphorus, with the least response to potassium. Doubling the rate N addition led to a very slight more relative yield increase of 3.7%. No more response was noted when the P or K rate was doubled. This indicates that long green pepper under covers responded more to nitrogen, phosphorus and potassium than in the open field. Covering the long green pepper Anaheim M variety in the open field with plastic in winter and shade in early summer over low tunnels, led to an average yield increase of 61.8% more than in the open field.

2.4 SUMMER FERTILITY TRIALS

Climatic conditions in Bahrain during summer limit vegetable yield. However, through modification of the microclimate and proper fertilization the yield may be improved. In this respect, fertility trials were conducted on tomato, cucumber and peppers under high plastic tunnels equipped with means to reduce temperature and under shade houses. In addition, a trial on yield response of okra to NPK fertilizer application was carried out in the open field since okra grows well in Bahrain during the summer. All trials described below, with the exception of that on okra, were conducted on the project site at Budaya. The okra trial was carried out at the Eastern Experimental Farm. The drip irrigation system with precoiled microtubes was used daily for 3 h at a discharge rate of 0.5 gal/h. Brackishwater of Budaya was used for irrigation. All trials had a basal treatment of poultry manure at the rate of 2 kg/m^2.

2.4.1 Yield response of tomato to nitrogen and potassium under different base mineral fertilizers in the presence of evaporative cooling and shade

An experiment on the yield response of tomato to nitrogen and potassium under different base mineral fertilizers in the presence of evaporative cooling and shade was carried out under a high plastic tunnel equipped with two extractor fans on one side and Kool-cell perforated pads on the opposite side. A plastic net cover shade was spread over the plastic cover of the tunnel from May to reduce the light intensity by 50%. The site soil characteristics are those previously indicated in Table 9. The chemically determined available K is low in this site.

Tomato variety Floradel was seeded in the nursery on 2 March 1982 and transplanted on 22 March 1982. Two treatments of base mineral fertilizers were applied at transplanting, namely 10 g/plant of the ordinary compound fertilizer 15-15-15, or 10.7 g/plant of the slow release fertilizer 14-14-14 (3-4 months longevity). Another two treatments of split nitrogen and potassium supplemental fertilizers were added once every two weeks, one month after transplanting. They were 5 g of urea 46% N either alone or together with 5 g of potassium sulphate 48% KO_2/plant. In other words, there were four factorial combinations of two base mineral fertilizers X 2 supplemental N or/and K fertilizers, with three replicates. The design of the experiment was a randomized complete block. The treatments were symbolized N_o, $(N+K)_o$, N_s, and $(N+K)_s$, where:

N_o refers to supplemental N and K in the presence of the slow release fertilizer;

$(N+K)_o$ refers to supplemental N and K in the presence of the ordinary complete fertilizer;

N_s refers to supplemental N in the presence of the slow release fertilizer;

$(N+K)_s$ refers to supplemental N and K in the presence of the slow release fertilizer.

During harvesting, from 12 May to 27 July 1982, 12 harvests were collected at an average rate of one harvest every 5 days.

Yield data are indicated in Table 64. Data were statistically analysed and the effects of the base and the supplemental mineral fertilizers as well as their interactions are indicated in Table 65. There were significant mean yield increases due to the base mineral fertilizer used. In summer, slow release 14-14-14 fertilizer of 3-4 months longevity led to significant mean yield increase of 31% more than the yield of the ordinary release fertilizer. Potassium addition under the slow release fertilizer led to insignificant increase in yield. There were significant increases in yield due to potassium addition under the ordinary release fertilizer.

The yield of tomato during the summer ranged between 312-710 g/plant. The high air temperature resulted in curling of basal foliage and low yield. This indicates that extension of the tomato season after May is possible but is not feasible, under such a modified system of the microclimate.

2.4.2 Yield response of cucumber to nitrogen and potassium under different base mineral fertilizers in presence of evaporative cooling

An experiment on yield response of cucumber to nitrogen and potassium under different base mineral fertilizers in presence of evaporative cooling was carried out under a high plastic tunnel equipped with two extractor fans on one side and a Kool-cell perforated pad on the opposite side. Cucumber variety Market King was seeded in the nursery on 6 March 1982 and transplanted on 18 March 1982. The same treatments as previously indicated in Experiment 2.4.1 were followed.

During harvesting from 24 April to 19 June 1982, 12 harvests were collected at an average rate of one harvest every 4-6 days.

Yield data are indicated in Table 66. Data were statistically analysed; the effects of the base and supplemental mineral fertilizers and their interactions are indicated in Table 67. The effects of the treatments were insignificant. This may be attributed to the wide variation encountered among the replicates and the relatively lower potassium requirement of cucumber than that of tomato in summer. It should also be noted that the level of available K in this soil is sufficient to meet the potassium requirement of cucumber.

The yield ranged between 1.47 -2.0 kg/plant, but there was a decrease in fruit uniformity and an increase in fruit dwarfness. This indicates that extension of the cucumber season after May is possible and probably feasible.

2.4.3 Yield response of cucumber to nitrogen and potassium under shade

An experiment on the yield response of cucumber to nitrogen and potassium under shade was carried out under a high plastic tunnel, 17 x 4 x 2.6 m (height), covered with plastic until April and with only plastic net cover shade from May to reduce the light intensity by 50% and for better ventilation.

Cucumber variety Femdan was seeded in the nursery on 16 February 1982 and transplanted on 28 February 1982. Two treatments of supplemental mineral fertilizer were used, namely 10 g calcium nitrate 12% N either alone or along with 5 g potassium sulphate 48% K_2O/plant. Three weeks after transplanting, the potash and nitrogen treatments were added once every two weeks. The replicates were five in a randomized complete block design. A basal mineral fertilization with 10 g of the slow release fertilizer 14-14-14 (3-4 months longevity) was added to all treatments at transplanting.

During harvesting from 8 April to 16 June 1982, 14 harvests were collected, at an average rate of one harvest every 5 days.

Yield data are indicated in Table 68. Data were statistically analysed and the difference between the mean yield of the two treatments was significant, indicating a yield response to potassium addition in summer. It should be noted that the chemically determined available K in this soil is low (50 ppm). The yield ranged between 3.1 - 4.3 kg/plant but there was a decrease in fruit uniformity and an increase in dwarfness of fruits. This indicates that extension of the cucumber season after May is possible, and feasible for Femdan variety.

2.4.4 Yield response of bell pepper to increasing rates of nitrogen and potassium under shade

An observational trial, similar to that of Experiment 2.4.3, was carried out under a high plastic tunnel on the yield response of bell pepper to increasing rates of nitrogen and potassium under shade. Bell pepper variety Yolo Wonder was seeded on 17 February 1980 and transplanted on 28 February 1982. There were 20 factorial combinations of 5 rates of nitrogen x 4 rates of potassium with no replications. Urea 46% N was added once every two weeks at the rate of nil, 3, 6, 9 and 12 g/plant for N_o, N_1, N_2, N_3 and N_4 nitrogen treatments respectively. Potassium sulphate 48% K_2O was added once every two weeks at the rate of nil, 3, 6 and 9 g/plant for K_o, K_1, K_2 and K_3 potash treatments respectively. A basal treatment of 20 g/plant of treble superphosphate was added in two split doses after transplanting.

During harvesting from 9 May to 15 July 1982, 7 harvests were collected at an average rate of one harvest every 5.5 days.

Yield data are indicated in Table 69 and were not statistically analysed since there were no replications. There was a general trend in the obtained yield pattern. There were increases in yield under N treatments No. 2, 3 and 4. The highest increase in yield was under nitrogenous treatment No. 3, which amounted to 39% over the control. Potassium addition did not result in any increase. This may be attributed to the high level of chemically determined available K in this soil (100 ppm K). The yield of bell pepper during the summer ranged between 0.8 - 1.38 kg/plant.

2.4.5 Comparative effect of different forms of nitrogen on yield of tomato under shade

An experiment on the comparative effect of different forms of nitrogen on yield of tomato under shade was carried out under a high plastic tunnel similar to that of Experiment 2.4.3. Tomato variety Floradel was seeded on 15 February 1982 and transplanted on 28 February 1982.

Three treatments of nitrogenous fertilizers were used:

- urea (U) nitrogen in amide form
- ammonium sulphate (A) nitrogen in ammonium form
- calcium nitrate (C) nitrogen in nitrate form.

Nitrogen was continuously added at the rate of 2.3 g N/plant, once a week from each nitrogen carrier. The design of the experiment was a randomized complete block with five replicates. A basal mineral fertilization with 10 g/plant of the slow release fertilizer 14-14-14 (3-4 months longevity) was added to all treatments at transplanting.

During harvesting, from 6 May to 18 July 1982, 17 harvests were collected at an average rate of one harvest every 4.2 days.

Yield data are indicated in Table 70. Data were statistically analysed and there was no significant difference between the treatments, i.e., tomato plants under summer conditions in Bahrain respond similarly to amide-N, NH_4-N or NO_3-N. The yield ranged between 1.78 - 2.93 kg/plant. This also indicates that the extension of the tomato season after May is possible and feasible for Floradel variety under shade and weekly split application of nitrogen.

2.4.6 Effect of different mineral fertilizers on yield of tomato under shade

An experiment on the effect of different mineral fertilizers on yield of tomato under shade was carried out under a high plastic tunnel similar to that of Experiment 2.4.3.

Tomato variety Floradel was seeded on 15 February 1982 and transplanted on 28 February 1982. Three treatments of base mineral fertilizers at the rate of 10 g/plant at transplanting were used:

15-15-15 ordinary release fertilizer (A);

14-14-14 slow release fertilizer with 3-4 months longevity (B);

18-11-11 slow release fertilizer with 3-4 months longevity (C).

The replicates were five in a randomized complete block design. Supplemental mineral fertilization was added weekly to all treatments at a rate of 3 g/plant potassium nitrate.

During harvesting, from 5 May to 18 July 1982, 16 harvests were collected with an average rate of one harvest every 4-6 days.

Yield data are indicated in Table 71. Data were statistically analysed and there was no significant difference between treatments. This may be attributed to the frequent application of supplemental mineral fertilization which might have taken care of any differences in supply of the base mineral fertilizers. The yield ranged between 1.78 - 2.93 kg/plant. This also indicates that the extension of the tomato season after May is possible and feasible for Floradel variety under shade.

2.4.7 Effect of rates and methods of phosphate application on bell pepper under shade

An observational trial on the effect of rates and methods of phosphate application on bell pepper under shade was carried out under a high plastic tunnel similar to the of Experiment 2.4.3.

Bell pepper variety Yolo Wonder was seeded on 17 February 1980 and transplanted on 28 February 1982. There were 20 factorial combinations of five methods of phosphate split applications x 4 rates of phosphate with no replications. The split application methods were once (1), twice (2), three times (3), four times (4) and five times (5). The rates were 9, 18, 27 and 36 g/plant of treble superphosphate for rates 1, 2, 3 and 4 respectively. A basal treatment of 6 g/plant supplemental potassium nitrate was added to all treatments once a month, and 3.0 g of urea once every 2 weeks.

During harvesting, from 2 May to 15 July 1982, 8 harvests were collected with an average rate of one harvest every 9.1 days.

Since this was an observational trial with no replications, data were not statistically analysed. The data (Table 72) indicate an interaction effect between the rate and method of application. At the highest two rates, adding the superphosphate once increased the yield more than split application. Split application of superphosphate twice, three times or four times at the lowest two rates increased the yield. The high application rate of phosphate might have limited the absorption of other nutrients, whereas at lower rates nutrients absorption was not affected. Split application into three doses is better than more frequent application of phosphates since the plant needs most of its requirements during the early stages of growth. The yield ranged between 0.8 - 1.38 kg/plant under shade.

2.4.8 Comparative effect of soil and foliar application of a complete fertilizer on okra yield in the open field

Indian okra variety Pusa Swani was seeded on 30 June 1982. Plants were 45 cm apart in rows 120 cm apart. Three treatments were used:

- no addition of mineral fertilizer (control);
- soil application of 2 g/plant of the mineral fertilizer side-dressed twice a week;
- foliar spraying the same fertilizer twice a week with 0.25% solution.

The mineral fertilizer used was Albatros complete fertilizer which contains N-P_2O_5 - K_2O in the ratio 15-30-15, as well as Fe, Mg, Mn, Cn, Zn, B and Mo in chelated forms at the concentrations of 0.13%, 0.8%, 0.2%, 0.06%, 0.06%, 0.04% and 0.009% respectively. The replicates were four in a randomized complete block design. The soil characteristics of the experimental site are indicated in Table 73. Analysis revealed that the soil is sandy loam in texture, very low in organic matter, calcareous, contains little gypsum, and is saline and moderately alkaline in reaction. It is also high in chemically determined available P and K.

During harvesting, from 7 September to 10 December 1982, 31 harvests were collected with an average rate of one harvest every 3 days.

Yield data are indicated in Table 74. Data were statistically analysed and differences between the control and the fertilized treatments were significant. Soil or foliar application of this complete mineral fertilizer led to 28% or 24% yield increase over control respectively. Differences in yield between foliar or soil application of the fertilizer were insignificant indicating that soil application is equally good as foliar application. The yield of okra ranged between 1.3 - 1.9 kg/plant, or 1.7 - 2.5 t/donum.

2.5 SOILS AND IRRIGATION WATER STUDIES

2.5.1 Evaluation of the potential fertility of soils under the plastic tunnels at Budaya

Surface (0-30 cm) and subsurface samples (30 cm to 60 cm where possible) of soils under the project's plastic tunnels at Budaya were collected and analysed. The soil characteristics are indicated in Table 75 and Table 76. Soluble ionic ratios in water saturation extracts for both surface and subsurface layers are included in Table 77 (plastic tunnel 1 is not included because it is used as a nursery).

The soils of the site are loamy sand in texture through the entire vegetable root zone depth, but occasionally sandy loam or loamy sand at the surface underlaid by a sandy loam layer. This shows that the site in general is coarse textured and sand predominates by more that 74%, whereas clay content ranges between 10-16%. Coarse texture commonly favours rapid water movement, low water-holding capacity and low fertility potential. The saturation percentage values range between 18-22. There is a compact cemented layer at a depth of 40 cm from the surface at the site of plastic tunnel 2. This layer occurs at progressively greater depths through tunnels 3 to 5, until the layer appears at depths of over 60 cm from plastic tunnel 6 onwards. The occurrence of this layer at shallow depth provides a barrier to maximum root penetration and water movement.

It is expected that the clay minerals present would be sepiolite-palygorskite-attapulgite since these minerals are frequently found in agrillaceous sediments associated with salinity in arid zones. The soils are calcareous with high values of calcium carbonate ranging from 12-23%. Calcareous soils usually are 100% base saturated, and their pH values are mainly controlled by the hydrolysis of calcium carbonate. Consequently the dissociation of calcium hydroxide and the production of OH^- ions will be greater than the production of H^+ ions from the weak carbonic acid. This creates an alkaline effect and the pH usually ranges from 7.9 to a maximum of 8.3. Gypsum in the surface layer ranges between 1.25 to 9.7%. It increases with depth and reaches a range from 1.6 to 15.5%. This indicates that gypsum content is very little to little at the surface, and very little to medium at the subsurface. The pH values at the surface range from 7.4-8. whereas at the subsurface they range from 7.0-8.1. Vegetable crops prefer a pH value of about 6.0 or a little higher. As a whole, good overall nutrie availability is know to be near pH 6.5. Higher pH values repress the availability of several nutrients, particularly P, Fe, Mn, and Zn. The alka line soil solution also has a corrosive action on the bark of roots and stems.

Salinity is generally moderate in the site except under plastic tunnel 2, where it is high. Saline soils have sufficient soluble salts to impair plant growth, mainly by increasing the osmotic pressure of soil solution and restricting water uptake. The nature and concentration of soluble salts in saline soils also influence the entrance of nutrient ions into root hairs of the plants. A comparison of Cl/SO_4 ratios in surface and subsurfac layers will indicate the degree of leaching. At the site of plastic tunnel 2, although considerable leaching down of salts has occurred, the degree of leaching the site is not as effective as under the other plastic tunnels. This is probably due to the presence of the cemented compact layer 40 cm from the soil surface under tunnel 2. All other Cl/SO_4 ratios indicate the dominance of sulphates over chlorides, with the exception of plastic tunnel 6. They also indicate the advanced degree of leaching occurring at the site. There is an upward capillary movement of salts at the site of plastic tunnels 4, 5, 6 and 10, indicated by the higher Cl/SO_4 ratios at the surface than the subsurface layers. It is expected that the proportion of Mg to Ca will not reduce the crop yield since the ratio values of Mg/Ca do not exceed 1.0. The proportions of Mg to Ca are generally higher ar the surface than the subsurface layer, except at the site of tunnels 4, 8 and 10. Ca/sum of cations or Mg/sum of cations ratios are over 0.15 and 0.05 respectively, indicating that their ionic proportions will not cause any yield reduction except at the site of tunnel 5. The Mg/sum of cations in the subsurface layer under this tunnel is marginal (0.05), and the incorporation of magnesium into the soil can be beneficial. Organic matter is extremely low (0.20-0.61% at surface and 0.26-0.56 at subsurface layer), and its build up in soil is very slow as would be expected because of the prevailing high oxidizing conditions. It is needed as a soil conditioner, to let the roots penetrate easily in the rhizosphere, organic mulching material as well as slow release nitrogen source and a good source of the micronutrients in highly available chelated forms.

Chemically determined available P values are medium to high in the surface layer under all plastic tunnels (6.0-16.8 ppm-P), but mostly low and variable in the subsurface layer (2.0-16.0 ppm-P). This indicates the restricted P penetrability and its high retention at the surface 0-30 cm layer of the site. High responses to phosphorus were obtained, and it is expected to be so until its build up is achieved and then low responses will be observed. Chemically determined available K is low for such textured soils (below 100 ppm-K). High responses were obtained for tomato and cucumber. Responses to potassium fertilization by other vegetable crops should also be tried.

2.5.2 Evaluation of potential fertility of some vegetable farms in Bahrain for protected vegetable production

2.5.2.1 Study of potential fertility of some vegetable production farms in Bahrain (1980/81)

Surface (0-30 cm) and subsurface (30-60 cm) soil samples of randomly selected eight vegetable production farms spread over Bahrain were collected, and analysed (Tables 78 and 79). Soluble ionic ratios in water saturation extracts for both surface and subsurface layers are included in Table 80.

Most of the soils are sand, loamy sand and sandy loam in texture. This shows that they are coarse textured and sand predominates at 70% or over. Silt contents range between 4%-25%, whereas clay varies from 4-14%. Coarse texture favours rapid water movement, low water-holding capacity and low fertility potential. These soils are commonly found in Shakhura, Markh, Hilat, Karrana, Zallaq and Hamala. This does not preclude the existence of fine textured soils with 64% or less sand, and clay contents range between 28-42%. These fine-textured soils contain a small amount of silt which does not exceed 8%. They are mostly found in Maqaba and Barbar and their texture is sandy clay loam and sandy clay respectively, especially in the surface 0-30 cm layer. This fine texture favours slow water movement, high water-holding capacity and higher fertility potential than those of the previously mentioned coarse textured soils. The soils are calcareous with high values of calcium carbonate ranging from 20.2-46.5%. Gypsum in the surface layers ranges between 2.9 to 30.3%, and is between 3.9-32.6% in the subsurface layers. This indicates that it is variable and covers a large rating range from very little to high. Its behaviour with depth is variable, sometimes, decreasing with depth and sometimes increasing.

Apart from soil subsidence and the formation of impeding layers, the presence of gypsum in itself is not harmful to the crops grown in Bahrain as it counteracts the harmful effect of sodium which is present in high amounts in both soils and brackish irrigation water. The pH values are slightly to moderately alkaline and range between 7.4 to 8.0.

Apart from Shakhura, salinity at the different farms is generally moderate to slightly high. Cl/SO_4 ratios indicate the dominance of sulphates over chlorides as well as the advanced degree of leaching at the farms. This is particularly evident in Markh, Hilat, Zallaq and Hamala. In Barbar, sulphates contribute equally with chlorides at the surface, and predominate over chlorides at the subsurface. There is also an upward capillary movement at Barbar. Chlorides predominate sulphates in Shakhura, Maqaba and Karrana. There is also an upward capillary movement of salts, and this is indicated by the higher Cl/SO_4 ratios at the surface than the subsurface. It is evident that the proportions of Mg to Ca will not cause any appreciable reduction in crop yield since their ratio values do not exceed 1.0. At Shakhura and Maqaba, the ratio of Mg/Ca is close to 1.0 at the subsurface layers, and care should be taken to reduce the magnesium content of these layers. Ratios of Ca/sum of cations or Mg/sum of cations are greater than 0.15 and 0.05 respectively, indicating that their ionic proportions will not cause any yield reduction.

Organic matter is extremely low (0.13-0.76%) at the surface and subsurface in all soils except at Shakhura and Karrana. At these two sites, the organic matter content varies between 1.21 and 1.66%, indicating a possible build up. Organic matter content declines with depth in all soils.

Chemically determined available P values are low to medium in all soils except at Shakhura, Maqaba and Karrana. Available P content declines with depth in all soils, indicating that it is highly retained at the surface 0-30 cm layer. The restricted P penetrability is expected in such soils, which are calcareous and gypsiferous in most cases. All the soils are well supplied with chemically determined available K, except at Zallaq, Barbar and Hamala which are low in available K. These soils should be supplied with appreciable quantities of potassium, and response to K fertilization are highly expected on such soils.

2.5.2.2 Study of potential fertility of 47 farms for future protected vegetable production in Bahrain (1982)

Randomly, 47 farms scattered in Bahrain were selected for study, to encourage the extension of protected vegetable production (see Table 81). The farms represent the agricultural area in Bahrain from the east to the west coasts of the main islands, also passing across the northern coast.

The acidity/alkalinity and salinity levels of the brackishwaters used for irrigating these farms are indicated in Table 82. Their pH values ranged from 7.0 to 7.5, indicating that the waters are neutral to slightly alkaline in reaction, and that their pH values lie within the normal range usually encountered for irrigation waters. The waters are highly saline since most of their electrolytic conductivity values range from 3 250-4 950 μmhos cm^{-1}. In very few cases, values of 5 060 to 7 700 μmhos cm^{-1} were recorded. Using these waters for irrigating vegetables will not lead to maximum yields, but relatively high yields can be obtained provided that necessary precautions and proper management of soil and water use are practised. Surface (0-30 cm) and subsurface (30-60 cm) soil samples were collected and analysed for characterization. Organic matter was determined only in surface layers as it is generally low in Bahrain soils and declines with depth. Hydraulic conductivity and cation exchange capacity were mostly determined in the surface layers, and sometimes in the subsurface layers when variations in texture were noted between the surface and subsurface layers.

(a) Farms 1 to 4

The site characteristics in farms 1, 2, 3 and 4 are indicated in Table 83; the soluble ionic ratios in water saturation extracts are included in Table 84. Data revealed that all sites apart from farm 1 are sandy loam in texture through the entire vegetable root zone depth and that sand fraction predominates other mechanical separates at 66.9% or over. Silt contents vary from 8.1 to 24.2%, whereas clay ranges between 8.9 and 14.9%. The hydraulic conductivity in farms 2 and 3 is very rapid and rapid respectively, indicating that both infiltration and percolation rates will also be so.

The soils in the four farms are slightly to moderately alkaline in reaction and calcareous with high contents of calcium carbonates, ranging from 17.0 to 40.5%. Gypsum is variable, very low in farms 2 and 3 and medium in farm 4.

Salinity at the different sites is generally very high, and periodic leaching is essential and should be done during soil preparation and before transplanting. The leachates should be removed from the sites. Cl/SO_4 ratios in the surface and subsurface layers at the four farms along with the salinity values indicate that there is an upward capillary movement of salts. Mg/Ca ionic proportions are balanced at farms 2 and 3, marginal at farm 4, and high at farm 1. Care should be taken to reduce the magnesium at farms 1 and 4, otherwise magnesium toxicity may appear; reduction in yield is presently expected at farm 1. Ratios of Ca/sum of cations in farm 1 indicate that calcium proportions with respect to all cations are low, but calcium status will improve after leaching the sodium chloride salts away from this site. In other farms, the proportions of calcium to all cations are above marginal limits and will improve after the use of periodic leaching. Ratios of Mg/sum of cations in all sites indicate balanced proportions of magnesium with respect to all cations. Organic matter contents vary between 0.83 to 1.74, indicating a possible build up which is desirable. The cation exchange capacity values are medium, illustrating that medium amounts of nutrients can be retained. Chemically determined available P is high and evenly distributed among surface and subsurface layers (farms 1 and 4), or highly retained at the surface 0-30 cm layers and decreases with depth (farms 2 and 3). Apart from farm 4, all sites are low in chemically determined available K; these soils should be supplied with appreciable quantities of potassium, and responses to K fertilization are highly expected. In farm 4, chemically determined available K is high.

The site at farm 1 is loam in texture through the entire vegetable root zone. The fine mechanical separates (silt + clay), exceed the sand fraction. The hydraulic conductivity is moderately slow, indicating that both infiltration and percolation rates will be slow. Ripping and heavy application rates of organic matter are needed to increase infiltration and percolation rates. The saturation percentage is high, illustrating high water-holding capacity. Frequency of irrigation should be of longer intervals, and the discharge rate of the drip irrigation should be slower than commonly used in the light textured soils in Bahrain. This soil is gypsiferous with high gypsum content, and soil subsidence is expected. Continuous addition of sweet sand is required to raise this soil level.

(b) Farms 5 to 8

The site characteristics in farms 5, 6, 7 and 8 are indicated in Table 85; the soluble ionic ratios in water saturation extracts are included in Table 84. Apart from farm 8, all sites are loamy sand in texture through the entire vegetable root zone, and the sand fraction predominates other mechanical separates with 83.6% or over. Silt contents vary from 1.5 - 7.5%, whereas clay ranges between 6.9 - 8.9%. The site at farm 8 is sandy clay loam in texture through the entire vegetable root zone. The fine mechanical separates (silt+clay), contribute with 37.2-43.2%. The sand fraction predominates other mechanical fractions, and shares with 56.8-62.8%. The hydraulic conductivity is rapid in farm 6. Hydraulic conductivity ratings will similarly reflect both infiltration and percolation rates. The soils at all sites are slightly to moderately alkaline in reaction and calcareous, with high values of calcium carbonate ranging from 16.0-40%. Gypsum is variable, but it is very low in farms 5, 7 and 8, and medium in farm 6.

Salinity is normal in farm 7, moderate in farm 8 and high in farms 5 and 6. Periodic leaching is essential, particularly when salinity is medium to high and should be done during soil preparation before transplanting. The leachates should be carried away from the sites. Cl/SO_4 ratios in surface and subsurface layers indicate the dominance of chlorides over sulphates in farms 5 and 6, whereas the reverse dominance pattern is true in farms 7 and 8.

Mg/Ca ionic proportions are balanced at all sites. Ratios of Ca/sum of cations or Mg/sum of cations indicate balanced proportions of calcium or magnesium with respect to all cations. Organic matter contents are very low in farms 5 and 6 and low in farms 7 and 8, and a possible build up is desirable. The cation exchange capacity is low at farms 5, 6 and 7, and medium at farm 8. This illustrates that little amounts of nutrients can be retained in the former farms, whereas medium amounts of nutrients will be retained in the latter farm.

All sites are high in chemically determined available P, and it is highly retained in the surface at farms 5, 6 and 8. Available P is evenly distributed in surface and subsurface layers at farm 7. Apart from farm 8, all sites are high in chemically determined available K at the surface, and medium in subsurface layers. In farm 8, chemically determined available K is high in both surface and subsurface layers and increases with depth. Little response to potassium fertilization is expected in farms 6 and 7.

(c) Farms 9 to 12

The site characteristics in farms 9, 10, 11 and 12 are indicated in Table 86; the soluble ionic ratios in water saturation extracts are included in Table 84. Data revealed that the soil texture is variable at all farm sites, and through surface and subsurface layers in farms 11 and 12. The hydraulic conductivity is moderately slow in farm 9, and moderate in farm 10. The soils at all sites are slightly to moderately alkaline in reaction and calcareous, with high values of calcium carbonate ranging from 19 to 48.5%. Gypsum is very low in farms 9, 11 and 12, whereas in farm 10 it is low at the surface and high in the subsurface layers. Soil subsidence is expected in farm 10.

Salinity is very high at farm 9, high in farms 10 and 11, and is medium at farm 12. Periodic leaching is essential, especially for soils of high salinity, and should be carried out during soil preparation and before transplanting. The leachates should be removed from the sites. Cl/SO_4 ratios in surface and subsurface layers indicate the dominance of chlorides over sulphates at all sites. The higher Cl/SO_4 ratios and the higher EC_e at the surface than the subsurface at farms 9 and 10, indicate that there is an upward capillary movement of salts at the two farms. Mg/Ca ionic proportions are balanced at all sites. Ratios of Ca/sum of cations or Mg/sum of cations indicate balanced proportions of calcium or magnesium with respect to all cations. Organic matter contents are low and a possible build up is desirable. The cation exchange capacities are medium at all sites, indicating that medium amounts of nutrients can be retained.

Apart from farm 9, all sites are high in chemically determined available P, and it is higher at the surface than subsurface layers. In farm 9, available P level is intermediate at the surface, and high at the subsurface layers. All sites are very low in chemically determined available K. High responses to potassium fertilization are expected at all farms.

(d) Farms 13 to 16

The site characteristics in farm 13, 14, 15 and 16 are indicated in Table 87; the soluble ionic ratios in water saturation extracts are included in Table 84. Data revealed that soil texture is variable at all farms, and through surface and subsurface layers in farms 14 and 16. The hydraulic conductivity is moderately rapid in farm 16. Hydraulic conductivities in other farms should be checked.

The soils in all sites are slightly to moderately alkaline in reaction and calcareous, with high values of calcium carbonate ranging from 10.5 to 38.5%. Gypsum is very low in farm 16, low in farms 14 and 15, whereas in farm 13 it is low at the surface and medium in the subsurface layer. Soil subsidence is expected in farm 13.

Salinity is high at all sites. Periodic leaching is essential, and should be done during soil preparation before transplanting. Cl/SO_4 ratios in surface and subsurface layers indicate the dominance of chlorides over sulphates at all sites. Mg/Ca ionic proportions are balanced in all sites. Ratios of Ca/sum of cations or Mg/sum of cations indicate balanced proportions of calcium or magnesium with respect to all cations. Organic matter contents are low and their build up is essential. The cation exchange capacities are medium in all sites indicating that intermediate amounts of nutrients can be retained.

All sites are high at surface layers in chemically determined available P, but very low in chemically determined available K at the surface and subsurface layers. High responses to potassium fertilization are expected at all farms.

(e) Farms 17 to 20

The site characteristics at farms 17, 18, 19 and 20 are indicated in Table 88; the soluble ionic ratios in water saturation extracts are included in Table 84. Data revealed that all sites apart from farm 19 are sandy loam in texture through the entire vegetable root zone, and the sand fraction predominates with 68.9% or more. Silt contents vary from 10.1-22.2%, whereas clay ranges between 6.0-14.9%. The site at farm 19 is sand in texture throughout the entire root zone. The hydraulic conductivities are moderately rapid to rapid. The soils in all sites are slightly to moderately alkaline in reaction and calcareous, with calcium carbonate contents ranging from 5.5 to 28%. Gypsum is very low in farm 19, medium to low in farm 17, low to medium in farm 20 and high in farm 18 where soil subsidence is particularly expected.

Salinity is normal at farm 19, medium at farm 18, high at farm 17 and very high at farm 20. Periodic leaching is essential, and should be done during soil preparation before transplanting. Cl/SO_4 ratios at farm 18 indicate the dominance of sulphates over chlorides in both surface and subsurface layers. At farm 19, Cl/SO_4 ratios indicate the dominance of sulphates over chlorides only at the surface layer, the reverse being true for the subsurface layer. At farm 17, Cl/SO_4 ratios indicate that both sulphates and chlorides contribute equally in the surface layer, and chlorides dominate sulphate in the subsurface layer. At farm 20, Cl/SO_4 ratios indicate that chlorides dominate sulphates in both surface and subsurface layers. Excessive leaching is very important, especially where salinity is intermediate or high. The leachate should be carried away from the site.

Mg/Ca ionic proportions are balanced in the surface layers of farms 19 and 20. Subsurface layers of farms 17 and 18 indicate the dominance of Mg over Ca and care should be taken to avoid magnesium toxicity. Ratios of Ca/sum of cations or Mg/sum of cations indicated balanced proportions of calcium or magnesium with respect to all cations in all farms.

Organic matter contents are very low in farms 19 and 20, and low in farms 17 and 18. The cation exchange capacities are low in farms 18, 19 and 20, and is medium in farm 17.

Chemically determined available P is high at all sites. P penetrability is high at farm sites 18 and 20, and low at farm sites 17 and 19. Chemically determined available K is high at farms No. 18 and 20, marginal at farm 19 and very low at farm 17. Response to potassium fertilization is highly expected at farm 17, and to a lesser extent at farm 19.

(f) Farms 21 to 24

The site characteristics of farms 21, 22, 23 and 24 are indicated in Table 89; the soluble ionic ratios in water saturation extracts are included in Table 84. Data revealed that the sites at farms 23 and 24 are loamy sand in texture throughout the root zone, sandy loam at farm 22, and loamy sand in the surface and sandy loam in the subsurface layers of farm 21. Sand fraction predominates other mechanical separates with 62.6% or more. Silt contents vary from 4.1% - 29.4%, whereas clay ranges between 4.9 - 14.9%.

The hydraulic conductivity at farm 21 is moderately rapid at the surface and moderate at the subsurface. This is expected since the texture is different through the surface and subsurface layers at this site. The discharge rate of the drip system should be adjusted according to the least hydraulic conductivity value of the soil layer in the root wetting zone otherwise water logging will occur, reducing conditions will prevail and aeration will be badly affected. Hydraulic conductivities at farms 22, 23 and 24 are very rapid.

The soils in all sites are slightly to moderately alkaline in reaction and calcareous, with high values of calcium carbonate ranging from 12.5 - 34.2%. Gypsum is very low in farm 21, low in the surface and very low in the subsurface layers at farm 24, medium to high in farm 23 and high in farm 22. Soil subsidence is expected, especially in farms 22 and 23.

Apart from farm 23, salinity is high at all sites. Periodic leaching is essential and should be done during soil preparation before transplanting. Cl/SO_4 ratios at farms 21 and 24 indicate the dominance of chlorides over sulphates in both surface and subsurface layers, whereas the reverse pattern of dominance is true for farms 22 and 23.

Mg/Ca ionic proportions are balanced in the surface and subsurface layers at farms 21, 22 and 23. At farm 24, the Mg/Ca ratio is normal at the subsurface and marginal at the surface, and care should be taken to avoid the build up of magnesium toxicity. Ratios of Ca/sum of cations or Mg/sum of cations indicate balanced proportions of calcium or magnesium with respect to all cations.

Organic matter contents are very low at farms 21, 23 and 24 and low at farm 22. The cation exchange capacities are low at farms 21, 22 and 23 and medium at farm 24. Only small amounts of nutrients can be retained in the former farms, and intermediate amounts in the latter.

Chemically determined available K is high at farms 21, 22 and 24, whereas it is medium at farm 23 where a high response to potassium fertilization can be expected. Chemically determined available P is high at farms No. 21 and 23; high at the surface and medium at the subsurface layers of farm 24; and medium at the surface and high at the subsurface layers of farm 22.

(g) Farms 25 to 28

The sites characteristics at farms 25, 26, 27 and 28 are indicated in Table 90; the soluble ionic ratios in water saturation extracts are included in Tables 84 and 91. Data revealed that all sites are sand or loamy sand in texture through the entire vegetable root zone, and that sand fraction predominates other mechanical separates with 87.1% or more. Silt contents vary from nil to 5.2%, whereas clay ranges between 4.8 - 10.9%. Hydraulic conductivity is very rapid at all sites. The soils are moderately alkaline in reaction and calcareous at all sites, with calcium carbonate contents ranging from 9 - 19%. Gypsum is very low in farms 25 and 26, low in farm 27 and medium to low in farm 28.

Salinity is moderate to high. Periodic leaching is essential, and should be carried out during soil preparation before transplanting. Cl/SO_4 ratios at farms 25 and 27 indicate the dominance of sulphates over chlorides, whereas the reverse pattern of dominance holds true for farms 26 and 28. There are indications of upward capillary rise of salts at all sites. Mg/Ca ionic proportions are balanced at all sites. Ratios of Ca/sum of cations or Mg/sum of cations indicate balanced proportions of Ca or Mg with respect to all cations.

Organic matter contents are extremely to very low, and high rates of organic matter addition are deemed essential. The cation exchange capacities are low at all sites. Chemically determined available K is high at farm 28, medium to farm 25 and extremely low at farms 26 and 27. High responses to potassium fertilization are expected at farms 25, 26 and 27. Chemically determined available P is high at surface layers, and medium to high at subsurface layers at all sites.

(h) Farms 29 to 32

The site characteristics at farms 29, 30, 31 and 32 are indicated in Table 92; the soluble ionic ratios in water saturation extracts are included in Table 91. Data revealed that the sites at farms 29 and 30 are loamy sand in texture throughout the root zone, loamy sand at the surface and sand at the subsurface layers at farm 31, whereas it is sandy loam at farm 32. Sand fraction predominates other mechanical separates with 72.9% or more. Silt contents vary from nil to 15.5%, whereas clay ranges between 6.9 and 17.0%. The hydraulic conductivity is very rapid at the surface layers, and moderate in the subsurface layer at farm 30. Discharge rates of the drip irrigation system should be adjusted accordingly to the least hydraulic conductivity value of soil layer in the root wetting zone. The soils in all sites are slightly to moderately alkaline in reaction and calcareous, with calcium carbonate contents varying from 9.5-17.0%. Gypsum is low in the surface and medium in the subsurface layers at farm 29, high in farm 30, medium in farm 31, and medium in the surface and low in the subsurface layers of farm 32. Soil subsidence is expected, especially in farms 30 and 31. The sites are moderately to highly saline, but extremely saline at farm 32. Periodic leaching is essential at farms 29, 30 and 31, whereas excessive leaching is essential at farm 32.

Cl/SO_4 ratios at farms 29, 31 and 32 indicate the dominance of chlorides over sulphates in both the surface and subsurface layers whereas the reverse pattern of dominance occurs at farm 30.

Mg/Ca ratios at all sites, apart from farm 32 indicate the absence of any potential magnesium toxicity. At farm 32, the Mg/Ca ratio at the surface layer indicates a potential Mg toxicity. Ratios of Ca/sum of cations indicate balanced proportions of calcium with respect to the cations at all sites, except farm 32 where the ratio is low at the surface and marginal at the subsurface. Excessive leaching and removing the leachates from the site will probably balance the proportions. Mg/sum of cations ratios indicate balanced proportions of magnesium with respect to all cations at all sites, except at farm 30 where the ratio is very low at the surface; magnesium should be included in the fertilization programme of this farm.

Organic matter contents are very low at all sites, and high rates of organic matter additions are deemed essential. The cation exchange capacities are low to medium. Chemically determined available P is high at all farms especially in the surface layers. It is also high at the subsurface layers of all farms except 32, where it is medium. Chemically determined available K is medium at farms 29 and 30, whereas it is high at farms 31 and 32. Response to potassium fertilization is expected at the first two farms.

(i) Farms 33 to 36

The site characteristics at farms 33, 34, 35 and 36 are indicated in Table 93; the soluble ionic ratios in water saturation extracts are included in Table 91. Data revealed that the sites in farms 34, 35 and 36 are sandy loam in texture throughout the entire vegetable root zone, whereas in farm 33 the texture is loamy sand at the surface and sand at the subsurface layers. Hydraulic conductivity is moderate to moderately rapid at the surface layers, whereas it is very rapid in the subsurface sand layer of farm 33. The soils are slightly to moderately alkaline in reaction and calcareous at all sites, with calcium carbonate contents ranging from 14.5 - 35%. Gypsum is low to very low in farm 33, medium in farm 36, medium to high in farm 35 and high in farm 34. Soil subsidence is expected especially in farms 34, 35 and 36.

Salinity is low in farm 33, high in farm 34 and extremely high in farms 35 and 36. Periodic leaching is essential at farms 33 and 34; excessive leaching is essential at farms 35 and 36.

Cl/SO_4 ratios at farms 34, 35 and 36 indicate the dominance of chlorides over sulphates in both the surface and subsurface layers, whereas the reverse pattern of dominance occurs at farm 33. Mg/Ca ratios at all sites indicate the absence of any potential magnesium toxicity. Ratios of Ca/sum of cations or Mg/sum of cations indicate balanced proportions of Ca or Mg for all cations. Organic matter is extremely low at farm 33 and low at farms 34, 35 and 36, and high rates of organic matter addition are essential. The cation exchange capacity is low at farm 33, and intermediate at the other three farms.

Chemically determined available K is low at farm 33, marginal at farm 34, and high at farms 35 and 36. Response to potassium fertilization is expected at farms 33 and 34. Chemically determined available P is high at farms 33 and 34, high at the surface and intermediate at the subsurface layers in farm 36, and intermediate at farm 35.

(j) Farms 37 to 40

The site characteristics at farms 37, 38, 39 and 40 are indicated in Table 94; the soluble ionic ratios in water saturation extracts are included in Table 91. Data revealed that the sites are loamy sand and sandy loam in texture. The sand fraction predominates other mechanical separates with 75% or over. Silt contents vary from nil to 16.2%, whereas clay ranges between 8.9 - 12.9%. The hydraulic conductivity is moderately rapid to very rapid. The soils are neutral to moderately alkaline in reaction and calcareous, with calcium carbonate contents varying from 11.0 - 38.0%. Gypsum is low to medium in farm 37, medium to low in farm 38, and medium in farms 39 and 40. The sites are highly to extremely saline, and periodic excessive leaching is essential.

Cl/SO_4 ratios of surface and subsurface layers at farms 37, 39 and 40 indicate the dominance of chlorides over sulphates. At farm 38, Cl/SO_4 ratios indicate that chlorides predominate sulphates in the surface layer, whereas sulphates predominate chlorides in the subsurface layer. Mg/Ca ratios at farms 38, 39 and 40 indicate the absence of any potential magnesium toxicity. Mg/Ca ratio at farm 37 is high in the subsurface layer, and care should be taken always to keep the magnesium below the toxicity level in the surface layer. Ratios of Ca/sum of cations indicate balanced proportions of calcium with respect to all other cations at all sites, except farm 37 where the ratio is balanced at the surface and low at the subsurface. Excessive leaching and removing the leachates from the site will probably balance the proportions. Ratios of Mg/sum of cations indicate balanced proportions of magnesium with respect to the other cations at all sites.

Organic matter is extremely low, and high rates of its addition are deemed essential. The cation exchange capacities are low to medium. Chemically determined available P is high at all sites. Chemically determined available K is high at farms 37, 38 and 39, but extremely low at farm 40. High responses to potassium fertilization are expected at the latter farm.

(k) Farms 41 to 44

The site characteristics at farms 41, 42, 43 and 44 are indicated in Table 95; the soluble ionic ratios in water saturation extracts are included in Table 91. Data revealed that the sites are loamy sand, sandy loam and sandy clay loam in texture. The sand fraction predominates other mechanical separates with 64.9% or more. Silt contents vary from 5.4 - 22.2%, whereas clay ranges between 6.8 - 17.4%. The hydraulic conductivity is rapid to very rapid. The soils are neutral to moderately alkaline in reaction and calcareous, with calcium carbonate contents varying from 6.0 - 30.5%. Gypsum is medium to high in farm 41, high in farm 42, medium to low in farm 43 and high to medium in farm 44.

The sites are highly to extremely saline, and periodic excessive leaching is essential.

Cl/SO_4 ratios indicate that chlorides predominate sulphates at the surface and subsurface soil layers at farms 41, 42 and 43. Cl/SO_4 ratios at farm 44 indicate that sulphates predominate chlorides at the surface and subsurface layers. Apart from farm 42, all farms have unbalanced Mg/Ca ratios at the surface and subsurface layers, indicating potential magnesium toxicity. Excessive leaching and removing the leachates from the site will probably improve these ratios. At farm 42, Mg/Ca ratios in the surface and subsurface layers indicate the absence of any magnesium toxicity. Low and marginal Ca/sum of cations ratios are noted at farms 41, 43 and 44, indicating unbalanced proportions of calcium in respect to other cations. Again, excessive leaching and removing the leachates from the site will take care of these ratios. At farm 42 the ratio of Ca/sum of cations indicates balanced proportion at the surface and subsurface layers. Ratios of Mg/sum of cations indicate balanced proportions of magnesium in respect to the other cations at all sites. Organic matter is extremely low to low and high rates of addition are essential. The cation exchange capacities are low to medium.

Chemically determined available P is high in almost all sites. Chemically determined available K is high at farms 41, 42 and 44, whereas it is low at farm 43. High responses to potassium fertilization are expected at the latter farm.

(1) Farms 45 to 47

The site characteristics at farms 45, 46 and 47 are indicated in Table 96; the soluble ionic ratios in water saturation extracts are included in Table 91. Data revealed that the sites are loamy sand and sandy loam in texture. The sand fraction predominates other mechanical separates with 70.9% or more. Silt contents vary from 9.4 - 18.2%, whereas clay ranges between 6.8 - 12.9%. The hydraulic conductivity is very rapid at farms 45 and 46, whereas it is moderately rapid at the surface and moderate at the subsurface layers of farm 47. The soils are slightly to moderately alkaline in reaction and calcareous, with calcium carbonate contents varying from 8.3 - 26.0%. Gypsum is high at farm 45, medium to low at farm 46 and high to low at farm 47.

The sites are highly and extremely saline, and periodic excessive leaching is essential.

Cl/SO_4 ratios of surface and subsurface layers indicate the dominance of chlorides over sulphates at all sites. Mg/Ca ratios at farm 45 indicate the absence of any magnesium toxicity. Mg/Ca ratios at farm 46 indicate that there is a possible magnesium toxicity at the site. At farm 47, the Mg/Ca ratio is high in the subsurface layer and care should be taken to keep the magnesium always below the toxicity level in the surface layer. Ratios of Ca/sum of cations indicate balanced proportions of calcium with respect to the other cations at all sites, except farm 46. Excessive leaching and removing the leachates from the site will probably balance the proportions at farm 46. Ratios of Mg/sum of cations indicate balanced proportions of magnesium with respect to the other cations at all sites. Organic matter is extremely low, and high rates of its addition are deemed essential. The cation exchange capacities are low to medium.

Chemically determined available P is high at all sites. Chemically determined available K is high at farms 45 and 46, and extremely low at farm 47 where high responses to potassium fertilization are expected.

2.5.3 Assessment of the quality of irrigation waters in Bahrain

Brackish waters are used to irrigate vegetable crops in Bahrain. In fact, the site of any farm is selected according to the availability of a water source. The suitability of water for irrigation, or in other words the quality of irrigation water, is mainly influenced by the total quantity of salts or total salt concentration in water, the relative concentration of sodium to calcium and magnesium (SAR values), and the presence of toxic constituents such as sodium, chloride and trace elements. Total salt concentration of water is determined by measuring its electrolytic conductivity. Trace elements which should be determined are Al, As, Be, B, Cd, Cr, Co, Cu, F, Fe, Pb, Li, Mn, Mo, Ni, Se, V and Zn.

Boron was the only trace element which was determined, due to lack of laboratory equipment at Budaya. The analyses of a group of brackish waters, from 16 sites in Bahrain, that are being used for irrigation purposes are presented in Table 97. Data revealed that their pH values range between 7.0 - 7.6, indicating that they are neutral to slightly alkaline in reaction and lie within the normal pH range (6.5 - 8.4) usually encountered for irrigation waters. The electrolytic conductivity values expressed in μmhos cm^{-1} at 25°C range mostly between 3 200-6 720, but this does not preclude the existence of some waters with 8 800 and 9 890 at Maqabah and Sitrah. When dissolved salts were calculated from electrolytic conductivity values, they reached a concentration range of 2 048 to 4 301 ppm but in a few cases, e.g., Maqabah and Sitrah, values reached 5 632 and 6 330 ppm. The salinity levels of the waters are very high since their electrolytic conductivity values are more than 3 000 μmhos cm^{-1} and severe potential salinity problems are expected.

The severity of the salinity problems are reduced in Bahrain because waters are relatively high in their content of dissolved lime (calcium carbonate and bicarbonate) and gypsum (calcium sulphate), and the soils in Bahrain are mostly coarse textured. Also applying leaching requirements, changing the method of irrigation from basin or furrow flood irrigation into trickle or sprinkler irrigation, irrigating more frequently and selecting vegetable varieties that are tolerant to existing salinity levels will reduce the effects of the high salinity levels in the brackish irrigation waters of Bahrain.

The sodium adsorption ratio reflects the alkali hazards involved in the use of water for irrigation. Apart from waters from Sitra, SAR values of the irrigation waters lie between 5.6 - 10.6, illustrating that these waters are medium to high sodium waters. Medium sodium waters present an appreciable sodium hazard in fine textured soils especially under low leaching conditions, unless gypsum is present in the soil. These waters may be used on coarse-textured soils with good permeability. High sodium waters may produce harmful levels of exchangeable sodium in most soils and will require good drainage, high leaching and good organic matter additions. Gypsiferous soils may not develop harmful levels of exchangeable sodium from such waters. Irrigation water at Sitrah should be blended with sweet water before use, because Sitrah water is very high sodium water. The chemical composition of the sweet water in Bahrain is indicated in Table 98. Sodium and chloride concentrations in all water are well above 10 meq/litre indicating possible potential toxicities.

Symptoms of sodium toxicity appear as a burn or drying of tissue at the outer edges of the leaf and as severity increases, progress inward between the veins towards the leaf centre. Sodium toxicity can be confirmed by chemical analysis of the leaf tissue. Symptoms of chloride toxicity appear first as a burn or drying at the extreme leaf tip rather than at the edges, and progress from the tip back along the edges as severity increases. Leaf burn is accompanied by abnormal early leaf drop and defoliation. Chloride toxicity can be confirmed by chemical analysis of the leaf tissue. Boron concentration ranges in these waters between 0.4 - 1.6 mg/litre.

Since most of the vegetable crops are tolerant to semitolerant to boron, it is expected that they will not be affected by the encountered boron level of these brackish waters. Drainage waters in Bahrain are 1.57 - 3.7 times more saline than their respective irrigation waters. Their chemical compositions are indicated in Table 99. Their electrolytic conductivity values range between 5 280 - 12 320 umhos cm^{-1}. Their SAR values are 1.25 - 2.4 times more than their respective irrigation waters. Boron concentrations vary between 1.2 - 1.9 mg/litre. These drainage waters may be reused for irrigation alone, or after blending with either sweet water or with their respective irrigation waters.

2.6 MANAGEMENT OF HYDROPONIC NUTRIENT SOLUTIONS

Notes on the management of hydroponic nutrient solutions are given below.

Inert crushed rock or gravel (granite or basalt) is placed in leakproof beds. Calcareous aggregates should be avoided whenever possible. The size of the gravel should be limited to 0.5 - 1.0 cm. Gravel in the beds should be sterilized with formaline (40% formaldehyde solution), by a solution made of 1 part formaline to 100 parts water, i.e.,4 000 ppm solution of active formaldehyde. If high calcium rock is the only available growth medium, it should be soaked for 24 hours in a phosphate solution of 250 ppm - P. The limestone aggregates will gradually be coated with insoluble phosphate, and the phosphorus concentration of the solution will decrease. After soaking, the solution should be drained to waste. Pump the gravel with water and drain at least twice.

Nutrient solutions are stored in tanks, carried by flumes and pumped through the gravel in the beds. The time to flood and drain should not exceed 30 minutes, and the drainage period should last at least four times as long. Samples of the drainage water should be collected and tested for total dissolved salts. When the drainage water has a salt concentration of 4 000 ppm, the entire gravel bed is leached to a point nearly equal to the salinity of the irrigation water.

The pH of the nutrient solution should range between 6.0 - 6. 8. In the case of noncalcareous aggregates, the pH of the nutrient solution is adjusted with H_2SO_4. In the case of calcareous aggregates, to adjust the pH, the bed must be irrigated twice with the nutrient solution. Then, the pH should be determined and the phosphorous level checked. If phosphorous drops to 75% of its initial concentration and the pH is above 6.8, more phosphate must be added. If the high pH is only due to the pH of the water, use H_2SO_4 only for pH adjustments.

The concentrations of the various essential elements in the nutrient solution must be monitored after the use of the solution for one week. Additional fertilizers might be needed to bring the nutrients content up again to the desired levels. As a rule of thumb, old nutrient solutions are topped with new solutions containing half the normal concentrations one week after the solution is completely changed. Nutrient tanks should be emptied once every two weeks.

Many formulas have been tried for tomatoes and cucumbers in Bahrain; the ideal formulas are indicated in Table 100. The chemicals used in the preparation of nutrient solutions and their element content are shown in Appendix 2. The rate at which the elements are consumed by the plants depends upon their stage of growth. Note that the optimum concentrations are used for the plants when they are growing from the seedling stage till the first fruit set; the maximum concentrations are those used from fruit set start till the termination of crops; and the minimum concentrations are those below which plants show nutrient deficiencies.

The recommended annual consumption for nutrient carriers for one hydroponic unit producing tomato and cucumber throughout a year is shown in Appendix 3.

3. RECOMMENDATIONS

3.1 RECOMMENDATIONS BASED ON RESEARCH FINDINGS

The recommendations below are based on the research findings resulting from experiments under high and low plastic tunnels and shade houses, as well as in the open field.

3.1.1 Soil management practices

The presence of a compact cemented layer of gypsum or calcium carbonate at 30 cm or more from the surface acts as a barrier to maximum root penetration and water movement, and increases the upward capillary movement of salts to the surface. Ripping to a depth of 50-60 cm and increasing effective soil depth by adding sweet sand are the practices recommended.

While most of the soils in Bahrain are coarse textured with low potential fertility (sand, loamy sand and sandy loam), it should be noted that fine textured soils with medium potential fertility (loam and sandy clay loam) are present in Samad, Al-Jufayr, Al-Naiem, Jabalet Habashi, Jidd-Hafs, Karranah, Magabah, Barbar and Karzakkan.

Most of the soils in Bahrain are gypsiferous. The presence of gypsum in itself is not harmful to the crops as it counteracts the harmful effect of sodium which is present in high amounts in both soils and brackish irrigation water. However, the presence of gypsum in such quantities leads to soil subsidence. A continual addition of sweet sand once every three years is recommended to compensate for the decrease in effective soil depth.

As the majority of the soils are saline, periodic leaching is essential before and after each vegetable crop. Removal of leachates by drainage is required to reduce soil salinity. Electrolytic conductivity and Cl/SO_4 ratios in soil water saturation extracts before and after leaching should be used to indicate the leaching efficiency.

The soils are calcareous to the extent that creates an alkaline pH effect. This leads to corrosive action on the bark of roots and stems, as it represses the availability of several nutrients particularly phosphorus, iron, manganese and zinc. Side-dressing of superphosphate at early stages of plant growth and organic matter application during soil cultivation are therefore recommended.

Organic matter is very low to low and its build up in soil is very slow due to the prevailing high oxidizing conditions. Its application at 2-3 kg/m^2 is needed as a soil conditioner to let the roots penetrate easily in the rhizosphere, and to provide organic mulching material as well as slow release nitrogen source and micronutrients in highly available chelated forms.

Consideration should be given in soil analysis to the ratios in soil solutions of Mg/Ca, Ca/sum of cations, Mg/sum of cations, as magnesium toxicity, and calcium and magnesium deficiencies occur, whenever these ratios exceed 1.0, or recede to less than 15% or 5%, respectively.

Since hydraulic conductivity reflects both infiltration and percolation rates, it should be included in the field soil tests of the representative sites. Where the hydraulic conductivity is moderate to slow, ripping and high application rates of organic matter (not less than 3 kg/m^2) are needed to increase infiltration and percolation rates.

High application rates of phosphate are needed for all soils, regardless of the sufficiency level of the chemically determined available P by Olsen's method, since high responses to phosphate application were noted in soils high in available P. Other chemical methods of available P extractions should be tried and correlated with yield response data.

High responses to potassium fertilization were noted where the ammonium acetate extractable K was less than 85 ppm for sands and loamy sands, and 100 ppm for sandy loams and loams.

3.1.2 Quality of irrigation waters

Irrigation waters are neutral to slightly alkaline in reaction and lie within the normal pH range encountered for irrigation waters (6.5 - 8.4).

Although the salinity levels are very high, their severity is reduced because Bahrain waters are relatively high in their content of dissolved lime (calcium carbonate and bicarbonate) and gypsum (calcium sulphate), and because Bahrain soils are mostly coarse textured.

Further reduction of the effect of the high salinity in waters is possible by applying leaching requirements with the crop water requirement, changing the method of irrigation from flood irrigation to drip irrigation, irrigating more frequently and selecting varieties that are tolerant to the existing salinity levels.

Waters are mostly of medium to high sodium quality. Although the soils may not develop harmful levels of exchangeable sodium from such water, in a few cases the water is very high in sodium as in Sitrah, to the extent that it should be blended with sweet water before use.

There are possible potential toxicities from sodium and chloride concentrations in all waters. This should be confirmed by the chemical analysis of the leaf tissue.

No harmful effect was noticed from the encountered boron level of these waters. On the contrary, there may be boron deficiency since the presence of calcium in abundant quantities in soil may render boron unavailable to the plants. Therefore, plant analysis for boron should be performed at the laboratory in the future.

Al, As, Be, Cd, Cr, Co, Cu, F, Fe, Pb, Li, Mu, Mo, Ni, Se and V should be checked in irrigation water as no information exists on these elements which may be hazardous to plant, animal and human life.

3.1.3 Mulching and irrigation under plastic tunnel conditions

Black polyethylene mulching should be used inside the plastic tunnels since it reduces the salinity in the surface 0-30 cm soil layer and controls weed growth better than the translucent mulch.

Irrigation with Budaya brackishwater for two hours daily in summer or every other day in winter at a discharge rate of 0.5 gal/h in Budaya calcareous loamy sand or sandy loam soils is a good practice for both cucumber and tomato. The longer duration of irrigation washes out nutrients and intensifies the nematode injury of the roots.

3.1.4 Fertilization

(a) Organic fertilization

Locally produced organic manures (cow manure or poultry manure) are equally as good as the biological organic fertilizer Cofuna.

There was a significant steady increase in yield with the increase in the rate of organic fertilizer addition, regardless of its type. The average increase in yield was 25%, 55% and 76% when the rates were 1, 2 and 3 kg/m^2.

Base organic fertilization is necessary, and the locally produced cow manure or poultry manure can be used. Rate of addition can be 3 kg/m^2 if it is to be mixed thoroughly with the soil after broadcasting, or 2 kg/m^2 if it is to be buried in furrows at a depth of 10-15 cm under the driplines during soil preparation. It should be thoroughly leached several times to reduce its salt effect.

(b) Base mineral fertilization

Side-dressing of a compound NPK fertilizer at transplanting is a good practice for vegetables. Ordinary fertilizers such as 15-15-15 or slow release fertilizer 14-14-14 and 18-11-11 of 3-4 months longevity at the rate of 10-20 g/plant can be used.

(c) Phosphate fertilization

Banding or side-dressing of treble superphosphate 46% P_2O_5, once at transplanting and twice within one month from transplanting, is a good practice for vegetables.

(d) Potash fertilization

Split application of potassium where needed in four doses applied at two-week intervals starting from transplanting, or by dissolving the potassium in water and applying with irrigation through the drip lines, is suggested.

(e) Nitrogen fertilization

Weekly split application of nitrogen, side-dressed or dissolving the nitrogen in water and applying with irrigation water through the drip lines, is suggested.

(f) Foliar fertilization

All macronutrients and micronutrients can be foliar sprayed twice a week with 0.5% solution in one compound foliar fertilizer, i.e., Albatros (15-30-15), which also contains N-P_2O_5-K_2O, Fe, Mg, Mn, Cu, Zn, B and Mo in chelated forms at concentrations 0.13%, 0.8%, 0.2%, 0.06%, 0.06%, 0.04% and 0.009% respectively.

Soil application of urea or potassium sulphate is better than foliar spray at concentrations of 0.1 and 0.2 solutions, respectively.

No nutrient disorders appear on the plants if the micronutrients are foliar sprayed or drenched at the following concentrations (mg/litre): Mn = 5-20, Fe = 6-24, Zn = 1-4, Cu and B = 0.5 - 2.0, Mo = 0.0015 - 0.06.

Foliar fertilization can be practised where there is difficulty in soil application, and should be done in the early morning or late afternoon.

(g) Recommended fertilizers

The following types of fertilizer are recommended:

1. Urea 46% N, to be used on a wide scale, as nitrogen is the main limiting factor in the fertility of the soils;

2. Treble superphosphate 46% P_2O_5 (granular);

3. Potassium nitrate with 13.8% and 38.6% K, to supply both potassium and nitrogen, especially for hydroponics and drip irrigation.

4. Ammoniated superphosphates, namely diammonium phosphates (18% N and 46% P_2O_5), to supply both nitrogen and phosphorus where the potassium level in the soil test is high (granular).

5. Albatros 15-30-15 foliar fertilizer with the micronutrients in chelated forms. This fertilizer can be foliar sprayed at the concentration indicated above or side-dressed three times a week at a rate of 2 g/plant or dissolved in irrigation water.

6. The compound mineral fertilizer nitrofoska 15-15-15, or slow release fertilizers 14-14-14 or 18-11-11 of 3-4 months longevity, to be used as base mineral fertilizers.

7. Magnesium sulphate, episom salt 9.9% Mg to correct the few cases of magnesium deficiency and to be used in the hydroponics nutrient solutions.

8. Iron sequestrine, ferrous sulphate, manganous sulphate, cupric sulphate, zinc sulphate, boric acid and sodium molybdate to correct any micronutrient deficiency and for the hydroponics.

(h) Recommended rates of mineral fertilizers for vegetables

The following recommendations hold true for the coarse textured (loamy sand or sandy loam) calcareous and gypsiferous soils, under the drip irrigation system:

Vegetable	Variety	Condition	Kg/donum		
			N	P_2O_5	K_2O
Tomato, indeterminate	Floradel	High plastic tunnel	20	40	40
Tomato, indeterminate		Open field, trellised	15	15	15
Tomato, determinate	VFN - 8	Open field/ low tunnel	30	30	15
Bell pepper	Yolo Wonder	Open field/ low tunnel	15	15	15
Long green pepper	Anaheim-M	Open field/ low tunnel	15	15	10
Cucumber	All tested varieties	High plastic tunnel	30	20	20

3.1.5 Cucumber varietal response to fertilization

Under fertilization, the top yielding varieties of cucumber were Feminex, Southern Cross, Topsy, Corona, Telegraph, Commander, Femdan and Market King. Yield average ranged between 3 0 - 4.4 kg/plant, or 7.0 - 10.0 t/donum of plastic tunnels in a four month period from seeding until the end of harvesting.

3.1.6 Soil sterilization

Soils in Bahrain and especially in Budaya are badly infected with root knot nematodes, and soil sterilization before transplanting is essential. Nemagon proved to be a poor sterilizer in such soils. D.D. Fumigant drenched at a rate of 25 ml/m^2 or Basamid to be broadcast and mixed thoroughly with the soil at a rate of 50 g/m^2 are effective nematocides. The choice of nematode resistant varieties is also recommended.

3.1.7 Blossom end rot of tomatoes

Blossom end rot of tomato is a varietal susceptibility and water stress phenomenon. Varieties which are susceptible (i.e., Big Set) should be avoided, and the irrigation scheme should be regulated so that the plants will not be subjected to moisture stress.

3.1.8 Microclimate modification during summer

It was found that evaporative cooling with shade cover over the plastic cover of the tunnel extends the tomato season after May, but is not feasible because it results in curling of basal foliage, low yield and some fruit cracking.

Evaporative cooling alone in the plastic tunnel can extend the season of cucumber variety Market King after May, and a moderate yield is feasible but a decrease in fruit uniformity and an increase in fruit dwarfness are to be expected.

Using plastic net cover shade alone to cover the tunnel provides shade which extends the season of tomato, cucumber and bell pepper varieties Floradel, Femdan and Yolo Wonder during the summer, and relatively high yields are feasible until end of July. It must be noted that there are decreases in fruit uniformity and increases in fruit dwarfness of all the vegetables.

3.1.9 Extension of protected vegetable production

Extension of protected vegetable production at the farmer's level started in the 1981/82 season within farms, and in 1982/83 another 47 sites were selected. Their soils and waters were characterized. Recommendations concerning their soil, water and fertilizer management are included in Chapter 2.

3.2 TECHNICAL AND ADMINISTRATIVE GUIDELINES

The recommendations below are offered as a guide to the administrative staff for future policy and planning, as well as to the technical staff for use during future phases of vegetable production.

3.2.1 Technical considerations

Further experimentation is needed on the use of plastics of varying thickness and colour, as mulching materials on different vegetable crops grown under plastic tunnels with the use of irrigation waters of different levels of salinity.

The farmer should be encouraged to produce vegetable crops of low water requirements, high market demand and good yield, such as tomato, cucumber, peppers, eggplant, potato and watermelons.

Protective and preventive sprays against diseases and insects should be applied in good time. Emphasis should be on the control of the widespread cucurbitaceae fruit fly (*Dacus* spp), eggplant stem borers, blights on tomato, powdery mildews, aphids and red spider mites.

At Budaya Eastern Farm, the distance in the open field between the drip lines is too wide for trellised tomatoes, eggplants and peppers. The yield obtained can practically be doubled if the number of the existing drip lines can be doubled on the same area.

Soil properties, weather conditions, crop water requirement and leaching fraction should all be considered in recommending the irrigation regime of the vegetable crops.

Drainage waters can be reused for irrigation alone, or after blending them with either sweet water or their respective irrigation waters, depending on the levels of water salinity.

Vegetable seed should be brought into the country from April and should be of high yielding, salt tolerant, heat resistant, virus free and nematode resistant varieties.

When sewage sludge and treated sewage effluent are used in agriculture, care should be taken in the microbiological tests. They should include besides the number of coliforms, the identification of Salmonella, Shegella, Staphyllococci as well as viruses and blood haemolysis. It is also advisable to free the effluent from viruses. Treated sewage effluent analysis should include the content of micronutrients, phytotoxic and heavy metals.

Fertility trials in farmers' fields should be undertaken. They should include responses to NPK, trace elements in conjunction with locally available organic manures and monitoring available soil nutrient levels to achieve the best economic returns.

Demonstration in farmer fields on composting farm refuse is recommended.

The demonstration plots on fertilizer placement in the farmers' fields should be continued under different management conditions (i.e., irrigation water, broadcasting, top dressing, sidedressing, drenching, splitting, frequency of application under different irrigation systems in use).

Means to reduce conveyance losses of irrigation water at farm fields should be carefully considered.

It is advisable to continue the experiments on the use of slow release fertilizers with longer longevity, and comparing these fertilizers with ordinary release fertilizers.

Consideration should be given to foliar diagnosis of nutrient disorders through chemical analysis of colour manifestations of plant leaves, or by both methods together.

In ordering fertilizers, care should be given to bag specifications and fertilizer guarantee.

3.2.2 Administrative matters

The services of the soil laboratory should be enlarged to include analysis of soil, water, plants and fertilizers. It should also offer its services on payment, to companies working with agrobusiness. The laboratory is in need of atomic absorption equipment, since analysis on heavy metals will be required particularly after the use of treated sewage effluent and sewage sludge in agriculture (for methods of analysis, see Appendix 4).

The establishment of a good scientific library would be of great benefit, and action should be taken in this regard.

Ways should be considered of improving the efficiency of field assistants.

TABLES 1 - 100

EXPERIMENTAL DATA

L E G E N D

CEC	-	Cation Exchange Capacity
donum	-	1 000 m^2
EC_e	-	Electrolytic Conductivity of soil and water saturation extract
EC_w	-	Electrolytic Conductivity of water
F	-	Fisher Statistical Value
LSD	-	Least Significant Differences
L	-	Litre
µmhos	-	micromhos
meq	-	milliequivalent
mg	-	milligram
ml	-	millimetre
mmhos	-	millimhos
N.S.	-	not significant
ppm	-	part per million
SAR	-	Sodium Anion Ratio

Table 1- Characteristics Of Budaya Irrigation Water During Three Successive Years 1979/80 - 1981/82

Character	1979-1980	1980-1981	1981-198.
pH	7.5	7.3	7.2
EC_w µmhos cm^{-1}	3200	3370	3620
Soluble Ions, meq/L			
HCO_3	1.6	3.4	3.0
Cl	24.8	22.3	24.0
SO_4	5.7	12.5	9.2
Ca	8.2	7.5	11.0
Mg	6.3	9.1	6.9
Na	17.0	20.7	17.6
K	0.6	0.5	0.7
Boron, mg/L	-	-	0.5
SAR	6.23	7.19	5.89

(-) not determined.

Table 2- Characteristics of Sweet Sand Used For Increasing Effective Soil Depth

Character	Value
Textural Analysis:	
% Sand	90.0
% Silt	4.0
% Clay	6.0
Textural Class	Sand
Saturation Percentage	18.0
pH	7.5
EC_e mmhos cm^{-1} at 25 °C	6.55
Anions, meq/L:	
HCO_3	1.64
Cl	38.0
SO_4	39.0
Cations, meq/L:	
Ca	37.7
Mg	9.3
Na	31.1
K	0.5
$CaCO_3$ %	9.5
$CaSO_4$ $2H_2O$%	7.74
Organic Carbon %	0.04
Available-P, ppm	3.5
Available-K, ppm	21.0
SAR	6.41

2.1 - RESEARCH UNDER HIGH PLASTIC TUNNEL CONDITIONS

Table 3- Effect of Polyethylene Mulching Under Drier Irrigation Regime on Yield Of Cucumber Under Plastic Tunnel (Kg/plot*)

Experiment 2.1.1

Treatment	Replications		Treatment Mean**
	1	2	
Without mulch	50	51	50.5
Translucent mulch	54	53	53.5
Black mulch	52	55	53.5
Replication Mean	52	53	

* Each plot is 5.33 m^2 in area and has 16 plants with a plant density of 3 plants/m^2

**Observed F value is nonsignificant.

Table 4- Effect of Polyethylene Mulching in Presence of Wetter Regime on Yield of Cucumber Under Plastic Tunnel (Kg/plot*)

Experiment 2.1.1

Treatment	Relications		Treatment Mean**
	1	2	
Without mulch	50	55	52.5
Translucent mulch	60	50	55.0
Black mulch	59	56	57.5
Replication Mean	56.3	53.7	

* Each plot is 5.33 m^2 in area and has 16 plants with a plant density of 3 plants/m^2.

** Observed F value is nonsignificant.

Table 5- Effect of Irrigation Regime On Average Yield of Cucumber Under Tunnels

Experiment 2.1.1

Irrigation Regime*	Yield/tunnel in Kg.**	Yield/donum in tons
W	2477	9.91
D	2362	9.45

* W : Irrigation for 3 hrs every other day at ½ gallon/hr.

D : Irrigation for 2 hrs every other day at ½ gallon/hr.

** Area of Tunnel = 240 m^2

Table 6- Effect of polyethylene Mulching On Soil Salinity at Plastic Tunnel Site.

Experiment 2.1.1

Soil Character	Surface Soil (0-30 cm)			Subsurface Soil (30-60cm)		
	No mulch	T*-mulch	B**-mulch	No mulch	T*-mulch	B**-mulch
pH	7.8	7.8	7.8	7.8	7.8	7.8
EC_e mmhos cm^{-1} at 25°C	4.07	3.74	3.85	4.73	4.29	5.06
Anions, meq/L:						
- HCO_3	2.57	3.04	5.15	1.64	1.87	1.87
- Cl	20.0	17.0	23.0	21.0	17.0	22.0
- SO_4	29.3	24.3	15.5	38.4	39.7	43.0
Cations, meq/L:						
- Ca	23.1	19.5	13.0	33.2	30.5	32.8
- Mg	9.87	8.19	8.10	8.40	9.35	11.6
- Na	17.0	15.0	20.0	18.5	17.5	21.0
- K	1.90	1.60	1.60	1.00	1.25	1.50
SAR	4.19	4.03	6.17	4.06	3.90	4.46

* T-mulch = Translucent mulch.

** B-mulch = Black mulch.

Table 7- Effect of Irrigation Regime On the Yield of Tomato Under Plastic Tunnel (Kg/plot*).

Experiment 2.1.2

Treatment	Replications			Treatment Mean **
	1	2	3	
Irrigation for 2 hrs (D)	71.6	79.0	84.8	78.5
Irrigation for 3 hrs (W)	61.4	83.0	71.3	71.9
Replication Mean	66.5	81.0	78.0	

* Each plot is 13.3 m^2 in area and has 32 plants with a plant density of 2.4 plants/m^2

** Observed F value is nonsignificant.

Table 8- Effect of Irrigation Regime On some Soil Characteristics

Experiment 2.1.2

Soil Character	0-30 cm			30-60 cm		
	Before*	After**		Before*	After**	
		W	D		W	D
pH	8.3	7.5	7.7	8.1	7.8	7.8
EC_e mmhos cm^{-1}	5.5	3.9	4.6	4.0	4.1	4.3
P, ppm	7.5	2.5	15.5	2.0	1.0	7.5

* At the start of the trial.

** At the termination of the trial.

Table 9- Properties of The Experimental Site - Foliar & Soil Application of Mineral Fertilizers On Tomato Under Plastic Tunnel Conditions

Experiment 2.1.3

Soil Character	Depth in cm	
	0-30	30-60
Textural Analysis		
% Sand	88.0	86.0
% Silt	2.0	4.0
% Clay	10.0	10.0
Textural Class	Loamy Sand	Loamy Sand
Saturation Percentage.	22.0	22.0
pH	7.9	7.8
EC_e mmhos cm^{-1} at 25°C.	3.1	3.6
Anion, meq/L.		
HCO_3	1.87	1.87
Cl	7.92	12.9
SO_4	35.6	36.6
Cations, meq/L.		
Ca	31.5	34.1
Mg	5.25	4.58
Na	8.50	12.6
K	0.09	0.05
$CaCO_3$%	14.0	13.8
$CaSO_4 \cdot 2H_2O$%	9.70	12.1
Organic Matter %	0.20	0.26
Available-P, ppm.	22.5	15.0
Available-K, ppm.	42.5	45.0

Table 10- Comparative Effect of Soil and Foliar Application of mineral fertilizers on the yield of indeterminate tomato under plastic tunnels (Kg/plot*).

Experiment 2.1.3.1

Treatment No.	Replications			Treatment Mean
	1	2	3	
1	46.6	48.4	47.2	47.40
2	43.4	46.3	42.8	44.17
3	44.4	48.7	43.5	45.53
4	50.0	48.0	48.5	48.83
5	51.0	49.0	45.0	48.33
6	50.0	52.5	46.0	49.50
Replication Mean	47.57	48.82	45.5	

$L.S.D._{0.05} = 3.33$

* Each experimental plot had 14 plants in two rows 40 cm apart and the plants were 35 cm apart. It occupied 4.4 m^2. Plant density was 3.2 plants/m^2.

Table 11- Yield Data of Cucumber Under Plastic Tunnel As Affected by Soil & Foliar Fertilization (Kg/plot*).

Experiment 2.1.3.2

Treatment	Replications			
	1	2	3	4
F1	59	50	50	48
F2	88	68	68	73
F3	77	69	69	70
S1	58	59	50	51
S2	66	62	76	58
S3	86	77	75	70

* Each plot has 22 plants in two rows 40 cm apart and plants were 35 cm apart. Plant density was 3.2 plants/m^2.

Table 12- Effect of Rate and Method of Fertilizer Application on Yield of Cucumber Under Plastic Tunnels(Kg/plot).

Experiment 2.1.3.2

Method of Fertilizer Application	*Rate of Fertilizer			Method Mean
	1	2	3	
	Rate x Method			
Foliar	51.75	74.25	71.25	65.75
Soil	54.5	65.5	77.0	65.67
Rate Mean	51.13	69.88	74.13	

* Rate 1: 2g/plant/week once soil applied or foliar spraying with 0.25% solution twice a week.

Rate 2: 4g/plant/week twice soil applied or foliar spraying with 0.5% solution twice a week.

Rate 3: 6g/plant/week applied to soil 3 times or foliar spraying with 1.0% solution twice a week.

$LSD_{0.05}$ rate = 5.82
$LSD_{0.05}$ rate x method = 8.23
$LSD_{0.05}$ method = n.s.

Table 13- Influence of Method of Fertilizer Application and Rate on Nutrient Concentration in Young Mature Leaves of Cucumber.

Experiment 2.1.3.2

Treatment	Nutrient Concentration					
	%P	%K	%Ca	%Mg	ppm Fe	ppm Mn
F1	0.50	2.54	4.30	5.33	125	120
F2	0.52	2.44	6.05	4.57	225	344
F3	0.65	2.44	4.31	4.41	325	744
S1	0.38	2.93	4.73	4.76	125	440
S2	0.40	2.44	4.71	4.63	225	344
S3	0.30	2.44	5.72	2.23	175	120

Table 14- Soil Characteristics of The Experimental Site of the Yield Response of Tomatoes to Foliar Application of Micronutrients.

Experiment 2.1.4

Soil Character	Depth in cm		
	0-30	30-45	45-60
Textural Analysis:			
% Sand	74.4	80.5	78.5
% Silt	10.2	4.1	6.1
% Clay	15.4	15.4	15.4
Textural Class	Sandy Loam	Sandy Loam	Sandy Loam
Saturation Percentage	17.8	16.4	17.6
pH-H_2O (1:2.5) :			
Suspension.	8.1	8.2	8.2
Supernatent.	7.8	7.7	7.5
$CaCO_3$ %	23.0	22.9	23.7
Ca SO_4 .$2H_2O$%	1.9	2.2	7.0
Organic Matter %	0.78	0.35	0.32
EC_e mmhos cm^{-1} at 25°C	7.23	7.96	6.23
Anions in Saturation Extract, meq/L:			
CO_3	0.6	-	-
HCO_3	2.35	2.3	1.8
Cl	36.3	37.1	27.2
SO_4	33.0	40.2	33.3
Cations in Saturation Extract, meq/L:			
Ca	35.4	47.6	38.9
Mg	5.95	8.3	7.8
Na	30.3	23.3	15.0
K	0.6	0.5	0.6

Table 15- Effect of Micronutrient Application on Yield of Floradel.

Experiment 2.1.4

Yield(Kg/plot*)

Treatment No.	Replications				Average effect of treatment
	1	2	3	4	
1	9.2	17.6	19.1	16.3	15.55
2	20.6	17.6	18.9	28.9	21.50
3	22.5	17.1	20.5	26.4	21.62
4	16.8	17.4	16.7	28.3	19.80
5	12.2	16.8	21.8	30.2	20.25
6	22.6	28.9	20.8	29.7	25.50
7	17.5	19.9	15.8	30.7	20.97
8	20.2	17.6	22.2	26.7	21.67
Average effect of replication	17.7	19.1	19.5	27.15	

* Plot size = 1.92 m^2

Average and Range of Yield "Floradel"

Treatment No.	Yield Range		Yield Average	
	Kg/plant	Kg/m^2	Kg/plant	Kg/m^2
1	1.15-2.39	4.79-9.95	1.94	8.10
2	2.20-3.61	9.17-15.05	2.69	11.20
3	2.14-3.30	8.91-13.75	2.70	11.26
4	2.09-3.54	8.70-14.74	2.48	10.31
5	1.53-3.78	6.35-15.73	2.53	10.55
6	2.60-3.71	10.83-15.47	3.19	13.28
7	1.98-3.84	8.23-15.99	2.62	10.92
8	2.20-3.34	9.17-13.90	2.71	11.29

Table 16- Effect of Micronutrient Application on Yield of Beef Steak

Experiment 2.1.4

Yield (Kg/plot).

Treatment No.	Replications			Average effect of treatment
	1	2	3	
9	13.6	12.6	17.9	14.7
10	12.7	16.2	14.5	14.5
11	9.0	14.7	13.7	12.5
12	10.7	13.4	14.3	12.8
13	9.5	18.4	16.8	14.9
14	17.1	17.7	17.4	17.4
15	16.4	12.7	18.7	15.9
16	17.5	9.5	11.7	12.9
Average effect of replication	13.3	14.4	15.6	

Average and Range of Yield of Beef Steak

Treatment No.	Yield Range		Yield Average	
	Kg/Plant	Kg/m^2	Kg/plant	Kg/m^2
9	1.58-2.24	6.56-9.32	1.84	7.66
10	1.59-2.03	6.61-8.44	1.81	7.55
11	1.13-1.84	6.69-7.66	1.56	6.51
12	1.34-1.79	5.57-7.45	1.60	6.67
13	1.19-2.30	4.95-9.58	1.86	7.76
14	2.14-2.21	8.91-9.22	2.18	9.06
15	1.59-2.34	6.61-9.74	1.99	8.28
16	1.19-2.19	4.95-9.11	1.61	6.72

Table 17- Effect of Micronutrient Application on Yield of Gross Lisse

Experiment 2.1.4

Yield (Kg/plot).

Treatment No.	Replications				Average effect of treatment
	1	2	3	4	
17	16.6	24.4	13.7	14.3	17.25
18	11.1	21.2	11.3	14.4	14.50
19	13.5	19.2	10.3	17.7	15.18
20	15.0	13.4	15.2	12.2	13.95
21	18.8	12.9	11.7	20.7	16.03
22	15.0	14.3	13.6	17.2	15.03
23	7.3	17.9	15.2	18.6	14.75
24	11.8	15.6	12.6	18.5	14.63
Average effect of replication.	13.6	17.4	13.0	16.7	

Average and Range of Yield of Gross Lisse

Treatment No.	Yield Range		Yield Average	
	Kg/plant	Kg/m^2	Kg/plant	Kg/m^2
17	1.71-3.05	7.14-12.70	2.16	8.98
18	1.39-2.65	5.78-11.04	1.81	7.55
19	1.29-2.40	5.36-9.99	1.90	7.91
20	1.53-1.90	6.35-7.92	1.74	7.27
21	1.46-2.59	6.09-10.78	2.00	8.35
22	1.70-2.15	7.08-8.96	1.88	7.83
23	0.91-2.33	3.80-9.69	1.84	7.68
24	1.48-2.31	6.15-9.64	1.83	7.62

Table 18- Ionic Composition Variability of the Saturation Extract of the Surface Soil (0-30 cm) from Several Sites of the Experiment.

Experiment 2.1.4

Site No.	EC_e mmhos cm^{-1}	Anions, meq/L				Cations, meq/L				SAR
		CO_3	HCO_3	Cl	SO_4	Ca	Mg	Na	K	
1	8.95	1.2	2.3	49.5	37.1	42.9	0.4	46	0.8	9.89
2	6.05	-	3.5	29.7	30.5	30.7	6.4	26	0.6	6.03
3	6.43	1.2	1.8	32.2	31.9	36.0	1.6	29	0.5	6.68
4	6.93	1.2	1.8	32.2	35.8	36.0	4.5	30	0.5	6.67
5	6.80	-	2.9	29.7	37.3	35.4	3.9	30	0.6	6.77
6	8.19	1.2	1.8	44.6	34.3	31.3	18.9	31	0.7	6.20

Table 19- Characteristics of Original and transported Experimental Soil Media Under Plastic Tunnels

Experiment 2.1.5.1 (Indeterminate tomato)

Media Character	Soil Depth in cm		
	0-30		30-60
	Original	Transported	
Textural Analysis:			
% Sand	83.1	83.1	78.5
% Silt	3.4	5.5	6.1
% Clay	13.5	11.4	15.4
Textural Class	Loamy Sand	Loamy Sand	Sandy Loam
Saturation Percentage	20	20	19
pH-H_2O (1:2.5):			
Suspension	8.4	8.4	8.2
Supernatent	8.4	8.3	7.8
EC_e mmhos cm^{-1} at 25^oC	5.5	3.6	8.82
$CaCO_3$%	24.0	15.0	24.3
Ca $SO_4 \cdot 2H_2O$%	0.9	19.6	4.3
Organic Matter %	0.78	0.11	0.32

Table 20 Effect of Media and Increasing rates of N, P and/or K on Tomato Yield (Kg/plot).

Experiment 2.1.5.1

(a) Tuckcross-K Variety

Media	Treatment					Average effect of media
	1	2	3	4	5	
	Media X Treatment					
Original	2.5	6.1	9.7	7.0	6.9	6.44
Transported	4.0	5.1	7.7	8.5	4.1	5.88
Average effect of treatment	3.25	5.60	8.70	7.75	5.50	

plot size = $8m^2$

(b) Tuckcross-O Variety

Media	Treatment					Average effect of media
	1	2	3	4	5	
	Media X Treatment					
Original	6.6	3.8	13.1	10.0	10.2	8.74
Transported	7.9	6.6	12.2	9.7	9.2	9.12
Average effect of treatment	7.25	5.20	12.65	9.85	9.70	

Table 20 (cont'd)

(c) N-69 variety

Media	Treatment			Average effect of media
	1	2	3	
	Media X Treatment			
Original	8.8	8.8	8.7	8.77
Transported	5.6	8.1	7.0	6.90
Average effect of Treatment	7.2	8.45	7.85	

Table 21- Soil Characteristics of the Winter Experiment 1981-82 Season.

Experiment 2.1.5.2

Soil Character	Depth in cm	
	0-30	30-60
Textural Analysis		
% Sand	88.0	88.0
% Silt	2.0	2.0
% Clay	10.0	10.0
Textural Class	Loamy Sand	Loamy Sand
Saturation Percentage	22.0	22.0
pH	7.9	7.9
EC_e mmhos cm^{-1} at 25°C	3.2	3.2
Anions, meq/L		
HCO_3	2.34	2.34
Cl	8.91	9.90
SO_4	35.08	32.18
Cations, meq/L		
Ca	33.08	31.50
Mg	4.16	2.80
Na	9.00	10.00
K	0.09	0.12
$CaCO_3$ %	13.83	13.75
$Ca\ SO_4.2H_2O$ %	6.00	5.34
Organic Matter %	0.20	0.20
Available-P, ppm	22.5	21.5
Available-K, ppm	50.0	47.50

Table 22- Effect of Increasing Rates and Different Ratios of N, P & K on the Yield of Tomato Under Plastic Tunnels (Kg/plot).

Experiment 2.1.5.2

Treatment No.	Replications			Treatment Mean
	1	2	3	
1	41.7	38.5	40.0	40.07
2	38.5	36.1	37.0	37.20
3	46.6	31.7	39.2	39.17
4	46.3	51.3	48.0	48.53
5	50.1	51.2	50.0	50.43
6	45.2	44.4	45.0	44.87
Replication Mean	44.73	42.20	43.20	

* Plot has 14 plants and 4.67 m^2 in area.

$LSD_{0.05} = 6.13$

Table 23- Soil Characteristics - The Site Of Cucumber Varieties Response To Fertilization

Experiment 2.1.6

Soil Character	Depth in cm	
	0-30	30-60
Textural Analysis		
% Sand	88	86
% Silt	1	3
% Clay	11	11
Textural Class	Loamy Sand	Loamy Sand
Saturation Percentage	20	20
pH	7.6	8.1
EC_e mmhos cm^{-1} at 25°C	6.9	5.3
Anions, meq/L		
HCO_3	3.0	2.8
Cl	29.0	18.0
SO_4	41.9	39.4
Cations, meq/L		
Ca	37.4	28
Mg	19.4	18.9
Na	16.5	12
K	1.3	1.2
$CaCO_3$ %	14.9	14.7
$CaSO_4 \cdot 2H_2O$ %	3.5	3.0
Organic Matter %	0.38	0.50
Available-P, ppm	15.0	16.0
Available-K, ppm	77.0	67.0

Table 24- Yield Average of Some Varieties of Cucumber.

Experiment 2.1.6

Order	Variety	Yield Average		
		Kg/plant	Kg/Tunnel*	Ton/donum
1	Feminex	4.4	1538	10.25
2	Southern Cross	3.6	1259	8.39
3	Topsy	3.5	1224	8.16
4	Corona	3.5	1224	8.16
5	Telegraph	3.4	1188	7.92
6	Commander	3.4	1188	7.92
7	Femdan	3.4	1188	7.92
8	Femdan F1	3.2	1119	7.46
9	Market King	3.0	1049	6.99
10	Titan	2.8	978	6.52
11	Fenumex	2.8	978	6.52
12	Poin Sett	2.8	978	6.52
13	Progress	2.7	944	6.29
14	Fertila	2.6	909	6.06

* The total area of the plastic tunnel is 150 m^2 and it accommodates 350 plants.

Table 25- Chemical Properties of Soil Site of Phenomenon Under Study (Blossom end rot of tomato)

Experiment 2.1.7

Chemical Property	Under End Rot		Free of End Rot	
	0-30cm	30-60cm	0-30cm	30-60cm
pH	7.9	7.9	7.9	8.0
EC_e mmhos cm^{-1} at 25°C	4.32	4.0	4.0	3.35
Anions, meq/L				
HCO_3	2.34	2.11	2.34	2.34
Cl	20.0	15.0	15.0	11.0
SO_4	34.5	36.8	37.0	35.1
Cations, meq/L				
Ca	28.6	29.6	28.6	28.6
Mg	9.1	8.0	8.9	6.9
Na	18.5	15.8	16.3	12.5
K	0.65	0.53	0.57	0.44
S.A.R.	4.26	3.63	3.76	2.97

2.2 - RESEARCH IN THE OPEN FIELD

Table 26- Soil Characteristics Of The Organic Fertilization Experimental Site In the Open Field (tomato) Experiment 2.2.1

Soil Character	Depth in cm	
	0-30	30-45
Textural Analysis		
% Sand	74.0	74.0
% Silt	8.0	6.0
% Clay	18.0	20.0
Textural Class	Sandy loam	Sandy loam
Saturation Percentage	22.0	22.0
pH	8.1	8.1
EC_e mmhos cm^{-1} at 25^0C	22.5	21.0
Anions, meq/L		
HCO_3	9.4	7.0
Cl	257	198
SO_4	65.6	70.1
Cations, meq/L		
Ca	78.8	63.0
Mg	53.6	60.0
Na	200	152
K	0.13	0.10
$Ca\ CO_3$ %	17.5	17.0
$Ca\ SO_4 \cdot 2H_2O$ %	9.86	7.85
Organic Matter %	0.65	0.51
Available-P, ppm	13.7	13.7
Available-K, ppm	267	250

Table 27- Some Properties Of The Organic Fertilizers Used In The Experiment (Tomato)

Experiment 2.2.1

Type	pH	EC* mmhos cm^{-1}	Moisture %	Loss on ignition** %
Cow manure	6.9	50.1	3.12	35.3
Poultry manure	7.5	48.4	2.78	24.0
Cofuna	7.6	2.75	62.8	76.5

* Determined in the saturation extract.

** On dry basis.

Table 28- Yield Data Of Tomatoes As Affected By Type And Rate Of Organic Fertilizers (Kg/plot*).

Experiment 2.2.1

Type of Organic Fertilizer	Organic Fertilizer Rates (Kg/m^2) 0	1	2	3	Organic Fertilizer mean
	Type X Rate				
Confuna	15.09	17.83	23.16	25.06	20.29
Cow Manure	13.50	18.18	23.08	26.23	20.25
Poultry Manure	15.23	18.84	21.76	25.65	20.37
Rate mean	14.61	18.28	22.67	25.65	

* Each plot has 8 plants

L.S.D among rate means = 0.76

0.05 among organic Fertilizer means = 0.6

among rates for the same organic materials = 1.3

among means for rates of different organic fertilizers = 0.59.

Table 29- Soil Characteristics Of The Comparison Of Nitrogen Forms Experimental Site (Squash)

Experiment 2.2.2

Soil Character	Depth, cm	
	0-30	30-45
Textural Analysis		
% Sand	78.2	78.2
% Silt	8.1	10.2
% Clay	13.7	11.6
Textural Class	Sandy Loam	Sandy Loam
$pH-H_2O$ (1:2.5)	7.7	7.7
EC_e mmhos cm^{-1} at 25^oC	19.0	27.0
Anions, meq/L :		
CO_3	2.3	-
HCO_3	2.3	4.6
Cl	167	250
SO_4	39.0	36.5
Cations, meq/L :		
Ca	68.0	75.0
Mg	47.0	42.0
Na	95.5	174.0
K	0.1	0.1
$CaCO_3$ %	25.0	23.0
Organic Matter %	1.18	0.40
$Ca SO_4.2H_2O$ %	5.2	12.2

Table 30- Yield Data Of Squash (Kg/plot).

Experiment 2.2.2

Treatment	Replications 1	2	3	4	Average of Treatment
U 1	4.4	3.7	3.9	2.8	3.70
U 2	2.5	2.8	2.5	3.6	2.85
U 3	4.3	6.2	6.9	4.2	5.40
A 1	4.4	5.5	5.1	2.7	4.43
A 2	3.8	3.9	4.8	3.2	3.92
A 3	3.8	3.5	4.2	3.6	3.78
C 1	2.6	3.2	2.6	6.0	3.60
C 2	2.7	4.7	3.4	5.4	4.05
C 3	2.5	3.3	3.8	3.1	3.18

U=Urea; A=Ammonium Sulphate; C=Calcium Nitrate; 1=Rate 1; (50 Kg N/ha); 2=Rate 2:(100 Kg N/ha); 3=Rate 3:(150 Kg N/ha).

Table 31- Effect of Nitrogen Source And Rate On The Yield Of Squash (Kg/plot).

Experiment 2.2.2

N-Rate Kg/ha	N-Source U	A	C	Average effect of Rate
	N-Source	X rate	means	
50	3.7	4.4	3.6	3.9
100	2.9	3.9	4.0	3.6
150	5.4	3.8	3.2	4.1
Average effect of source	4.0	4.0	3.6	

$L.S.D_{0.05}$ Source X rate = 1.05

Table 32- Soil Characteristics - Experimental Site Of Soil & Foliar Application Of Phosphate (Okra)

Experiment 2.2.3

Soil Character	Depth, cm	
	0-30	30-45
Textural Analysis:		
% Sand	76.1	80.2
% Silt	8.2	6.1
% Clay	15.7	13.7
Textural Class	Sandy Loam	Sandy Loam
pH-H_2O (1:2.5)	7.7	7.6
EC_e mmhos cm^{-1} at 25°C	31.0	12.0
Anions, meq/L :		
CO_3	0.6	1.2
HCO_3	3.5	4.7
Cl	290	100
SO_4	66.1	46.1
Cations , meq/L :		
Ca	71	53
Mg	75	18
Na	214	80.8
K	0.2	0.2
$CaCO_3$ %	24.1	24.0
$CaSO_4.2H_2O$ %	4.0	11.1
Organic Matter %	1.34	0.35

Table 33- Yield Data Of Okra (Kg/plot)

Experiment 2.2.3.1

Treatment	Replications				Average of Treatment
	1	2	3	4	
S1R1	7.34	8.95	8.10	9.57	8.49
S1R2	7.44	7.78	6.89	8.00	7.53
S1R3	7.84	8.10	9.93	6.32	8.04
S2R1	5.00	7.43	8.73	6.14	6.83
S2R2	4.95	10.04	7.50	9.82	8.08
S2R3	6.44	9.66	6.58	6.75	7.36
S3R1	9.52	6.87	8.39	6.00	7.70
S3R2	4.48	5.49	8.69	8.05	6.68
S3R3	6.39	7.00	9.50	9.20	8.02
FR 1	5.09	4.98	8.04	3.95	5.52
FR 2	8.40	5.65	8.67	5.43	7.04
FR 3	8.83	12.00	10.63	8.15	9.90

Table 34- Effect Of Rate And Method Of Application of Superphosphate On The Yield Of Okra (kg/plot).

Experiment 2.2.3.1

Rate Kg P_2O_5/ha	Method of Application				Rate mean
	S1	S2	S3	F	
	Rate X Method of Application				
100	8.49	6.83	7.70	5.52	7.14
200	7.53	8.08	6.68	7.04	7.33
300	8.04	7.36	8.02	9.90	8.33
Application mean	8.02	7.42	7.47	7.49	

$L.S.D._{0.05}$ Rate X Method = 1.56

Table 35- Soil Characteristics - Experimental Site Of Soil & Foliar Application Of Urea (Okra)

Experiment 2.2.3.2

Soil Character	Depth, cm	
	0-30	30-45
Textural Analysis:		
% Sand	82.2	80.2
% Silt	6.2	8.2
% Clay	11.6	11.6
Textural Class	Sandy Loam	Sandy Loam
$pH-H_2O$ (1:2.5)	7.8	7.7
EC_e mmhos cm^{-1} at 25^oC	19.5	10.1
Anions, meq/L:		
CO_3	0.6	0.6
HCO_3	3.5	3.5
Cl	157	65
SO_4	54.2	49.1
Cations, meq/L:		
Ca	63	51
Mg	60	27
Na	92	40
K	0.3	0.2
$Ca\ CO_3$ %	25.5	26.0
$Ca\ SO_4.2H_2O$ %	9.7	9.0
Organic Matter %	1.02	0.76

Table 36- Yield Data on Okra (Kg/plot)

Experiment 2.2.3.2

Treatment	Replications				Average of Treatment
	1	2	3	4	
S1R1	4.58	3.99	7.32	7.98	5.97
S1R2	4.17	4.71	6.75	7.36	5.75
S2R1	6.21	5.69	4.18	6.20	5.57
S2R2	6.99	4.30	6.32	9.75	6.84
FR 1	3.29	3.77	6.49	4.05	4.40
FR 2	4.18	3.99	6.58	9.84	6.15

Table 37- Effect of Rate And Method Of Application Of Urea On the Yield Of Okra (Kg/plot).

Experiment 2.2.3.2

Rate Kg N/ha	Method of Application			Rate Mean
	S1	S2	F	
	Rate X Method of Application			
100	5.97	5.57	4.40	5.31
200	5.75	6.84	6.15	6.25
Application mean	5.86	6.21	5.28	

N.S.

Table 38- Soil Characteristics Of Experiment
Experiment 2.2.4

Soil Character	Depth in cm	
	0-30	30-45
Textural Analysis		
% Sand	78	78
% Silt	4	8
% Clay	18	14
Textural Class	Sandy Loam	Sandy Loam
Saturation Percentage	22	22
pH	8.1	8.0
EC_e mmhos cm^{-1} at 25^oC	22	13
Anions, meq/L		
HCO_3	9.4	5.85
Cl	178	94.1
SO_4	56.5	48.3
Cations, meq/L		
Ca	61.4	54.6
Mg	36.6	19.4
Na	146	74.0
K	0.10	0.17
$CaCO_3$ %	17.5	17.4
$CaSO_4.2H_2O$%	7.1	6.6
Organic Matter %	0.5	0.5
Available-P, ppm	17.2	17.2
Available-K, ppm	218	163

Table 39- Comparative Effect Of Soil And Foliar Application Of Mineral Fertilizers On the Yield Of Trellised Tomato In Open Field (Kg/plot*).

Experiment 2.2.4

Treatment	Replications				Treatment Mean **
	1	2	3	4	
1	10.6	13.5	10.3	10.3	11.18
2	11.9	10.3	9.2	9.4	10.20
3	10.0	11.2	12.0	10.0	10.80
4	12.9	10.8	11.8	12.8	12.08
5	9.6	14.8	12.0	13.5	12.48
6	11.8	13.1	14.2	12.8	12.98
Replication Mean	11.13	12.28	11.58	11.47	

* Each plot has 6 plants

** Observed F is not significant.

Table 40- Soil Characteristics - Experimental Site Of Yield Response Of Squash to NPK Fertilizers. Experiment 2.2.5.1

Soil Character	Depth, cm	
	0-30	30-45
Textural Analysis:		
% Sand	76.1	78.2
% Silt	10.2	6.1
% Clay	13.7	15.7
Textural Class	Sandy Loam	Sandy Loam
pH-H_2O (1:2.5)	7.6	7.7
EC_e mmhos cm^{-1} at $25^{o}C$	23.0	14.0
Anions, meq/L:		
CO_3	-	0.6
HCO_3	4.7	5.8
Cl	210	117
SO_4	48.3	56.7
Cations, meq/L:		
Ca	68	59
Mg	57	34
Na	138	87
K	0.1	0.1
$CaCO_3$ %	22.8	25.1
$CaSO_4.2H_2O$ %	4.1	15.0
Organic Matter %	1.23	0.96

Table 41- Effect of N,P and/or K-Fertilizers on the Yield of Squash (Kg/plot).

Experiment 2.2.5.1

Treatment		Replications				Average
No	Kg/ha $N-P_2O_5-K_2O$	1	2	3	4	
1	0-0-0	4.07	3.22	1.67	2.85	2.95
2	0-100-50	4.50	4.90	2.85	4.50	4.19
3	50-100-50	6.00	4.16	4.78	4.26	4.80
4	100-100-50	3.25	4.78	7.16	4.81	5.00
5	50-0-50	2.17	2.17	4.63	3.82	3.20
6	50-200-50	5.10	5.76	5.00	6.15	5.50
7	50-100-0	6.32	3.55	2.30	3.82	4.00
8	50-100-100	6.00	4.50	4.67	6.70	5.47

$L\ S\ D_{0.05} = 1.78$

Table 42- Characteristics Of The Soil Site

Experiment 2.2.5.2

Soil Character	Depth in cm	
	0-30	30-40
Textural Analysis:		
% Sand	78	78
% Silt	8	10
% Clay	14	12
Textural Class:	Sandy Loam	Sandy Loam
Saturation Percentage	22	22
pH	7.9	8.0
EC_e mmhos cm^{-1} at 25°C	20	15
Anions, meq/L		
HCO_3	5.6	4.6
Cl	170	120
SO_4	44.4	40.0
Cations, meq/L		
Ca	60	55
Mg	40	25
Na	120	84.9
K	0.1	0.1
$CaCO_3$ %	19.0	18.0
$CaSO_4.2H_2O$ %	8.0	9.0
Organic Matter %	0.6	0.5
Available-P, ppm	18	17
Available-K, ppm	200	170

Table 43- Yield Data Of Determinate Tomato As Affected By Mineral Fertilizers (1980-1981).
Experiment 2.2.5.2 (a)

Treatment	Average Yield			Yield Increase Over Control		
	Kg/plot*	Kg/plant	Ton/ Donum	Kg/plot	Percen-tage	Tons/ donum
O	120	1.5	1.63	-	-	-
N	240	3.0	3.25	120	100	1.62
P	156	1.95	2.11	36	30	0.48
K	145	1.81	1.97	25	21	0.34
NP	260	3.25	3.52	140	117	1.89
NK	255	3.19	3.46	135	113	1.83
PK	150	1.88	2.03	30	25	0.40
NPK	271	3.39	3.67	151	126	2.04

* Each plot was 73.8 m^2 and had 80 plants.

Table 44- Effect Of N-,P-, and/or K- Fertilizers On the Yield Of Determinate Tomato (1981-1982 Season) Kg/plot*
Experiment 2.2.5.2 (b)

Treatment		Replications				Average
No	Kg/ha $N-P_2O_5-K_2O$	1	2	3	4	
1	0 - 0 - 0	40	42	39	43	41.0
2	0-150-150	41	40	42	43	41.5
3	150-150-150	54	56	55	57	55.5
4	300-150-150	64	67	63	66	65.0
5	150-0-150	49	52	47	50	49.5
6	150-300-150	58	60	61	59	59.5
7	150-150-0	51	52	50	53	51.5
8	150-150-300	55	58	56	59	57.0

* Each plot was 6.75 m^2 and had 9 plants.

$LSD_{.05}$ = 1.8 kg/plot

Table 45- Yield Increases Of Determinate Tomato As Affected By N- P- and/or K- Mineral Fertilizers. (1981-1982 Season).

Experiment 2.2.5.2 (b)

Treatment No	Average Yield			Yield Increase Over Control		
	Kg/plot*	Kg/plant	Ton/ donum	Kg/plot	Percen- tage	Tons/ donum
1	41.0	4.56	6.07	-	-	-
2	41.5	4.61	6.15	0.5	0.08	1.3
3	55.5	6.17	8.22	14.5	2.14	35.0
4	65.0	7.22	9.63	24.0	3.56	58.6
5	49.5	5.50	7.33	8.5	1.26	20.8
6	59.5	6.61	8.81	18.5	2.74	45.1
7	51.5	5.72	7.63	10.5	1.56	25.7
8	57.0	6.33	8.44	16.0	2.37	39.0

* Each plot was 6.75 m^2 and had 9 plants.

Table 46- Characteristics Of The Soil Site

Experiment 2.2.5.3

Soil Character	Depth in cm	
	0-30	30-50
Textural Analysis:		
% Sand	78	74
% Silt	4	8
% Clay	18	18
Textural Class	Sandy Loam	Sandy Loam
Saturation Percentage	22	22
pH	7.9	8.1
EC_e mmhos cm^{-1} at 25°C	21.5	11.0
Anions, meq/L		
HCO_3	9.4	5.85
Cl	198	69.3
SO_4	86.4	50.7
Cations, meq/L:		
Ca	69.3	42.0
Mg	44.4	31.5
Na	180	52.2
K	0.10	0.11
Ca CO_3 %	17.9	27.4
Ca $SO_4 \cdot 2H_2O$ %	9.90	6.60
Organic Matter %	0.46	0.11
Available-P, ppm	25.0	13.0
Available-K, ppm	200	95

Table 47- Effect Of Mineral Fertilizer Treatments On Yield Of Trellised Tomatoes In the Open Field (Kg/plot*).

Experiment 2.2.5.3

Treatments	Replications				Treatment Mean
	1	2	3	4	
O	12.9	13.5	14.3	14.9	13.90
N	17.5	18.0	16.2	17.0	17.18
P	16.0	15.0	15.5	15.5	15.50
K	14.0	14.5	15.0	15.0	14.63
NP	18.0	17.5	17.0	16.5	17.25
NK	17.5	17.5	17.5	18.0	17.63
PK	15.0	16.0	15.5	14.9	15.35
NPK	20.0	21.0	20.5	22.0	20.88
Replication Mean	16.36	16.63	16.44	16.74	

* Each plot had 8 plants

$LSD_{0.05}$ = 0.98

Table 48- Yield Increases Of Indeterminate Trellised Tomatoes As Affected By Mineral Fertilizers (1980-1981 Season)

Experiment 2.2.5.3

Treatment	Average Yield			Yield Increase Over Control		
	Kg/plot*	Kg/plant	Ton/ donum	Kg/plot	Percen- tage.	Tons/ donum
O	13.90	1.74	2.32	-	-	-
N	17.18	2.15	2.87	3.28	23.6	0.55
P	15.50	1.94	2.59	1.60	11.5	0.27
K	14.63	1.83	2.44	0.73	5.25	0.12
NP	17.25	2.16	2.88	3.35	24.1	0.56
NK	17.63	2.20	2.93	3.73	26.8	0.61
PK	15.35	1.92	2.56	1.45	10.4	0.24
NPK	20.88	2.61	3.48	8.43	60.6	1.16

* Each plot had 8 plants.

Table 49- Effect Of N-, P-, and/or K- Fertilizers On the Yield Of Indeterminate Tomato (1981-1982 Season) Kg/plot*

Experiment 2.2.5.3 (b)

Treatment Kg/ha $N-P_2O_5-K_2O$	Replications					Treatment mean
	1	2	3	4	5	
1) 0 - 0 - 0	46	30	33	38	23	34.10
2) 0-150-150	45	39	32	37	30	36.6
3) 150-150-150	65	45	42	46	38	47.2
4) 300-150-150	62	51	44	48	47	50.4
5) 150-0-150	50	47	35	40	28	40.0
6) 150-300-150	57	49	43	46	45	48.0
7) 150-150-0	53	51	34	40	32	42.0
8) 150-150-300	55	50	44	46	42	47.4
Replication mean	54.13	45.25	38.38	42.63	35.63	

* Each plot had 14 plants

$LSD_{.05} = 4.34$

Table 50- Yield Increases Of Indeterminate Tomato As Affected By N-P- and K- Mineral Fertilizers (1981-1982 Season).

Experiment 2.2.5.3 (b)

Treatment No	Average Yield			Yield Increase Over Control		
	Kg/plot*	Kg/plant	Ton/donum	Kg/plot	Percentage	Tons/donum
1	34	2.41	3.21	-	-	-
2	36.6	2.60	3.47	2.6	7.5	0.26
3	47.2	3.35	4.47	13.2	38.3	1.26
4	50.4	3.58	4.77	16.4	47.6	1.56
5	40.0	2.84	3.79	6.0	17.4	0.58
6	48.0	3.41	4.55	14.0	40.6	1.34
7	42.0	2.98	3.97	8.0	23.2	0.76
8	47.4	3.37	4.49	13.4	38.9	1.28

* Each plot had 14 plants.

Table 51- Characteristics Of The Soil Site

Experiment 2.2.5.4

Soil Character.	Depth in cm	
	0-30	30-50
Textural Analysis		
% Sand	78	78
% Silt	6	8
% Clay	16	14
Textural Class	Sandy Loam	Sandy Loam
Saturation Percentage	22	22
pH	7.8	7.9
EC_e mmhos cm^{-1} at 25°C	21	14
Anions, meq/L		
HCO_3	6.0	5.0
Cl	160	100
SO_4	59.0	45
Cations, meq/L		
Ca	65	50
Mg	40	20
Na	120	80
K	0.1	0.1
$CaCO_3$%	16	17.5
$CaSO_4 \cdot 2H_2O$ %	7	6
Organic Matter %	0.4	0.5
Available-P, ppm	17	16
Available-K, ppm	205	170

Table 52- Yield Data Of Eggplant As Affected By Mineral Fertilizers.

Experiment 2.2.5.4

Treatment	Average Yield			Yield Increase Over Control		
	Kg/plot*	Kg/plant	Ton/ donum	Kg/plot	percen- tage	Tons/ donum.
O	45.1	1.13	1.25	-	-	-
N	74.0	1.85	2.06	28.9	64	0.81
P	58.6	1.47	1.63	13.5	30	0.38
NP	78.0	1.95	2.17	32.9	73	0.92
NPK	78.0	1.95	2.17	32.9	73	0.92

* Each plot had 40 plants.

Table 53- Effect of N-, P- and/or K- Fertilizers On The Yield Of Bell Peppers (Kg/plot*).

Experiment 2.2.5.5 (a)

Treatments		Replications				Treatment Mean
No	Kg/ha $N-P_2O_5-K_2O$	1	2	3	4	
1	0 - 0 - 0	5.0	5.4	4.9	5.5	5.20
2	0-150-150	6.3	7.0	5.5	7.8	6.65
3	150-150-150	9.3	8.2	9.0	8.5	8.75
4	300-150-150	9.0	9.7	9.9	8.8	9.35
5	150-0-150	7.0	8.0	7.2	7.8	7.50
6	150-300-150	8.4	9.2	9.5	8.9	9.00
7	150-150-0	7.9	7.8	8.0	7.7	7.85
8	150-150-300	9.5	8.4	9.0	8.9	8.95
Replication Mean		7.80	7.96	7.88	7.99	

* Each plot had 8 plants. $LSD_{.05}$ = 0.86 kg/plot

Table 54- Yield Increases Of Bell Peppers As Affected By N-, P- and K- Mineral Fertilizers.

Experiment 2.2.5.5 (a)

Treatment No	Average Yield			Yield Increase Over Control		
	Kg/plot*	Kg/plant	Ton/donum	Kg/plot	Percentage	Tons/donum
1	5.20	0.65	0.866	-	-	-
2	6.65	0.83	1.106	1.45	27.8	0.240
3	8.75	1.09	1.453	3.55	68.2	0.587
4	9.35	1.17	1.560	4.15	79.7	0.694
5	7.50	0.94	1.253	2.30	44.2	0.387
6	9.00	1.25	1.666	3.80	73.0	0.800
7	7.85	0.98	1.306	2.65	50.9	0.440
8	8.95	1.12	1.493	3.75	72.0	0.627

* Each plot had 8 plants.

Table 55- Effect of N-, P- and/or K- Fertilizers On The Yield Of Long Peppers (Kg/plot*).

Experiment 2.2.5.5 (b)

Treatment No	Treatment Kg/ha $N-P_2O_5-K_2O$	Replications 1	2	3	4	Treatment Mean
1	0 - 0 - 0	4.6	6.1	5.0	5.7	5.35
2	0-150-150	4.7	6.5	5.2	6.0	5.60
3	150-150-150	6.6	7.3	6.8	7.1	6.95
4	300-150-150	6.9	7.6	7.4	7.9	7.45
5	150-0-150	6.2	6.4	6.6	6.0	6.30
6	150-300-150	7.2	7.6	6.7	6.5	7.00
7	150-150-0	6.6	6.8	6.9	6.5	6.70
8	150-150-300	6.5	6.8	7.1	7.4	6.95
	Replication Mean	6.16	6.89	6.46	6.64	

* Each plot had 8 plants. $LSD_{.05}$ = 0.59 kg/plot

Table 56- Yield Increases Of Long-Peppers As Affected By N-, P- and K- Mineral Fertilizers.

Experiment 2.2.5.5 (b)

Treatment No.	Average Yield Kg/plot*	Kg/plant	Ton/donum	Yield Increase Over Control Kg/plot	Percentage	Tons/donum
1	5.35	0.67	0.893	-	-	-
2	5.60	0.70	0.933	0.25	4.7	0.040
3	6.95	0.87	1.160	1.60	29.9	0.267
4	7.45	0.93	1.240	2.10	39.3	0.347
5	6.30	0.79	1.053	0.95	17.8	0.160
6	7.00	0.88	1.173	1.65	30.9	0.280
7	6.70	0.84	1.120	1.35	25.2	0.227
8	6.95	0.87	1.160	1.60	29.9	0.267

*Each plot had 8 plants.

Table 57. Yield Of Determinate Tomato In a Farmer's Field As Affected By Rate And Method Of Fertilization Under Flood Irrigation.

Experiment 2.2.6

Treatment No	Yield			Increase Over Farmer's Fertilization.	
	Kg/furrow*	Kg/m^2	Tons/donum	Tons/donum	Percentage
8	177	11.86	11.86	5.43	84.71
5	160	10.72	10.72	4.29	66.92
7	149	9.98	9.98	3.55	55.38
4	126	8.44	8.44	2.01	31.36
9	126	8.44	8.44	2.01	31.36
2	121	8.11	8.11	1.68	26.21
6	121	8.11	8.11	1.68	26.21
1	96	6.43	6.43	-	-
3	94	6.30	6.30	-	-

* Each furrow is 15 m^2 in area.

2.3 - RESEARCH UNDER LOW TUNNEL CONDITIONS

Table 58- Effect Of N-, P- and/or K-Fertilizers On the Yield Of Determinate Tomato Under Low Tunnels (Kg/plot*).

Experiment 2.3.1

Treatment No.	Treatment Kg/ha $N-P_2O_5-K_2O$	Replications 1	2	3	4	Treatment Mean
1	0 - 0 - 0	47	48	50	45	47.50
2	0-150-150	45	47	52.8	51	48.95
3	150-150-150	60	62	64	60.4	61.60
4	300-150-150	75	72.1	70	75.5	73.15
5	150-0-150	57	55.1	52	60.3	56.10
6	150-300-150	63.5	70	65	65.5	66.00
7	150-150-0	49.5	54	55	57.1	53.90
8	150-150-300	64	61.5	60	62.6	62.00

* Each plot had 9 plants. $LSD_{.05}$ = 4.11 kg/plot

Table 59- Yield Increases Of Determinate Tomato As Affected By N-, P, and/or K- Mineral Fertilizers Under Low Tunnels

Experiment 2.3.1

Treatment No.	Average Yield Kg/plot	Kg/plant	Ton/ donum	Yield Increase Over Control Kg/plot	Percen- tage.	Ton/ donum
1	47.50	5.32	7.09	-	-	-
2	48.95	5.48	7.30	1.45	3.05	0.21
3	61.60	6.90	9.20	14.1	29.6	2.11
4	73.15	8.19	10.92	26.65	56.0	3.83
5	56.10	6.28	8.37	8.60	18.1	1.28
6	66.00	7.39	9.85	18.5	38.9	2.76
7	53.90	6.04	8.05	45.85	92.3	0.96
8	62.00	6.94	9.25	14.5	30.5	2.16

Table 60- Effect Of N-, P- and/or K- Fertilizers On The Yield Of Bell-Peppers Under Low Tunnels (Kg/plot*).

Experiment 2.3.2

Treatment No	Treatment Kg/ha $N-P_2O_5-K_2O$	Replications 1	2	3	4	Treatment Mean
1	0 - 0 - 0	7.8	10.0	9.8	10.0	9.40
2	0-150-150	9.2	10.8	10.5	9.5	10.00
3	150-150-150	16.4	17.2	17.0	16.6	16.80
4	300-150-150	20.4	18.2	18.5	20.2	19.30
5	150-0-150	12.8	13.8	13.0	13.6	13.30
6	150-300-150	18.5	16.4	17.0	17.9	17.45
7	150-150-0	13.0	11.2	13.0	11.8	12.40
8	150-150-300	16.5	16.3	17.5	16.9	16.8

* Each plot had 8 plants. $LSD_{.05}$ = 4.9 kg/plot

Table 61- Yield Increases Of Bell-Peppers As Affected By N-, P- and/or K-Mineral Fertilizers Under Low Tunnels

Experiment 2.3.2

Treatment No	Average Yield			Yield Increase Over Control		
	Kg/plot	Kg/plant	Ton/donum	Kg/plot	Percentage	Ton/donum
1	9.4	1.18	1.573	-	-	-
2	10.0	1.25	1.666	0.6	6.4	0.093
3	16.8	2.10	2.799	7.4	79.2	1.226
4	19.3	2.41	3.213	9.9	105.9	1.640
5	13.3	1.66	2.213	3.9	41.7	0.640
6	17.45	2.18	2.906	8.05	86.1	1.333
7	12.4	1.55	2.066	3.00	32.1	0.493
8	16.8	2.10	2.799	7.40	79.2	1.226

Table 62- Effect Of N-, P- and/or K- Fertilizers On The Yield Of Long Green Peppers Under Low Tunnels (Kg/plot*).

Experiment 2.3.3

Treatment No.	Treatment Kg/ha $N-P_2O_5-K_2O$	Replications. 1	2	3	4	Treatment Mean
1	0 - 0 - 0	7.3	8.2	7.8	7.3	7.65
2	0-150-150	8.1	10.0	9.8	8.3	9.05
3	150-150-150	11.5	12.0	10.9	12.6	11.75
4	300-150-150	11.3	12.1	13.2	14.2	12.70
5	150-0-150	9.9	9.5	9.0	10.4	9.70
6	150-300-150	12.2	10.4	11.9	12.5	11.75
7	150-150-0	11.4	10.2	10.6	11.0	10.80
8	150-150-300	11.9	11.5	12.2	11.2	11.70

* Each plot had 8 plants. $LSD_{.05}$ = 1.19 kg/plot

Table 63- Yield Increases Of Long Green Peppers As Affected By N-, P- and/or K- Mineral Fertilizers Under Low Tunnels.

Experiment 2.3.3

Treatment No.	Average Yield			Yield Increase Over Control		
	Kg/plot	Kg/plant	Ton/donum	Kg/plot	Percentage.	Ton/donum
1	7.65	0.96	1.28	-	-	-
2	9.05	1.13	1.51	1.40	18.3	0.23
3	11.75	1.47	1.96	4.10	53.7	0.68
4	12.70	1.59	2.12	5.05	66.2	0.84
5	9.70	1.21	1.61	2.05	26.9	0.33
6	11.75	1.47	1.96	4.10	53.7	0.68
7	10.80	1.35	1.80	3.15	41.3	0.52
8	11.70	1.46	1.95	4.05	53.1	0.67

2.4 - SUMMER FERTILITY TRIALS

Table 64 Data of Yield Response to N & K Supplemental Fertilizers in Presence of Different Base Mineral Fertilizers on Summer Tomatoes under Shade and Evaporative Cooling (Kg/plot*)

Experiment 2.4.1

Treatment	Replications			Treatment Mean
	1	2	3	
N_o	6.3	6.25	8.5	7.02
$(N + K)_o$	10.7	12.0	10.6	11.10
N_s	14.2	13.1	10.6	12.63
$(N + K)_s$	10.3	10.7	12.45	11.15
Replication Mean	10.38	10.51	10.54	

* Each plot has 20 plants

Table 65 The Effect of N & K Supplemental Fertilizers in Presence of Different Base Mineral Fertilizers on Summer Yield of Tomato under Shade and Evaporative Cooling (Kg./plot)

Experiment 2.4.1

Supplemental Mineral Fertilizer	Base Mineral Fertilizer		Supplemental Fertilizer Mean
	Ordinary	Slow	
	Base X Supplemental		
N	7.02	12.63	9.83
N + K	11.10	11.15	11.13
Base Fertilizer Mean	9.06	11.89	

$LSD_{.05}$

- Base X Supplemental Fertilizer = 3.04 Kg/plot
- Base Fertilizer = 2.15 Kg/plot

Table 66 Data of Yield Response to N & K Supplemental Fertilizers in Presence of Different Base Mineral Fertilizers on Summer Cucumber under Evaporative Cooling (Kg/plot*)

Experiment 2.4.2

Treatment	Replications		Treatment Mean
	1	2	
N_o	58.7	77.0	67.9
$(N + K)_o$	62.1	80.2	71.2
N_s	73.9	63.4	68.7
$(N + K)_s$	51.5	72.3	61.9
Replication Mean	61.55	73.22	

* Each plot has 40 plants

Table 67 The Effect of N & K Supplemental Fertilizers in Presence of Different Base Mineral Fertilizers on Summer Yield of Cucumber Under Evaporative Cooling (Kg./plot)

Experiment 2.4.2

Supplemental Mineral Fertilizer	Base Mineral Fertilizer		Supplemental Fertilizer Mean
	Ordinary	Slow	
	Base X Supplemental		
N	67.9	68.7	68.30
N + K	71.2	61.9	66.55
Base Fertilizer Mean	69.55	65.30	

Table 68 Effect of N & K Fertilizers on Summer Yield of Cucumber Under Shade (Kg/plot*)

Experiment 2.4.3

Treatment	Replications					Treatment Mean
	1	2	3	4	5	
N	67.4	66.6	70.3	58.2	61.8	64.9
NK	75.8	76.6	80.1	78.2	80.8	78.3
Replication Mean	71.6	71.6	75.2	68.2	71.3	

$LSD_{.05}$ = 6.92 Kg/plot

* Each plot has 19 plants

Table 69 Effect of Increasing Rates of N & K Applications On Summer Yield of Bell-Peppers (Kg/plot*)

Experiment 2.4.4

N - Rate	K - Rate				N - Rate Mean
	0	1	2	3	
	N X K				
0	9.3	9.1	7.2	8.9	8.62
1	9.4	9.8	6.4	8.7	8.57
2	11.7	11.3	11.2	10.4	11.15
3	12.4	11.7	11.3	12.6	12.00
4	11.2	10.3	11.3	10.9	10.92
K - Rate Mean	10.8	10.4	9.5	10.3	

* Each plot has 9 plants

Table 70 Effect of Different Form of Nitrogen on Summer Yield of Tomato Under Shade (Kg/plot*)

Experiment 2.4.5

Treatment 1/	Replications					Treatment Mean
	1	2	3	4	5	
U	29.8	23.8	24.5	28.6	33.55	28.05
A	30.7	20.6	20.9	25.8	34.0	26.40
C	33.45	28.35	31.45	32.8	29.8	31.17
Replication Mean	31.32	24.25	25.62	20.07	32.45	

* Each plot has 12 plants

1/ U (urea) : nitrogen in amide form

A (ammonium sulphate): nitrogen in ammonium form

C (calcium nitrate): nitrogen in nitrate form

Table 71 Effect of Different Mineral Base Fertilizers on Summer Yield of Tomatoes Under Shade (Kg/plot*)

Experiment 2.4.6

Treatment	Replications					Treatment Mean
	1	2	3	4	5	
A	23.3	30.7	29.6	25.2	26.9	27.1
B	33.1	25.9	28.8	21.4	32.5	28.3
C	35.1	26.8	26.4	29.8	27.9	29.2
Replication Mean	30.5	27.8	28.3	25.5	29.1	

* Each plot has 12 plants

Table 72 Effect of Rates and Methods of Phosphate Application On Summer Yield of Bell-Peppers under Shade (Kg/plot*)

Experiment 2.4.7

Method of Phosphate Application	Rate				Method Mean
	1	2	3	4	
	Method X Rate				
1	7.8	8.5	11.4	9.2	9.23
2	11.0	12.4	8.3	8.0	9.93
3	11.5	9.6	8.6	7.9	9.40
4	10.0	10.0	8.1	8.1	9.05
5	9.5	7.2	7.2	6.8	7.68
Rate Mean	9.96	9.54	8.72	8.0	

* Each plot has 9 plants

TABLE 73 Soil Characteristics of Site

Experiment 2.4.8

Soil Character	Depth in cm	
	0 - 30	30 - 60
Textural Analysis		
- % Sand	78	78
- % Silt	6	8
- % Clay	16	14
Textural Class	Sandy Loam	Sandy Loam
Saturation Percentage	22	22
- pH	7.7	7.8
EC_e mmhos cm^{-1} at 25^oC	14.0	10.0
Anions, meqlL		
- HCO_3	4.0	4.0
- Cl	107	60
- SO_4	41	42
Cations, meqlL		
- Ca	44	36
- Mg	27	15
- Na	8.0	55
- . K	1.0	1.0
$CaCO_3$ %	16	17.5
$CaSO_4 \cdot 2H_2O$	7.0	6.0
Organic Matter %	0.4	0.5
Available - P, ppm	25	20
Available - K, ppm	200	160

Table 74 Comparative Effect of Soil and Foliar Application of a Complete Fertilizer on Okra Field in the Open Field (Kg/plot*) Experiment 2.4.8

Treatment	Replications				Treatment Mean
	1	2	3	4	
Control	13.4	12.0	12.5	12.6	12.60
Soil	16.4	15.1	15.7	17.2	16.10
Foliar	15.6	14.9	15.5	16.3	15.58
Replication Mean	15.13	14.00	14.57	15.37	

* each plot has 9 plants

** $LSD_{.05}$ = 0.73 kg/plot.

2.5 - SOIL AND IRRIGATION WATER STUDIES

Table 75 - Characteristics Of Soils Under The High Plastic Tunnels at Budaya. (0-30 cm layer).

Study 2.5.1

Soil Character.	Plastic Tunnel No.								
	2	3	4	5	6	7	8	9	10
Textural Analysis									
% Sand	84	82	88	86	74	84	88	88	88
% Silt	5	3	1	1	10	5	2	2	1
% Clay	11	15	11	13	16	11	10	10	11
Textural Class	LS	SL	LS	LS	SL	LS	LS	LS	LS
Saturation Percentage.	20	22	20	20	18	20	20	22	20
pH	8.1	7.9	7.7	7.9	7.8	7.8	7.4	7.9	7.6
EC mmhos cm^{-1}	12.5	5.64	5.77	6.04	7.23	4.49	5.06	3.1	6.95
Anions, meq/L									
HCO_3	3.61	2.21	2.11	3.21	3.0	3.51	3.51	1.87	3.04
Cl	71	21	24	33	36	24	22	7.9	29
SO_4	57.4	46.8	37.4	42.2	33	31.9	39.5	35.6	42
Cations, meq/L									
Ca	47.8	31.2	33.8	43.2	35.4	29.6	40.0	31.5	37.4
Mg	26.6	18.8	11.3	9.76	5.95	14.5	6.76	5.25	19.4
Na	55.0	18.5	17.2	24.2	30.3	14.5	16.7	8.50	16.5
K	2.5	1.5	1.2	1.3	0.6	0.8	1.5	0.09	1.35
$CaCO_3$%	12.5	13.0	12.0	14.0	23.0	14.2	15.9	14.0	14.9
$CaSO_4.2H_2O$%	1.25	1.97	1.64	4.13	1.90	3.02	2.33	9.70	3.51
Organic Matter%	0.61	0.45	0.40	0.45	0.78	0.44	0.42	0.2	0.39
Available-P, ppm	16.8	7.0	6.0	13.0	-	13.5	9.0	-	15.5
Available-K, ppm	67.5	82.5	45.0	68.8	-	48.8	90.0	-	77.5

(-) Means not determined because these tunnels were used for research purposes.

Table 76 -Characteristics Of Soils Under The High Plastic Tunnels At Budaya (30 - 60 cm Layer).

Study 2.5.1

Soil Character	Plastic Tunnel No.								
	2	3	4	5	6	7	8	9	10
Textural Analysis									
% Sand	84	82	86	82	79	82	86	86	86
% Silt	3	5	1	3	5	5	3	4	3
% Clay	13	13	13	15	16	13	11	10	11
Textural Class	LS	SL	LS	SL	SL	SL	LS	LS	LS
Saturation Percentage	20	22	20	22	18	22	20	22	20
pH	8.1	7.7	7.6	7.0	8.2	7.0	7.0	7.8	8.2
EC_e mmhos cm^{-1}	13.0	5.9	5.9	5.29	7.96	7.19	4.77	3.6	5.37
HCO_3	3.45	2.34	2.81	3.98	2.3	3.74	3.51	1.87	2.81
Cl	82	28	24	25	37.1	41	20	13	18
SO_4	53.6	43.6	41.4	35.4	40.2	39.9	36.9	36.6	39.4
Cations,meq/L									
Ca	47.3	37.4	35.9	41.6	47.6	36.4	35.9	34.1	28.1
Mg	24.2	17.4	13.1	3.48	8.3	12.6	8.32	4.58	19.0
Na	65	18.5	17.6	18.5	23.3	35.0	14.5	12.6	12.0
K	2.5	0.6	1.6	0.8	0.5	0.65	1.0	0.05	1.2
$CaCO_3$%	15.7	13.7	14.9	14.0	22.9	14.2	13.3	13.8	14.7
$CaSO_4.2H_2O$%	1.6	2.3	1.6	15.5	2.2	9.5	3.4	12.1	3.5
Organic Matter%	0.56	0.26	0.34	0.26	0.35	0.35	0.31	0.26	0.33
Available-P,ppm	12.0	2.0	2.0	10.5	-	2.0	9.0	-	16.0
Available-K,ppm	77.5	72.5	46.3	75.0	-	52.5	82.5	-	67.5

(-) Means not determined because these tunnels were used for research purposes.

Table 77 -Soluble Ionic Ratios* In Saturation Extracts Of The Soils Under The High Plastic Tunnels At Budaya.

Study 2.5.1

Site of Tunnel No.	Cl/SO_4		Mg/Ca		Ca/cations		Mg/cations	
	0-30cm	30cm	0-30cm	30cm	0-30cm	30cm	0-30cm	30cm
2	1.24	1.53	0.56	0.51	0.36	0.34	0.20	0.17
3	0.45	0.64	0.60	0.47	0.45	0.51	0.27	0.24
4	0.64	0.58	0.33	0.36	0.53	0.53	0.18	0.19
5	0.78	0.71	0.23	0.08	0.55	0.65	0.12	0.05
6	1.09	0.92	0.17	0.18	0.49	0.60	0.08	0.11
7	0.75	1.03	0.49	0.35	0.50	0.43	0.24	0.15
8	0.56	0.54	0.17	0.23	0.62	0.60	0.10	0.14
9	0.22	0.36	0.17	0.14	0.70	0.67	0.12	0.09
10	0.69	0.46	0.52	0.68	0.50	0.47	0.26	0.32

* Concentrations of all ions involved in the ratios are expressed in meq/L.

Note: Tunnel 1 not included as used as a nursery

Table 78 -Soils Characteristics Of Eight Vegetable Production Farms in Bahrain (Surface 0-30 cm layer).

Study 2.5.2

Soil Character	Soil Location							
	Shakhu-ra	Markh	Hilat	Maqaba	Karra-na	Zallaq	Barbar	Hamala
Textural Analysis								
% Sand	70	84	92	64	70	88	52	78
% Silt	26	10	4	8	22	8	6	8
% Clay	4	6	4	28	8	4	42	14
Textural Class	SL	LS	S	SCL	SL	S	SC	SL
Saturation Percentage	26	20	16	30	24	17	40	22
pH	7.6	7.5	7.9	7.5	7.8	7.8	7.7	7.9
EC_e mmhos cm^{-1} at 25°C	18.4	4.1	7.98	6.50	5.7	4.56	5.47	4.79
Anions, meq/L								
HCO_3	4.68	1.52	5.85	2.46	4.33	4.68	3.86	4.68
Cl	14.9	16.8	45.5	49.5	42.6	18.81	31.7	17.8
SO_4	63.4	40.2	48.2	21.1	16.4	34.77	32.0	37.6
Cations, meq/L								
Ca	59.9	28.4	44.9	28.8	26.7	34.1	35.4	34.1
Mg	34.2	12.2	10.0	9.38	10.5	7.1	8.74	7.59
Na	111	17.0	42.6	33.0	24.8	16.5	22.2	17.4
K	11.5	1.0	2.0	1.8	1.3	0.6	1.2	1.0
$CaCO_3$%	41.7	33.3	34.7	33.7	39.0	27.5	20.7	27.5
$CaSO_4.2H_2O$%	24.2	12.1	30.3	2.9	5.32	13.4	24.2	6.31
Organic Matter%	1.66	0.76	0.63	0.65	1.59	0.47	0.34	0.13
Available-P, ppm	19	9	1.5	11.5	24	9.0	1.5	8.5
Available-K ppm	750	113	125	100	188	38	63	75

Table 79- Soil Characteristics Of Eight Vegetable Production Farms In Bahrain (Subsurface 30-60 cm Layer).

Study 2.5.2

Soil Character	Soil Location							
	Shakhu-ra	Markh	Hilat	Maqaba	Karra-na	Zallaq	Barbar	Hamala
Textural Analysis								
% Sand	86	82	76	86	64	88	74	82
% Silt	10	14	18	10	26	8	10	4
% Clay	4	4	6	4	10	4	16	14
Textural Class	LS	LS	SL	LS	SL	S	SL	SL
Saturation Percentage	20	22	24	20	28	17	26	22
pH	7.7	7.4	8.0	7.5	7.6	7.7	7.5	8.0
EC_e mmhos cm^{-1} at 25°C	18.2	5.36	6.84	5.13	11.4	4.56	6.27	3.99
Anions, meq/L								
HCO_3	4.1	1.64	3.74	1.64	4.67	3.28	2.34	4.68
Cl	10.4	22.8	52.5	38.6	70.0	20.8	28.7	18.8
SO_4	56.7	40.4	28.6	20.4	52.4	36.7	47.5	34.9
Cations, meq/L								
Ca	56.7	28.1	34.2	18.5	42.8	37.5	39.5	31.7
Mg	54.1	12.0	14.3	15.3	17.23	4.7	7.52	9.93
Na	43.7	22.2	34.8	25.4	64.8	18	30.0	15.7
K	10.5	2.4	1.5	1.4	2.25	0.6	1.5	1.0
$CaCO_3$%	35.7	33.7	32.3	35.0	46.5	25.8	20.2	26.0
$CaSO_4 \cdot 2H_2O$%	15.7	10.1	32.6	4.0	3.91	17.5	31.9	6.31
Organic Matter%	1.23	0.72	0.76	0.27	1.21	0.34	0.13	0.29
Available-P,ppm	14.5	2.3	1.0	7.0	13.5	1.0	1.0	1.0
Available-K,ppm	375	150	100	62.5	219	37.5	87.5	37.5

Table 80 - Soluble Ionic Ratios* In Saturation Extracts Of Eight Soils Under Vegetable Production In Bahrain.

Study 2.5.2

Soil Location	Cl/SO_4		Mg/Ca		Ca/Cations		Mg/Cations	
	0-30 cm	30-60 cm	0-30 cm	30-60 cm	0-30 cm	30-60 cm	0-30 cm	30-60 cm
Shakhura	2.35	1.83	0.57	0.95	0.28	0.34	0.16	0.33
Markh	0.42	0.56	0.43	0.43	0.48	0.43	0.21	0.19
Hilat	0.94	1.84	0.22	0.42	0.45	0.40	0.10	0.17
Maqaba	2.35	1.89	0.33	0.83	0.39	0.31	0.13	0.25
Karrana	2.66	1.34	0.39	0.40	0.42	0.34	0.17	0.14
Zallaq	0.54	0.57	0.21	0.13	0.58	0.62	0.12	0.08
Barbar	0.99	0.60	0.25	0.19	0.52	0.50	0.13	0.10
Hamala	0.47	0.54	0.22	0.31	0.57	0.54	0.13	0.17

*Concentrations of all ions involved in the ratios are expressed in meq/L.

Table 81 - Distribution Of Farms For Protected Vegetable Production In Bahrain.

Study 2.5.2.2

District	Farm Serial No.	Site	District	Farm Serial No.	Site
Sanad	1	Hasan A. Sarhan	Al-Budaya	25	Jaafar A.Mahdi
"	2	Ahmad H. Sarhan	Bani-Jamrah	26	Abbas S.Fardan
Sitrah	3	Sayed J.S.Hashim	" "	27	Mansour J. Saleh
Arad	4	Ali M. Jassim	" "	28	Hassan Tarrish
Qalali	5	Abdul-Latif El-Manna	" "	29	Mohsin El-Khaier
Samahij	6	Salman A.El-Karrani	El-Qurayyah	30	A.Aziz Ben Naser
Al-Busaytin	7	Hassan El-Aradi	" "	31	Jaafar M. Haider
Al-Jufayr	8	Hafez Ahmad	Al-Jasrah	32	Mahdi Sliman
Al-Naiem	9	Jawad Khamees	" "	33	Mansour El-Hadar
Jabalet-Habashi	10	A.Aziz Mansour	Buri	34	Mohamad H.M. Ali
" "	11	Yaqoub Y. Marzouk.	"	35	Sayed H. Al-Alawi.
Jidd-Hafs	12	Ali Jassim	"	36	Ahmad H. Ebrahim
" "	13	Hassan El-Baqli	Al-Hamalah	37	Mohamed A.Dief
Karranah	14	Ahmad S. Ahmad	" "	38	Ebrahim El-Haddar
"	15	Salman A. Ali	" "	39	Silman A. Silman
Janusan	16	Ebrahim Jawad	" "	40	Ahmad H. Moubarak
"	17	Abdulla A. Solyman	Dumistan	41	Ahmad M. Abdulla
Shakhourah	18	Abdulla J.El-Saieg	Karzakkan	42	Mohamed E. Majed
El-Markh	19	Jaafar Saleh	"	43	Abdulla El-Mowalshi
MaQabah	20	Sayed E. Ali	Al-Malikiyah	44	Mohamed A. ~~Ahmad~~
Barbar	21	Salman Dawoud	Sadad	45	Yousef A. Yousef.

Continued Table 81.

District	Farm Serial No.	Site	District	Farm Serial No	Site
Bu-Sabea	22	Sayed J. Alawi	Az-Zallaq	46	Abdul-Hazeen Jassim
Al-Budaya	23	Abdulla El-Soubah	" "	47	Ebrahim Kazzim
" "	24	Ali Yousef			

Table 82 -Acidity/Alkalinity And Salinity Levels Of Brackish Irrigation Water Used At Farms For Protected Vegetable Production In Bahrain.

Study 2.5.2.2

Disctrict	Serial Farm No.	pH	EC_w umhos cm^{-1}	District	Serial Farm No.	pH	EC_w umhos cm^{-1}
Sanad	1	7.2	7040	Al-Budaya	25	7.1	3800
"	2	7.0	4500	Bani-Jamrah	26	7.2	3740
Sitrah	3	7.0	7040	" "	27		4180
Arad	4	7.3	5200	" "	28	7.4	3850
Qalali	5	7.3	3450	" "	29	7.2	3250
Samahij	6	7.0	3500	El-Qurayyah	30	7.2	3850
Al-Busaytin	7	7.2	3860	" "	31	7.1	3800
Al-Jufayr	8	7.0	4430	Al-Jasrah	32	7.5	5610
Al-Naiem	9	7.4	4270	" "	33	7.4	3630
Jabalet-Habashi	10	7.0	7800	Buri	34	7.2	3960
" "	11	7.0	3850	"	35	7.2	4020
Jidd-Hafs	12	7.2	5830	"	36	7.2	4070
" "	13	7.1	4500	Al-Hamalah	37	7.4	5280
Karranah	14	7.1	3960	" "	38	7.4	4070
"	15	7.0	4790	" "	39	7.4	4950
Janusan	16	7.1	3960	" "	40	7.1	7700
"	17	7.2	5830	Dumistan	41	7.3	5100
Shakhourah	18	7.2	4500	Karzakkan	42	7.5	3740
El-Markh	19	7.1	4240	"	43	7.0	6930
Maqabah	20	7.0	4790	Al-Malikiyah	44	7.3	5500
Barbar	21	7.1	3850	Sadad	45	7.4	5100
Bu-Sabea	22	7.2	4500	Az-Zallaq	46	7.3	5120
Al-Budaya	23	7.2	3850	" "	47	7.1	5060
" "	24	7.0	4070				

Table 83 -Soil Characteristics Of Surface And Subsurface Samples Of Farms For Protected Vegetables Production At Sanad, Sitrah and Arad. Study 2.5.2.2

Soil Character:	Serial Farm No.							
	1		2		3		4	
	a*	b*	a	b	a	b	a	b
Textural Analysis								
% Sand	46.1	44.0	72.9	78.4	77.0	77.0	66.9	66.9
% Silt	43.6	45.7	12.8	9.3	10.1	8.1	24.2	24.2
% Clay	10.3	10.3	14.3	12.3	12.9	14.9	8.9	8.9
Textural Class	L	L	SL	SL	SL	SL	SL	SL
Hydraulic Conductivity, cm hr^{-1}	1.6	-	40.6	-	18.1	-	-	-
Saturation Percentage.	30	28	20	20	24	22	24	28
pH	7.0	7.2	7.4	7.5	7.6	7.7	7.4	7.0
EC_e mmhos cm^{-1} at 25oC	91.3	70.4	33.5	28.6	22.6	17.1	47.3	35.9
Anions, meq/L:								
HCO_3	3.51	4.68	3.51	4.68	3.51	4.68	4.68	4.68
Cl	1155	885	350	280	205	145	530	335
SO_4	130	115	84.5	81.3	59.8	60.7	64.3	89.3
Cations, meq/L								
Ca	166	131	85.5	67.0	69.4	52.0	97.0	81.1
Mg	254	147	58.5	58.0	46.6	31.0	105	61.9
Na	835	702	287	235	148	124	383	279
K	33.8	25.0	7.0	6.0	4.25	3.35	14	7.0
$CaCO_3$ %	29.0	29.5	36.0	37.0	17.0	40.5	29.5	32.5
$CaSO_4 \cdot 2H_2O$ %.	30.0	28.9	1.73	2.26	2.74	1.99	14.4	10.2
Organic Matter %.	0.83	-	1.17	-	1.09	-	1.74	-
CEC, meq/100 g soil	14	-	11.4	-	7.4	-	8.1	-
Available-P, ppm	66	68	134	82	36	27	14	17
Available-K, ppm	46	36	10	13	10	8	438	282

a: Surface 0-30 cm layer.
b: Subsurface 30-60 cm layer.

-: not determined.

Table 84 -Soluble Ionic Ratios* In Saturation Extracts Of Farm Sites For Protected Vegetable Production In Bahrain (Sanad to Al-Budaya).

Experiment 2.5.2.2

Distrct	Farm Serial No.	Cl/SO_4		Mg/Ca		Ca/Cations		Mg/Cations	
		a*	b*	a	b	a	b	a	b
Sanad	1	8.88	7.70	1.53	1.12	0.13	0.13	0.20	0.15
"	2	4.14	3.44	0.68	0.87	0.20	0.18	0.13	0.16
Sitrah	3	3.43	2.39	0.67	0.60	0.26	0.25	0.17	0.15
Arad	4	8.24	3.75	1.08	0.76	0.16	0.19	0.18	0.14
Qalali	5	2.79	3.13	0.68	0.54	0.19	0.32	0.13	0.18
Samahij	6	3.44	3.31	0.92	0.49	0.21	0.32	0.20	0.16
Al-Busaytin	7	0.82	0.85	0.35	0.43	0.44	0.32	0.15	0.14
Al-Jufayr	8	0.67	1.07	0.58	0.43	0.38	0.38	0.22	0.16
Al-Naiem	9	4.54	4.32	0.86	0.83	0.18	0.20	0.15	0.16
Jabalet-Habashi	10	2.86	1.81	0.50	0.44	0.29	0.32	0.14	0.14
" "	11	1.76	1.99	0.33	0.47	0.25	0.30	0.08	0.14
Jidd-Hafs	12	1.15	1.22	0.39	0.37	0.31	0.34	0.12	0.12
" "	13	2.10	1.61	0.45	0.30	0.37	0.37	0.16	0.11
Karranah	14	3.18	1.65	0.63	0.67	0.29	0.25	0.19	0.17
"	15	1.61	1.21	0.55	0.88	0.32	0.30	0.18	0.27
Janusan	16	2.31	1.01	0.50	2.37	0.28	0.21	0.14	0.49
"	17	0.99	2.25	0.85	1.12	0.29	0.18	0.24	0.20
Shakhourah	18	0.34	0.65	0.25	1.94	0.69	0.24	0.17	0.46
El-Markh	19	0.57	1.16	0.47	0.40	0.41	0.38	0.20	0.15
Maqabah	20	5.88	12.78	0.47	0.96	0.26	0.13	0.12	0.12
Barbar	21	1.43	1.63	0.71	0.61	0.20	0.21	0.14	0.13
Bu-Sabea	22	0.79	0.73	0.53	0.41	0.43	0.46	0.23	0.19
Al-Budaya	23	0.23	0.33	0.20	0.06	0.61	0.69	0.12	0.04
" "	24	1.97	1.94	1.05	0.61	0.15	0.23	0.15	0.14
" "	25	0.74	0.79	0.50	0.45	0.36	0.46	0.18	0.20

*Concentrations of all ions involved in the ratios are expressed in meq/L.

* a: 0-30 cm soil surface layer.
b: 30-60 cm soil subsurface layer.

Table 85 -Soil Characteristics Of Surface And Subsurface Samples Of Farms For Protected Vegetables Production At Qalali, Samahij, Al-Busaytin & Al-Jufayr.
Experiment 2.5.2.2

Soil Character	Serial Farm No.							
	5		6		7		8	
	a*	b*	a	b	a	b	a	b
Textural Analysis								
% Sand	83.6	85.7	87.7	89.7	87.1	89.1	62.8	56.8
% Silt	7.5	7.4	3.4	1.5	4.0	2.0	16.2	22.2
% Clay	8.9	6.9	8.9	8.9	8.9	8.9	21.0	21.0
Textural Class	LS	LS	LS	LS	LS	LS	SCL	SCL
Hydraulic Conductivity, cm hr^{-1}	-	-	13.0	-	-	-	-	-
Saturation Percentage.	22	25	22	22	24	30	38	26
pH	7.6	7.8	7.1	7.2	7.5	8.0	8.0	7.7
EC_e mmhos cm^{-1} at 25°C	30.8	15.3	20.9	15.4	4.95	3.30	7.76	7.0
Anions, meq/L:								
HCO_3	4.68	4.68	5.85	5.85	1.76	1.76	3.51	2.34
Cl	310	125	195	125	22.5	17.5	37.5	42.5
SO_4	111	39.9	65.3	37.8	27.5	20.6	55.9	39.7
Cations, meq/L								
Ca	82.7	55.1	56.7	54.6	22.8	12.7	37.1	31.8
Mg	56.3	30.3	52.3	27.0	7.9	5.5	21.5	13.8
Na	279	81.8	152	85.3	19.6	20.5	36.9	37.5
K	8.0	2.4	5.25	1.65	1.45	1.15	1.35	1.40
$CaCO_3$ %	25.0	25.0	16.0	17.0	28.5	25.5	40	40
$CaSO_4.2H_2O$%	2.21	1.14	21.5	20.8	1.76	1.28	1.96	1.55
Organic Matter%	0.83	-	0.52	-	1.25	-	1.99	-
CEC, meq/100g soil	2.6	-	3.2	-	6.7	-	8.0	-
Available-P,ppm	19	14	40	23	19	20	31	26
Available-K,ppm	189	89	124	74	99	68	150	207

a: Surface 0-30 cm layer
b: Subsurface 30-60 cm layer
-: not determined

Table 86 -Soil Characteristics Of Surface And Subsurface Samples Of Farms For Protected Vegetables Production At Al-Naiem, Jabalet-Habashi & Jidd-Hafs.

Experiment 2.5.2.2

Soil Character	Serial Farm No.							
	9		10		11		12	
	a*	b*	a	b	a	b	a	b
Textural Analysis								
% Sand.	50.7	50.7	60.8	56.8	50.7	58.8	42.6	26.5
% Silt.	32.3	30.3	28.3	36.3	28.3	22.2	32.4	52.5
% Clay	17.0	19.0	10.9	6.9	21.0	19.0	25.0	21.0
Textural Class	L	L	SL	SL	SCL	SL	L	SCL
Hydraulic Conductivity, cm hr^{-1}	2.6	-	5.4	-	-	-	-	-
Saturation Percentage.	30	30	30	30	24	28	34	26
pH	7.7	7.3	7.5	7.4	7.4	7.5	7.4	7.3
EC_e mmhos cm^{-1} at 25°C	79.2	47.3	20.9	12.7	14.9	12.7	7.15	7.03
Anions, meq/L:								
HCO_3	7.02	7.02	4.68	7.02	3.51	3.51	3.51	4.10
Cl	840	510	180	80	115	95	57.5	40
SO_4	185	118	62.9	44.1	65.3	47.8	50.1	32.8
Cations, meq/L:								
Ca	181	125	71.6	41.3	46.1	44.0	34.5	26.0
Mg	156	104	36.4	18.2	15.3	20.8	13.5	9.5
Na	631	383	136	69	119	78.6	60.7	39.9
K	63.8	23	3.65	2.60	3.4	2.9	2.35	1.45
$CaCO_3$ %	19.0	21.0	21.5	23.5	48.0	48.5	22.0	22.0
$CaSO_4.2H_2O$%	2.43	2.21	7.81	26.4	2.52	2.32	1.68	1.57
Organic Matter%	1.91	-	1.71	-	1.48	-	1.69	-
CEC, meq/100g soil	15.0	-	12.3	-	16.0	12.0	13.0	16.0
Available-P, ppm	8.0	14	58	40	47	23	33	19
Available-K, ppm	59.0	36	10	10	10	10	10	13

Table 87 -Soil Characteristics Of Surface And Subsurface Samples Of Farms For Protected Vegetables Production At Jidd-Hafs, Karranah and Janusan.

Experiment 2.5.2.2

Soil Character	Serial Farm No.							
	13		14		15		16	
	a*	b*	a	b	a	b	a	b
Textural Analysis								
%Sand	62.8	56.8	58.8	58.8	52.7	50.7	56.8	54.8
% Silt	28.3	28.3	30.3	20.2	28.3	30.3	20.2	26.2
% Clay	8.9	14.9	10.9	21.0	19.0	19.0	23.0	19.0
Textural Class	SL	SL	SL	SCL	L	L	SCL	SL
Hydraulic Conductivity, cm hr^{-1}	-	-	-	-	-	-	6.8	-
Saturation Percentage.	30	30	30	26	30	30	30	24
pH	7.7	7.6	7.5	7.4	7.3	7.3	7.1	7.2
EC_e mmhos cm^{-1} at 25°C	11.8	11.6	13.2	13.4	11.8	11.0	20.9	20.8
Anions, meq/L:								
HCO_3	3.51	4.68	5.85	4.68	4.68	5.85	4.68	5.85
Cl	90	75	120	95	90	85	165	145
SO_4	42.8	46.6	37.7	57.5	55.8	70.2	71.3	143
Cations, meq/L:								
Ca	49.8	46.6	48.2	39.2	48.8	48.8	67.3	60.4
Mg	22.2	13.9	30.5	26.1	27.0	42.9	33.7	143
Na	62.6	64.3	80	86.9	70.2	66.7	131	85.3
K	1.70	1.45	4.75	5.0	4.5	2.6	9.0	6.0
$CaCO_3$%	14.5	10.5	26.0	30.5	23.5	38.5	14.0	15.0
$CaSO_4 \cdot 2H_2O$%	4.44	16.9	10.0	2.5	6.74	9.50	1.58	1.40
Organic Matter%	1.60	-	0.83	-	0.91	-	1.09	-
CEC, meq/100g soil	13.5	12.0	9.5	14.0	14.0	-	14.0	10.0
Available-P, ppm	36	36	19	6	16	19	38	29
Available-K, ppm	8.0	10	10	15	15	15	15	20

Table 88 -Soil Characteristics Of Surface And Subsurface Samples Of Farms For Protected Vegetables Production At Janusan, ShaKhourah, El-Markh & Maqabah.

Experiment 2.5.2.2

Soil Character	Serial Farm No.							
	17		18		19		20	
	a*	b*	a	b	a	b	a	b
Textural Analysis								
% Sand	68.9	68.9	74.6	72.6	91.1	91.1	79	70.9
% Silt	22.2	16.2	13.4	21.4	0.0	2.0	10.1	18.2
% Clay	8.9	14.9	12.0	6.0	8.9	6.9	10.9	10.9
Textural Class	SL	SL	SL	SL	S	S	SL	SL
Hydraulic Conductivity, cm hr^{-1}	-	-	9.8	-	20.3	-	18.1	8.6
Saturation Percentage	28	28	30	32	22	22	24	24
pH	7.7	7.5	7.1	7.4	7.9	8.0	7.0	7.2
EC_e mmhos cm^{-1} at 25°C	11.0	14.9	5.28	7.7	5.5	3.9	27.0	54.0
Anions, meq/L:								
HCO_3	7.02	8.19	4.7	4.7	4.68	4.10	4.68	4.68
Cl	75	165	25	50	27.5	22.5	235	575
SO_4	76.0	73.4	73	76.8	47.8	19.4	40	45
Cations, meq/L:								
Ca	45.1	44.0	70.6	31.4	32.9	17.5	72.1	80.0
Mg	38.4	49.1	17.7	60.8	15.6	7.0	33.9	77.0
Na	66.7	140	13.5	38.3	29.8	20.5	164	435
K	7.75	13.5	1.0	1.0	1.65	1.0	10	28
$CaCO_3$%	21.0	21.0	22.0	25.0	24.0	5.5	20.5	28.0
$CaSO_4.2H_2O$%	10.5	3.25	43.4	39.3	1.23	1.60	8.69	14.9
Organic Matter%	1.29	-	1.45	-	0.34	-	0.56	-
CEC, meq/100g soil	9.0	-	2.0	-	4.8	-	5.0	6.0
Available-P ppm	26	19	12.8	12.8	58	28	29	26
Available-K, ppm	15	20	142	142	99	96	240	534

*a: Surface 0-30 cm layer.
b: Subsurface 30-60 cm layer.

-: not determined.

Table 89 -Soil Characteristics Of Surface And Subsurface Samples Of Farms For Protected Vegetable Production At Barbar, Bu-Sabea & Al-Budaya.

Experiment 2.5.2.2

Soil Character.	Serial Farm No.							
	21		22		23		24	
	a*	b*	a	b	a	b	a	b
Textural Analysis								
% Sand	79.0	81.0	67.2	62.6	87.7	87.7	83.6	85.7
% Silt	8.1	4.1	21.4	29.4	5.4	5.4	9.5	9.4
% Clay	12.9	14.9	11.4	8.0	6.9	6.9	6.9	4.9
Textural Class	LS	SL	SL	SL	LS	LS	LS	LS
Hydraulic Conductivity, cm hr^{-1}	7.1	2.4	32.5	-	34.2	-	65	-
Saturation Percentage.	22	22	26	28	22	22	28	28
pH	7.4	7.5	7.7	7.0	7.5	7.2	7.2	7.5
EC_e mmhos cm^{-1} at 25°C	20.4	17.6	16.5	17.5	3.85	3.96	27	16.5
Anion, meq/L:								
HCO_3	5.85	5.85	5.9	4.7	2.93	2.93	5.85	7.02
Cl	125	120	100	90	10	12.5	240	125
SO_4	87.6	73.7	127	124	43.6	37.4	122	64.5
Cations, meq/L								
Ca	44.0	42.4	99.9	99.9	34.5	36.6	54.1	46.1
Mg	31.4	25.8	53.1	41.1	6.8	2.3	56.9	28.3
Na	129	119	73.4	74.8	14.3	13.1	248	119
K	14.0	12.3	6.0	3.0	0.85	0.80	9.0	3.15
$CaCO_3$%	21.0	17.5	34.2	29.6	17.0	12.5	20	23
$CaSO_4.2H_2O$ %	1.84	1.85	33.5	28.6	11.8	27.3	6.01	1.8
Organic Matter%	0.66	-	1.45	-	0.47	-	0.45	-
CEC, meq/100g soil	6.0	6.0	4.8	-	1.5	-	8.5	-
Available-P, ppm	21	19	9.2	16.0	46	21	19	9
Available-K, ppm	414	427	458	203	61	66	252	140

* a: Surface 0-30 cm layer.
b: Subsurface 30-60 cm layer. -: not determined.

Table 90 - Soil Characteristics Of Surface And Subsurface Samples Of Farms For Protected Vegetable Production At Al-Budaya and Bani-Jamrah.

Experiment 2.5.2.2

Soil Character	Serial Farm No.							
	25		26		27		28	
	a*	b*	a	b	a	b	a	b
Textural Analysis								
% Sand	93.7	93.7	88.5	90.5	89.1	89.1	87.1	91.1
% Silt	1.5	1.5	5.2	3.2	2.0	2.0	2.0	0.0
% Clay	4.8	4.8	6.3	6.3	8.9	8.9	10.9	8.9
Textural Class	S	S	LS	S	LS	LS	LS	S
Hydraulic Conductivity, cm hr^{-1}	81.3	-	108	81	81	-	32.5	-
Saturation Percentage	22	22	20	20	20	20	24	24
pH	7.5	7.5	7.8	8.0	7.6	7.9	7.6	7.6
EC_e mmhos cm^{-1} at 25°C	6.49	4.79	23.1	14.3	9.9	6.6	11.6	7.15
Anions, meq/L:								
HCO_3	2.93	3.51	4.68	4.68	4.68	3.51	4.68	2.34
Cl	30	22.5	185	100	60	30	80	42.5
SO_4	40.3	28.6	71.3	50.9	63.6	50.5	48.5	42.9
Cations, meq/L:								
Ca	26.0	24.9	55.6	42.8	38.2	33.4	41.3	37.1
Mg	12.9	11.1	47.4	27.8	13.6	11.2	20.1	10.9
Na	33.3	17.8	150	80	69	35.7	67.9	36.6
K	1.0	0.8	8.0	5.0	7.5	3.7	3.85	3.10
$CaCO_3$ %	17.0	18	11.5	11.0	9.5	9.0	19.0	19.0
$CaSO_4.2H_2O$ %	1.25	1.08	2.13	1.53	5.69	5.53	13.9	4.85
Organic Matter %	0.52	-	0.52	-	0.19	-	0.19	-
CEC, meq/100g soil	6.0	-	2.6	1.8	4.8	-	4.8	-
Available-P, ppm	21	9	23	21	34	38	14	8
Available-K, ppm	71	53	10	13	10	8	119	192

*a: Surface 0-30 cm layer.
b: Subsurface 30-60 cm layer.

-: not determined.

Table- 91 -Soluble Ionic Ratios* In Saturation Extracts Of Farms Sites For Protected Vegetable Production In Bahrain (Bani-Jamarah to Az-Zallaq).

Experiment 2.5.2.2

Disctrict	Farm Serial No.	Cl/SO_4		Mg/Ca		Ca/Cations		Mg/Cations	
		a*	b*	a	b	a	b	a	b
Bani-Jamrah	26	2.59	1.96	0.85	0.65	0.21	0.28	0.18	0.18
" "	27	0.94	0.59	0.36	0.34	0.30	0.40	0.11	0.13
" "	28	1.65	0.99	0.49	0.29	0.31	0.42	0.15	0.12
" "	29	2.99	2.50	0.39	0.48	0.39	0.35	0.15	0.17
El-Qurayyah	30	0.50	0.67	0.04	0.14	0.65	0.59	0.02	0.08
" "	31	3.11	1.60	0.48	0.21	0.22	0.40	0.10	0.08
Al-Jasrah	32	2.46	2.39	1.59	0.63	0.08	0.15	0.13	0.10
" "	33	0.54	0.65	0.18	0.18	0.59	0.56	0.10	0.13
Buri	34	2.52	4.45	0.23	0.25	0.41	0.43	0.11	0.11
"	35	5.41	4.69	0.62	0.78	0.18	0.19	0.11	0.15
"	36	5.16	4.61	0.85	0.46	0.19	0.26	0.17	0.12
Al-Hamalah	37	4.61	3.96	0.49	1.54	0.21	0.09	0.10	0.14
" "	38	2.02	0.58	0.80	0.39	0.22	0.41	0.18	0.16
" "	39	2.26	2.48	0.70	0.73	0.25	0.25	0.18	0.18
" "	40	3.81	2.50	0.69	0.57	0.24	0.27	0.16	0.15
Dumistan	41	1.08	0.56	4.24	5.42	0.12	0.10	0.50	0.52
Karzakkan	42	1.58	1.57	0.85	0.55	0.20	0.29	0.17	0.16
"	43	14.8	4.3	1.61	1.28	0.12	0.15	0.19	0.19
Al-Malikiyah	44	0.84	0.90	1.88	6.06	0.18	0.09	0.34	0.53
Sadad	45	1.11	1.05	0.78	0.37	0.31	0.47	0.24	0.18
Az-Zallaq	46	6.38	3.92	2.23	1.67	0.08	0.10	0.17	0.17
" "	47	1.45	2.43	0.58	1.15	0.29	0.21	0.17	0.24

* Concentrations of all ions involved in the ratios are expressed in meq/L.

*a: 0-30 cm soil surface layer.
b: 30-60 cm soil subsurface layer.

Table 92 -Soil Characteristics Of Surface And Subsurface Samples Of Farms For Protected Vegetable Protected At Bani-Jamrah, El-Qurayyah and Al Jasrah.

Experiment 2.5.2.2

Soil Character	Serial Farm No.							
	29		30		31		32	
	a*	b*	a	b	a	b	a	b
Textural Analysis								
% Sand	89.1	89.1	85.7	77.6	85.7	89.7	72.9	81.0
% Silt	0.0	0.0	5.4	15.5	7.4	3.4	10.1	4.1
% Clay	10.9	10.9	8.9	6.9	6.9	6.9	17.0	14.9
Textural Class	LS	LS	LS	LS	LS	S	SL	SL
Hydraulic Conductivity, cm hr^{-1}	108	-	54.2	4.3	81	-	-	-
Saturation Percentage	22	22	22	30	23	24	22	22
pH	7.1	7.3	7.3	7.2	7.7	7.1	7.0	7.2
EC_e mmhos cm^{-1} at 25°C	13.2	13.2	4.73	5.34	23	11.6	59.4	29.7
Anions, meq/L:								
HCO_3	5.85	4.68	3.51	2.93	4.68	7.02	1.76	2.34
Cl	110	110	17.5	25	190	85	600	265
SO_4	36.8	44.0	35.3	37.3	61	53.8	244	111
Cations, meq/L:								
Ca	59.9	56.2	36.6	38.2	58.3	58.3	68.4	58.3
Mg	23.6	26.8	1.3	5.5	28.1	12.3	109	36.5
Na	66.1	73.1	17.4	20.9	152	70.2	643	271
K	2.95	2.55	0.95	0.6	17.3	5.0	26	12
$CaCO_3$ %	14.5	14.0	14.0	9.5	14.5	12.5	15	17
$CaSO_4 \cdot 2H_2O$ %	7.93	14.5	23.4	36.5	16.5	17.7	10.7	4.6
Organic Matter %	0.31	-	0.34	-	0.47	-	0.31	-
CEC, meq/100g soil	4.5	-	3.2	9.0	7.5	-	7.9	-
Available-P, ppm	56	33	33	14	19	16	17	8
Available-K, ppm	71	64	66	59	300	129	480	216

*a: Surface 0-30 cm layer.
b: Subsurface 30-60 cm layer.

-: not determined.

Table 93-Soil Characteristics Of Surface And Subsurface Samples Of Farms For Protected Vegetable Production At Al-Jasrah and Buri.

Experiment 2.5.2.2

Soil Character	Serial Farm No.							
	33		34		35		36	
	a*	b*	a	b	a	b	a	b
Textural Analysis								
% Sand	79.0	91.1	73.5	69.5	55.4	49.3	61.4	57.4
% Silt	12.1	0.0	19.6	23.6	36.3	45.9	29.7	29.7
% Clay	8.9	8.9	6.9	6.9	8.9	4.8	8.9	12.9
Textural Class	LS	S	SL	SL	SL	SL	SL	SL
Hydraulic Conductivity, cm hr^{-1}	6.5	163	8.6	-	5.8	10.8	-	-
Saturation Percentage.	22	22	30	28	32	38	36	30
pH	7.0	7.1	7.5	7.5	7.0	7.2	7.1	7.0
EC_e mmhos cm^{-1} at 25°C	4.62	4.68	13.8	16.0	84.7	36.1	51.7	42.9
Anion, meq/L:								
HCO_3	2.93	3.51	4.68	5.85	3.51	2.34	5.85	5.85
Cl	20	22.6	105	125	1000	430	460	425
SO_4	37.1	34.8	41.6	28.1	185	91.7	89.2	92.2
Cations, meq/L:								
Ca	35.5	33.9	61.5	68.9	209	98.6	108	134
Mg	6.3	7.9	16.7	17.0	130	77.4	92	61
Na	17.4	18.1	71.3	71.3	833	340	348	322
K	0.85	1.0	1.75	1.65	16.0	8.0	7.0	6.0
$CaCO_3$ %	14.5	15.5	16.5	15.5	18.0	26.5	35.0	30.0
$CaSO_4.2H_2O$ %	7.85	2.23	32.5	37.3	23.3	30.6	12.6	16.5
Organic Matter %	0.19	-	0.83	-	1.60	-	1.09	-
CEC, meq/100g soil	3.2	3.2	9.8	-	14.5	12.5	12.3	-
Available-P, ppm	26	43	30	16	9	6	27	9
Available-K, ppm	46	48	109	99	792	372	270	252

*a: Surface 0-30 cm layer.
b: Subsurface 30-60 cm layer.

-: not determined.

Table 94 - Soil Characteristics Of Surface And Subsurface Samples Of Farms For Protected Vegetable Production At Al-Hamalah.

Experiment 2.5.2.2

Soil Character	Serial Farm No.							
	37		38		39		40	
	a*	b*	a	b	a	b	a	b
Textural Analysis								
% Sand	89.1	75.0	81.0	83.0	89.1	87.1	83.0	72.9
% Silt	2.0	12.1	8.1	6.1	0.0	2.0	6.1	16.2
% Clay	8.9	12.9	10.9	10.9	10.9	10.9	10.9	10.9
Textural Class	LS	SL	LS	LS	LS	LS	LS	SL
Hydraulic Conductivity, cm hr^{-1}	65	-	6.8	-	40.6	-	32.5	10.2
Saturation Percentage	22	24	22	22	22	22	20	28
pH	7.0	7.0	7.0	7.7	7.7	7.8	7.6	7.7
EC_e mmhos cm^{-1} at 25°C	23.1	59.4	20.7	8.14	18.7	16.3	25.3	19.3
Anions, meq/L:								
HCO_3	4.68	4.68	4.68	2.93	4.68	5.85	3.51	5.85
Cl	200	670	165	32.5	165	150	215	155
SO_4	43.4	169	81.6	55.7	73.0	60.4	56.5	62.1
Cations, meq/L:								
Ca	51.9	75.3	56.7	37.1	61.0	53.5	65.7	59.4
Mg	25.4	115.7	45.3	14.3	43.0	39.1	45.3	33.7
Na	164	631	140	36.3	133	121	157	126
K	6.75	22.0	9.3	3.4	5.8	2.8	7.0	3.8
$CaCO_3$ %	17.5	18.0	13.5	16.0	13.0	11.5	11.0	38
Ca $SO_4 \cdot 2H_2O$ %	3.33	16.9	16.7	7.51	12.0	13.7	19.3	15
Organic Matter %	0.1	-	0.45	-	0.19	-	0.36	-
CEC, meq/100g soil	3.3	8.4	6.8	-	3.7	-	8.8	14.6
Available-P, ppm	21	22	22	22	36	19	34	9
Available-K, ppm	183	498	234	147	127	91	10	10

Table 95 -Soil Characteristics Of Surface And Subsurface Samples Of Farms For Protected Vegetable Production At Dumistan, Karzakkan & Al-Malikiyah.

Study 2.5.2.2

Soil Character	Serial Farm No.							
	41		42		43		44	
	a*	b*	a	b	a	b	a	b
Textural Analysis								
% Sand	87.8	77.6	81	81	64.9	64.9	77.2	85.8
% Silt	5.4	11.6	10.1	10.1	22.2	18.1	5.4	5.4
% Clay	6.8	10.8	8.9	8.9	12.9	17.0	17.4	8.8
Textural Class	LS	SL	LS	LS	SCL	SL	SL	LS
Hydraulic Conductivity, cm hr^{-1}	54.2	14.8	36.1	-	16.3	16.3	20.3	20.3
Saturation Percentage	22	24	24	30	22	28	22	24
pH	7.7	7.7	7.8	7.6	6.8	7.3	7.6	7.5
EC_e mmhos cm^{-1} at 25^oC	18.8	13.9	18.7	11.0	91.3	39.6	24.2	15.9
Anions, meq/L:								
HCO_3	4.7	4.7	4.65	3.51	4.68	3.51	4.7	3.5
Cl	120	60	140	85	1165	415	185	115
SO_4	111	108	88.6	54	78.6	96.5	220	128
Cations, meq/L:								
Ca	27.8	16.5	46.6	41.9	145	76.9	75.2	21.6
Mg	118	89.5	39.8	22.9	234	98.1	141	131
Na	85.5	65.3	140	75	833	331	188	87
K	4.5	2.0	6.75	2.7	36.3	9.0	6.3	6.0
$CaCO_3$ %	16.9	13.3	6.5	6.0	23.0	30.5	23	21
$CaSO_4.2H_2O$ %	11.3	30.4	37.0	41.6	13.8	3.53	25.2	12
Organic Matter %	0.53	-	0.34	-	1.81	-	0.62	-
CEC, meq/100g soil	5.2	6.6	4.3	-	13.2	14.6	8.8	3.6
Available-P, ppm	16	13	26	20	31	8	16	22
Available-K, ppm	195	125	152	91	36	20	248	209

Table 96 -Soil Characteristics Of Surface And Subsurface Samples Of Farms For Protected Vegetable Production At Sadad & Az-Zallaq.

Study 2.5.2.2

Soil Character.	Serial Farm No.					
	45		46		47	
	a*	b*	a	b	a	b
Textural Analyais						
% Sand	81.8	83.8	70.9	75.0	79	77
% Silt	11.4	9.4	18.2	12.1	12.1	12.1
% Clay	6.8	6.8	10.9	12.9	8.9	10.9
Textural Class	LS	LS	SL	SL	LS	SL
Hydraulic Conductivity, cm hr^{-1}	32.5	-	59.1	-	9.6	4.6
Saturation Percentage	31	32	24	32	24	24
pH	7.3	7.1	7.4	7.8	7.3	7.4
EC_e mmohs cm^{-1} at 25^oC	23.1	12.1	79.2	44.0	11.6	13.2
Anions, meq/L:						
HCO_3	5.9	3.5	5.85	4.68	3.51	4.68
Cl	190	85	900	415	85	105
SO_4	171	81.1	141	106	58.7	43.2
Cations, meq/L:						
Ca	116	79.3	81.1	55.1	42.9	32.3
Mg	90	29.7	181	91.9	24.8	37.3
Na	161	59.4	762	366	76.2	78.3
K	3.0	1.3	23	13	3.3	5.0
$CaCO_3$ %	8.3	11.8	22.0	24.5	16.8	26.0
$CaSO_4 . 2H_2O$ %	37.5	32.8	22.1	6.37	28.7	6.96
Organic Matter %	0.53	-	0.81	-	0.71	-
CEC, meq/100g soil	1.8	-	3.7	-	8.0	12.8
Available-P ppm	14.4	15.8	36	27	10	11
Available-K, ppm	131	98	433	396	8	10

Table 97 -Chemical Composition Of Brackish Waters Used For Irrigation In Bahrain.

Study 2.5.3

Serial No.	Location	pH	EC_w umhos cm^{-1}	Dissolved solids ppm	Boron mg/L	Milliequivalents per litre									SAR
						Ca	Mg	Na	K	Sum Cations	CO_3	HCO_3	Cl	SO_4	
1	Sitrah	7.0	9890	6330	0.8	17.8	17.4	69.0	1.8	106	0.0	5.9	90	10.1	16.4
2	Al-Ekr	7.2	6720	4301	0.6	14.8	11.9	38.6	1.9	67.2	0.0	2.6	55	9.6	10.6
3	Sanad	7.4	5090	3258	0.7	12.5	8.5	27.7	1.3	50	0.0	3.3	40	6.7	8.5
4	Arad	7.3	3840	2458	0.4	11.2	7.3	18.9	0.9	38.3	0.0	3.3	28	7.0	6.2
5	Karranah	7.3	3200	2048	0.8	10.5	7.3	19.3	0.9	38	0.0	3.0	27	8.0	6.5
6	Janusan	7.6	3850	2464	0.5	12.3	6.9	21.4	1.0	41.6	0.0	3.7	28	9.9	6.9
7	Shakhourah	7.2	3520	2253	0.5	11.5	5.4	20.8	0.9	38.6	0.0	3.7	25	9.9	7.1
8	El-Markh	7.2	3520	2253	0.6	10.8	6.0	20.8	0.9	38.5	0.0	3.5	27	8.0	7.2
9	Magabah	7.2	8800	5632	1.6	37.4	22.6	57.6	2.6	120.2	0.0	3.3	71	45.9	10.5
10	Barbar	7.1	5610	3590	1.2	21.4	11.9	32.5	1.5	67.3	0.0	3.7	38.0	25.6	8.0
11	Ad-Draz	7.5	3630	2323	0.6	10.8	5.6	21.4	0.9	38.7	0.0	3.3	27.0	8.0	7.5
12	Al-Budaya	7.2	3620	2317	0.5	11.0	6.9	17.6	0.7	36.2	0.0	3.0	24.0	9.2	5.9
13	Bani-Jamrah	7.4	3200	2048	0.8	10.5	7.9	17.0	0.9	36.3	0.0	3.3	26.0	7.0	5.6
14	Al-Jasrah	7.1	3300	2112	0.8	10.0	7.3	19.0	0.7	37.0	0.0	3.4	23.0	10.6	5.9
15	Al-Hamalah	7.1	4620	2957	1.0	11.9	8.8	26.0	1.0	47.7	0.0	3.3	32.0	12.4	8.1
16	Dumistan	7.4	5200	3328	0.5	16.7	10.8	25.0	1.2	53.7	0.0	3.5	34.0	16.2	6.7

Table 98 -Chemical Composition Of Sweet Water In Bahrain.

pH	EC_w umhos cm^{-1}	Dissolved Solids ppm	B mg/L	Milliequivalents per litre									SAR
				Ca	Mg	Na	K	Sum Cations	CO_3	HCO_3	Cl	SO_4	
7.6	910	582	0.8	1.7	3.9	8.0	0.2	13.8	0.0	1.4	8.0	4.4	4.8

Table 99 -Chemical Composition Of Drainage Waters At Some Farms In Bahrain.

Serial No	Location	Type	pH	EC_w umhos cm^{-1}	Dissolved solids ppm	Boron mg/L	Milliequivalents per litre									SAR
							Ca	Mg	Na	K	Sum Cations	CO_3	HCO_3	Cl	SO_4	
1	Janusan	S*	7.3	8360	5350	1.4	38.8	15.5	47.6	2.0	103.9	0.0	4.2	53	46.7	9.1
2	Ad-Draz	S	7.1	6380	4083	1.2	40.7	8.2	28.5	1.0	78.4	0.0	6.1	36	36.3	5.8
3	Al-Hamalah	D*	7.1	9790	6266	1.9	37.5	20.7	55	2.3	115.5	0.0	5.5	65	45	10.2
4	Al-Jasrah	S	7.4	5280	3379	1.6	35	9.6	22	0.5	67.1	0.0	4.6	27	35.5	4.66
5	Al-Jasrah	D	7.9	12320	7885	2.0	37.1	29.0	81.5	4.0	151.6	0.0	4.6	89	58.0	14.2
6	Barbar	D	8.0	6440	4122	-	30.9	21.3	32.5	1.9	86.6	0.0	3.0	39	44.6	6.4

S: Shallow perched water. D: Drainage water.

TABLE 100 Ideal Formulas of Nutrient Solutions For Hydroponics in Bahrain

Nutrient Element	TOMATO			CUCUMBER		
	Concentration, PPm			Concentration, PPm		
	Minimum	Optimum	Maximum	Minimum	Optimum	Maximum
N	90	140	200	120	200	300
P	40	60	90	40	60	90
K	200	300	400	150	200	250
Ca	120	150	240	150	250	350
Mg	40	50	60	40	50	60
Fe	2	4	5	2	4	5
Mn	0.10	0.50	1.0	0.10	0.50	1.0
Cu	0.03	0.05	0.10	0.03	0.05	0.10
Zn	0.05	0.10	0.20	0.05	0.10	0.20
Mo	0.02	0.04	0.10	0.02	0.04	0.10
B	0.20	0.50	1.0	0.20	0.5	1.0

TABLES 101 - 113

ANALYSIS OF VARIANCE TABLES FOR THE EXPERIMENTS

2.1 - RESEARCH UNDER HIGH PLASTIC TUNNEL CONDITIONS

Table 101

Experiment 2.1.1 Effect of mulching on improvement of soil productivity and management for cucumber production in high tunnels

Mulching Under Drier Irrigation Regime (2 h once every other day)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean of Squares	Observed F	Required F 5%
Total	5	17.5			
Replications	1	1.5	1.5		
Treatments	2	12.0	6.0	3	19
Error	2	4.0	2.0		

N.S.

Mulching Under Wetter Irrigation Regime (3 h once every other day)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean of Squares	Observed F	Required F 5%
Total	5	92			
Replications	1	10	10.0		
Treatments	2	25	12.5	0.44	19
Error	2	57	28.5		

N.S.

Table 102

Experiment 2.1.2 Observational trial on the effect of irrigation regime on indeterminate tomato production

Source of Variation	Degrees of Freedom	Sum of Squares	Mean of Squares	Observed F	Required F 5%
Total	5	386.05			
Replications	2	219.30	109.65	2.15	
Treatments	1	64.68	64.68	1.27	18.5
Error	2	102.07	51.04		

N.S.

Table 103 Experiment 2.1.3 Comparative study of soil and foliar applications of mineral fertilizers and their effects on yield under plastic tunnel conditions

Experiment 2.1.3.1 Effect on yield of indeterminate totato

Source of Variation	Degrees of Freedom	Sum of Squares	Mean of Squares	Observed F	Required F 5 %
Total	17	130.09			
Replications	2	33.67	16.84		
Treatments	5	63.62	12.72	3.88*	3.33
Error	10	32.80	3.28		

* Significant at 5%

Experiment 2.1.3.2 Effect on yield of cucumber

Source of Variation	Degrees of Freedom	Sum of Squares	Mean of Squares	Observed F	Required F 5%
Total	24	2970.96			
Replications	3	382.13	127.38		
Treatments	5	2206.7	441.34	14.65*	2.85
Method	1	0.04	0.04	0.001	4.49
Rate	2	1972.34	986.17	32.73*	3.63
Method X Rate	2	234.32	117.16	3.89*	3.63
Error	16	482.13	30.13		

* Significant at 5%

Table 104

Experiment 2.1.4 Yield response of indeterminate tomato varieties to foliar application of micronutrients

Floradel Treatments

Source of Variation	Degrees of Freedom	Sum of Squares	Mean of Squares	Observed F	Required F 5%
Total	31	905.44			
Replications	3	436.18	145.39		
Treatments	7	211.58	30.23	2.46	2.49
Error	21	257.68	12.27		

N.S.

Experiment 2.1.4

b- Beef Steak Treatments

Source of Variation	Degrees of Freedom	Sum of Squares	Mean of Squares	Observed F	Required F 5%
Total	23	205.9			
Replications	2	21.42			
Treatments	7	60.68	8.67	0.98	2.76
Error	14	123.8	8.84		

N.S.

Experiment 2.1.4

c- Gross Lisse Treatments

Source of Variation	Degrees of Freedom	Sum of Squares	Mean of Squares	Observed F	Required F 5%
Total	31	398.49			
Replications	3	115.39			
Treatments	7	29.95	4.28	0.36	2.49
Error	21	253.15	12.05		

N.S.

Table 105

Experiment 2.1.5 Yield response of indeterminate tomato to increasing rates and ratios of N, P and K

Experiment 2.1.5.2

Winter of 1981-1982 Season

Source of Variation	Degrees of Freedom	Sum of Squares	Mean of Squares	Observed F	Required F 5%
Total	17	569.55	33.5		
Replications	2	19.54	9.77	0.86	
Treatments	5	436.32	87.26	7.67*	3.33
Error	10	113.69	11.37		

* Significant at 5 %

Table 106 2.4 - SUMMER FERTILITY TRIALS

Experiment 2.2.1 Effect of organic fertilizer application to a light soil on tomato yield

Source of Variation	Degrees of Freedom	Sum of Sqares	Mean of Squares	Observed F	Required F 5%
(Main plots)	11	10.83			
Replications	3	7.79	2.60	5.31	4.76
Organic Fertilizer	2	0.13	0.07	0.14	5.14
Error (a)	6	2.91	0.49		
(Sub-plots)	47	897.59			
Rates	3	848.32	282.77	357.94*	2.96
Org. FX Rates	6	16.98	2.83	3.58*	2.46
Error (b)	27	21.46	0.79		

* Siginificant at the 5% level

\- Org. F = Type of organic fertilizer

Table 107

Experiment 2.2.2 Comparative effect of various forms and rates of nitrogen on the yield of squash

Source of Variation	Degrees of Freedom	Sum of Squares	Mean of Squares	Observed F	Required F 5%
Total	35	44.42			
Blocks	3	2.49	0.9	0.88	3.01
Treatments	8	17.27	2.16	2.12	2.36
N-Source	2	1.33	0.67	0.66	4.26
N-Rate	2	1.57	0.79	0.77	4.26
S X R	4	14.37	3.59	3.52*	2.78
Error	24	24.46	1.02		

* Significant at the 5% level

Table 108

Experiment 2.2.3: Comparative study of soil and foliar application of phosphorus or nitrogen on okra yield (open field)

Experiment 2.2.3.1 Soil and foliar application of phosphates

Source of Variation	Degrees of Freedom	Sum of Squares	Mean of Squares	Observed F	Required $F_{5\%}$
Total	47	147.86			
Blocks	3	18.44	6.15		
Treatments	11	51.55	4.69	1.97	2.08
P - Method	3	2.90	0.97	0.41	2.09
P - Rate	2	13.27	6.64	2.79	3.29
Rate X Method	6	35.38	5.90	2.48*	2.40
Error	33	77.87	2.36		

* Significant at the 5% level

Experiment 2.2.3.2 Soil and foliar application of urea

Source of Variation	Degrees of Freedom	Sum of Squares	Mean of Squares	Observed F	Required $F_{5\%}$
Total	23	78.27			
Blocks	3	35.73	11.91		
Treatments	5	12.97	2.59	1.31	2.90
N - Method	2	3.54	1.77	0.9	3.68
N - Rate	1	5.21	5.21	2.64	4.54
Rate X Method	2	4.22	2.11	1.07	3.68
Error	15	29.57	1.97		

N.S.

Table 109

Experiment 2.2.4 Comparative study of soil and foliar application of chemical fertilizers on trellised tomatoes in the open field

Source of Variation	Degrees of Freedom	Sum of Squares	Mean of Squares	Observed F	Required F 5%
Total	23	58.11			
Blocks	3	4.21	1.4	0.67	
Treatments	5	22.64	4.53	2.18	2.9
Error	15	31.26	2.08		

N.S.

Table 110

Experiment 2.2.5 Elucidation of addition necessity of NPK fertilizers to vegetable crops grown on light textured soils

Experiment 2.2.5.1 Yield response of squash

Source of Variation	Degrees of Freedom	Sum of Squares	Mean of Squares	Observed F	Required F 5%
Total	31	59.18			
Blocks	3	2.11	0.7		
Treatments	7	26.44	3.78	2.59*	2.49
Error	21	30.63	1.46		

Significant at 5% level

Experiment 2.2.5.2 Yield response of determinate tomato

Source of Variation	Degrees of Freedom	Sum of Squares	Mean of Squares	Observed F	Required F 5%
Total	31	2053.8			
Replications	3	32.6	10.87	7.55	
Treatments	7	1990.9	284.4	197.5*	2.49
Error	21	30.3	1.44		

* Significant at 5%.

Experiment 2.2.5.3(a): Yield response of indeterminate trelissed tomato 1980/81 season

Source of Variation	Degrees of Freedom	Sum of Squares	Mean of Squares	Observed F	Required F 5%
Total	31	145.71			
Replications	3	0.66	0.22		
Treatments	7	136.00	19.43	45.19*	2.49
Error	21	9.01	0.43		

* Significant at 5%

Experiment 2.2.5.3(b):Yield response of indeterminate trelissed tomato 1981/82 season

Source of Variation	Degrees of Freedom	Sum of Squares	Mean of Squares	Observed F	Required F 5%
Total	39	3816.00			
Replications	4	2318.68	579.67		
Treatments	7	1183.00	169.00	15.05*	2.38
Error	28	314.32	11.23		

* Significant at 5 %

Table 111

Experiment 2.2.5.5 Yield response of peppers (a) Bell peppers

Source of Variation	Degrees of Freedom	Sum of Squares	Mean of Squares	Observed F	Required F 5%
Total	31	63.62			
Replications	3	0.21			
Treatments	7	56.23	8.03	23.6*	2.49
Error	21	7.18	0.34		

* Significant at 5%

Experiment 2.2.5.5 (b) Long peppers

Source of Varation	Degrees of Freedom	Sum of Squares	Mean of Squares	Observed F	Required F 5%
Total	31	20.65			
Replications	3	2.23	0.74		
Treatments	7	15.03	2.15	13.4*	2.49
Error	21	3.39	0.16		

* Significant at 5%

2.3 - RESEARCH UNDER LOW TUNNEL CONDITIONS

Table 112 - **Experiment 2.3**

Experiment 2.3.1 Yield response of determinate tomato under low tunnels

Source of Variation	Degrees of Freedom	Sum of Squares	Mean of Squares	Observed F	Required $F_{5\%}$
Total	31	2307.9			
Replications	3	16.86	5.62		
Treatments	7	2127.4	303.9	39*	2.49
Error	21	163.65	7.79		

* Significant at 5%

Experiment 2.3.2 Yield response of bell peppers under low tunnels

Source of Variation	Degrees of Freedom	Sum of Squares	Mean of Squares	Observed F	Required $F_{5\%}$
Total	31	613.76			
Replications	3	0.60			
Treatments	7	381.07	54.44	4.91*	2.49
Error	21	232.69	11.08		

* Significant at 5% level

Experiment 2.3.3 Yield response of long green pepper under low tunnels

Source of Variation	Degrees of Freedom	Sum of Squares	Mean of Squares	Observed F	Required $F_{5\%}$
Total	31	95.78			
Replications	3	1.2	0.4		
Treatments	7	80.84	11.55	17.77*	2.49
Error	21	13.74	0.65		

* Significant at 5% level

2.4 - SUMMER FERTILIZER TRIALS

Table 113

Experiment 2.4.1 Yield response of tomato to nitrogen and potassium under different base mineral fertilizers in the presence of evaporative cooling and shade

Source of Variation	Degrees of Freedom	Sum of Squares	Mean of Squares	Observed F	Required F 5%
Total	11	66.34			
Blocks	2	0.062	0.03		5.14
Treatments	3	52.40	17.467	7.55*	4.76
Base (B)	1	24.08	24.08	10.4 *	5.99
Supplemental (s)	1	3.929	3.929	1.699	5.99
BXS	1	24.39	24.39	10.545*	5.99
Error	6	13.878	2.313		

* Significant at 5%

Experiment 2.4.2 Yield response of cucumber to nitrogen and potassium under different base mineral fertilizers in the presence of evaporative cooling

Source of Variation	Degrees of Freedom	Sum of Squares	Mean of Squares	Observed F	Required F 5%
Total	8	694.85	86.86		
Blocks	1	272.61	272.61		
Treatments	3	92.15	30.72	0.09	6.59
Base (B)	1	35.7	35.7	0.11	7.71
Supplemental (s)	1	5.95	5.95	0.02	7.71
BXS	1	50.5	50.5	0.15	7.71
Error	4	330.1			

N.S.

Experiment 2.4.3 Yield response of cucumber to nitrogen and potassium under shade

Source of Variation	Degrees of Freedom	Sum of Squares	Mean of Squares	Observed F	Required F 5%
Total	9	563.02	62.56		
Blocks	4	49.22	12.31		
Treatments	1	451.59	451.59	29.04*	5.12
Error	4	62.21	15.55		

* Significant at 5%

Experiment 2.4.5 Comparative effect of different forms of nitrogen on yield of tomato under shade

Source of Variation	Degrees of Freedom	Sum of Squares	Mean of Squares	Observed F	Required F 5%
Total	14	281.23	20.09		
Blocks	4	150.68	37.67		
Treatments	2	58.69	29.35	3.27	4.46
Error	8	71.86	8.98		

N.S.

Experiment 2.4.6 Effect of rates and methods of phosphate application on tomato under shade

Source of Variation	Degrees of Freedom	Sum of Squares	Mean of Squares	Observed F	Required F 5%
Total	14	192.75			
Blocks	4	41.2	10.3		
Treatments	2	10.71	5.36	0.30	4.46
Error	8	140.84	17.61		

N.S.

Experiment 2.4.8 Comparative effect of soil and foliar application of a complete fertilizer on okra yield in the open field

Source of Variation	Degress of Freedom	Sum of Squares	Mean of Squares	Observed F	Required F 5%
Total	11	32.53			
Blocks	3	3.37	1.12		
Treatments	2	28.07	14.03	77.9*	5.14
Error	7	1.09	0.18		

* significant at 5%

A P P E N D I X E S

Appendix 1 – METEOROLOGICAL DATA (1980-82)

A1.1 Meteorological Data at Budaya, Bahrain (1980)*

Month	Mean daily Temperature °C			Mean daily relative humidity %	Mean daily sunshine hr/day	Mean daily evaporation class A pan mm	Mean daily wind Km/day	Total rain fall mm	Number of rainy days
	Max.	Min.	Mean						
Jan	23.8	21.2	22.5	80	7.0	3.6	83.9	-	-
Feb	22.3	20.3	21.3	80	6.5	3.7	78.7	-	-
Mar	26.2	21.3	23.7	76	7.7	4.5	80.0	4.5	1
Apr	30.7	24.9	27.8	73	8.7	4.0	100.0	3.0	1
May	32.7	27.0	28.6	72	9.1	4.3	94.8	-	-
Jun	36.6	28.2	32.4	59	10.8	5.3	89.6	-	-
Jul	46.1	30.6	37.5	67	10.2	7.5	59.7	-	-
Aug	42.7	-	35.9	31	10.2	6.0	70.8	-	-
Sep	42.8	27.7	35.3	78	9.2	5.9	64.6	-	-
Oct	40.8	24.7	32.7	63	8.4	4.3	59.8	-	-
Nov	27.8	22.4	24.9	77	7.6	3.8	62.9	-	-
Dec	26.5	15.2	20.8	71	7.1	2.4	79.8	-	-
Total	-	-	-	-	-	-	-	7.5	2

Source: Dastane, N.G. More crop per drop in the Gulf desert.

A1.2 - Meteorological Data At Budaya, Bahrain (1981)*

Month	Mean daily temperature °C			Mean daily relative humidity %	Mean daily sunshine hr/day	Mean daily evaporation class A pan mm	Mean daily wind km/day	Total rainfall mm	Number of rainy days
	Max.	Min.	Mean						
Jan	29.5	16.6	22.9	79.6	6.6	2.0	78	25.4	6
Feb	30.3	15.1	22.8	68.6	7.0	2.9	101	0.3	1
Mar	31.5	18.4	25.1	70.9	7.7	4.4	92	7.5	3
Apr	31.0	21.5	26.3	69.4	8.7	5.5	104	-	-
May	31.6	25.7	28.8	68.2	8.6	6.2	105	-	-
Jun	36.7	27.6	31.7	64.4	10.9	7.4	90	-	-
Jul	36.8	29.3	33.8	55.7	10.5	7.8	74	-	-
Aug	37.7	30.0	33.7	63.9	10.3	7.8	79	-	-
Sep	33.5	29.8	31.7	69.7	9.7	4.4	56	-	-
Oct	32.8	24.3	28.6	71.9	8.6	4.7	54	-	-
Nov	27.8	19.4	24.2	78.5	7.7	3.0	75.9	-	-
Dec	22.9	16.1	19.9	84.6	7.4	3.0	59.9	-	-
Total	-	-	-	-	-	-	-	33.2	10

Source: Dastane, N.G. More crop per drop in the Gulf desert.

A1.3 - Meteorological data at Budaya, Bahrain (1982)*

Month	Mean daily temperature °C			Mean daily relative humidity %	Mean daily sunshine hr/day	Mean daily evaporation class A pan mm	Mean daily wind Km/day	Total rainfall mm	Number of rainy days
	Max.	Min.	Mean						
Jan	19.9	13.3	16.6	78.6	6.5	2.3	85.8	0.5	3
Feb	18.9	13.3	16.3	78.3	7.2	2.5	117.3	41.0	3
Mar	21.5	17.4	19.8	79.3	5.4	3.5	96.5	65.0	13
Apr	27.9	20.4	24.0	67.2	7.7	4.9	5.0	1.0	1
May	32.4	25.6	29.0	73.8	8.5	5.4	7.7	-	-
Jun	35.8	29.7	32.2	80.3	9.6	6.7	95.9	-	-
Jul	39	29.1	34.0	84.8	10.3	6.5	37.3	-	-
Aug	36.5	30.2	33.3	95.3	11.5	6.7	80.9	-	-
Sep	37.4	28.4	33.2	91.3	9.2	5.4	32.4	-	-
Oct	33.7	27.3	30.7	63.3	7.9	5.4	29.7	3.0	2
Nov	24.0	20.0	22.0	79.0	4.5	2.0	56.5	2.9	2
Dec	22.5	15.5	18.5	85.0	4.0	3.0	78.4	5.0	5
Total	-	-	-	-	-	-	-	218.4	28

* Recorded and compiled by S.M. Al Alawi & M. Selfo.

Appendix 2

CHEMICAL COMPOSITION OF MACRONUTRIENT AND MICRONUTRIENT COMPOUNDS

Chemical Composition of Fertilizers of Primary and Secondary Macronutrients

Chemical Compound "Fertilizer Grade"	% supplied macronutrient				
	N	P	K	Ca	Mg
Ammonium Nitrate	35				
Ammonium Sulphate	21				
Urea	46				
Calcium Nitrate	11.8			17	
Potassium Nitrate	13.8		38.6		
Monocalcium Phosphates:					
a. Single superphosphate		8.3		18	
b. Treble superphosphate		21.0		14	
Ammonium Phosphates:					
a. Dihydrogen	12.1	27			
b. Monohydrogen	21.2	23.4			
Potassium Sulphate			44.8		
Potassium Dihydrogen Phosphate		22.8	28.7		
Calcium Sulphate (Gypsum)				23.2	
Magnesium Sulphate "episom salt"					9.9

Chemicals of Micronutrients

Chemical Compound	Chemical Formula	Molecular weight	Element Supplied	%
Ferrous Sulphate	$FeSO_4.7H_2O$	278	Fe	20.1
Manganous Sulphate	$MnSO_4.4H_2O$	223	Mn	24.6
Cupric Sulphate	$CuSO_4.5H_2O$	249	Cu	25.6
Zinc Sulphate	$ZnSO_4.7H_2O$	287	Zn	22.8
Boric Acid	H_3BO_3	61.8	B	17.5
Sodium Molybdate	$Na_4MoO4.2H_2O$	242	Mo	39.6

Appendix 3

RECOMMENDED ANNUAL CONSUMPTION FOR NUTRIENT CARRIERS FOR ONE HYDROPONIC UNIT PRODUCING TOMATO AND CUCUMBER THROUGH A YEAR

Chemical Compound 'Fertilizer Grade'	Quantity
Potassium Nitrate	250 kg
Calcium Nitrate	250 kg
Treble Superphosphate	200 kg
Magnesium Sulphate	150 kg
Iron Sequestrine	3.5 kg
Manganous Sulphate	1.2 kg
Boric Acid	1.0 kg
Copper Sulphate	150 g
Zinc Sulphate	150 g
Ammonium Molybdate	30 g
or Sodium Molybdate	40 g

Appendix 4

METHODS OF ANALYSES

The methods used for analyses were the standard methods of routine analyses, and are appropriate to the available facilities of the soil and water laboratory of the Directorate of Agriculture in Bahrain. Action was taken to organize and equip the laboratory so that most of the required analyses on soil, water, plant and fertilizers can be undertaken there. The methods used are briefly indicated below.

SOIL ANALYSIS

- Mechanical analysis	:	By Bouyoucos hydrometer method
- pH - Determination	:	By Orion 701 digital pH meter
- Electrolytic Conductivity	:	By PW9505 Philips Conductivity Meter
- Hydraulic Conductivity	:	By permeameter on a disturbed sample
- Carbonates and bicarbonates	:	By titration with acid
- Chlorides	:	By titration with silver nitrate
- Sulphates	:	By difference
- Calcium and Magnesium	:	By compleximetric titration with ethylene diamine tetra-acetate (Versenate)
- Sodium and Potassium	:	Flamephotometrically by Gallenkamp Flame Analyser FH - 500
- Calcium carbonate	:	By acid neutralization method
- Gypsum	:	By increase in soluble calcium plus magnesium content upon dilution
- Organic Matter	:	By Walkley Black chromic oxidation method

- Cation Exchange Capacity Method : By ammonium acetate method

- Available Phosphorus: Extracted by 0.5 M sodium bicarbonate, pH 8.5 at 1-20 soil - extractant ratio and measured by Unicam SP-600 series 2 spectrophotometer or WPAS-105 spectrophotometer

- Available Potassium : Extracted by 1.0 N Ammonium acetate pH 7.0 at soil: extractant ratio of 1:10 and measured by Gallen-Kamp Flame Analyser FH - 500

WATER ANALYSIS

- pH, electrolytic conductivity, calcium and magnesium, sodium & potassium, carbonate & bicarbonate, chlorides and sulphates were determined by the same aforementioned soil analysis methods.

- Baron: Soluble in irrigation & drainage waters was determined colourimetrically using curcumine and measured by WPS - 105 spectrophotometer.

- Dissolved solids, ppm: was calculated by the formula $T.D.S. = EC_w \times 0.64$

- Sodium Adsorption Ratio (SAR): was calculated by the formula

$$SAR = Na \Big/ \sqrt{\frac{Ca + Mg}{2}}$$

PLANT ANALYSIS

- Ashing : Plant leaves were dry ashed at 550^{o}C in Gallenkamp Hotspot Muffle Furnace

- Total Phosphorus : was determined colourimetrically by the chlorostannous reduced molybdophosphoric blue colour method.

- Total Potassium : Flamephotometrically by Gallenkamp Flame Analyser FH - 500.

- Total Calcium & Magnesium : By compleximetric titration with ethylene diamine tetra-acetate (Versenate)

- Total Iron : Colourimetrically as O-phananthroline red ferrous complex

- Total Manganese : Colour was developed by potassium metaperiodata and measured by WPAS-105 spectrophotometer.

Appendix 5

LIST OF DOCUMENTS PREPARED DURING THE ASSIGNMENT

1. Plan of work, 1979. 11 p.
2. A short note on investigating a new reclaimed area of agriculture. 1979.
3. A short note of sampling a soil for fertility tests (in Arabic). 1979. 2 p.
4. The study and improvement of soil fertility in Bahrain: Results of investigations (1979-1980). S.A. Amer and N.S. Al-Hamdan. 1980. 68 p.
5. Methods of soil and water analyses, a manuscript (in Arabic). 1980.
6. Plan of work for 1980-1981. 1980. 10 p.
7. Investigation on protected vegetable projects in neighbouring Gulf States. A duty trip report. S.A. Amer and A.N. Ahmed. 17 p.
8. Fertility program for production plastic tunnels at Budaya for 1981-1982 season. 1981. 3 p.
9. Nutrition program for the hydroponics. 1981. 3 p.
10. Guidelines in fertilization of protected vegetable cultivation at farm fields. 1981.
11. Plan of work for 1981-1982. 1981. 8 p.
12. The study and improvement of soil fertility in Bahrain: Results of investigations (1980-1981). S.A. Amer and A. El-Saad. 1981. 74 p.
13. Fertilization of vegetable crops in Bahrain, extension note (in Arabic). 1982. 5 p.
14. Recommendations in soil and fertilizer management for protected vegetable extension project in some farms in Bahrain (1982-1983). 1982. 4 p.
15. Research plan on trials in the open field of the vegetable research section for 1982-1983. S.A. Amer, M.A.W. Al-Khalifa and M. El-Aradi (in Arabic). 1982. 8 p.
16. Plan of work for 1982 - 1983 (in Arabic). 1982.

17. Short notes on town refuse compost and sewage sludge, presented to the administrative staff of the Directorate of Agriculture in Bahrain. 1982.

18. Advice on some soil survey studies for the agricultural experimental station at Budaya and Hamala project. Prepared by Soil and Water Laboratory staff. 1982.