PREFACE

The Rural Enterprise & Agricultural Development Project (READ) is a six years project funded by the Government of Guyana and the International Fund for Agricultural Development. It is being implemented by the Ministry of Agriculture and is managed by the Agriculture Sector Development Unit (ASDU).

One of the objectives of the READ Project is to improve the capacity of rural producers to efficiently and effectively produce and market non- traditional products and develop small scale enterprises. In order for this is to be achieved, it is necessary that rural producers be provided with the necessary technologies by service providers.

The objective of this training on Climate Smart Agricultural Practices was intended to build the capacity of service providers to improve their knowledge, attitudes and services to beneficiaries in the areas of demand-driven technology, technical skills and technologies that are specific to the productive enterprises and transfer of technical information to producers in a manner that was easily understood by the target group.

The training course on Climate Smart Agriculture was conducted for Extension & Research Staff of the National Agricultural Research and Extension Institute, specifically to build the capacity of service providers to provide better services to stakeholders, become acquainted with opportunities and relevant technologies with respect to adaptation to climate change (Climate Smart Agriculture), become familiar with the establishment and monitoring of climate smart practices and to conduct training programmes related to climate smart agriculture for farmers.

The information presented in this manual is intended for use by all service providers. It provides a summary of the lectures and practicals that were conducted. Special thanks are extended to Research Scientists, Mr. David Fredericks and Mrs. Somwattie Pooran-DeSouza for their assistance in conducting the training sessions and their inputs in this manual.

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May 2012.

1.0 CLIMATE CHANGE- GENERAL ASPECTS

1.1 Introduction

Climate Change is a change in the climate that persists for decades or longer, arising from either natural causes or human activity. It is now considered 'unequivocal' that global climate is changing, principally as a result of the burning of fossil fuels and agriculture related land use change which contributes to the greenhouse effect. According to the IPCC Fourth Assessment Report (IPCC WGII 2007), the temperature of the earth's surface is expected to increase between 2^{o}C and 5^{o}C over the next century, assuming greenhouse gas emissions continue to rise at current rates. There is gradual warming of the planet and having a number of knock-on effects in terms of changing rainfall patterns, rising sea levels, and more unpredictable weather events. Climate Change is expected to lead to more frequent, more extreme or more unpredictable occurrence of existing natural hazards (such as temporal distribution of rainfall, floods, droughts, hurricanes and cyclones). It can also result in the emergence of new hazards which did not occur previously in a particular locality, such as new pest or disease outbreak resulting from rising temperatures (Zhu, 2011).

1.2 Climate Change and Agriculture

The impacts of climate change on agriculture have been summarised by Zhu (2011). Agricultural activity is highly sensitive to climate change, largely because it depends on biodiversity and environmental conditions. Sufficient freshwater supplies, fertile soil, the right balance of predators and pollinators, air temperature and average weather conditions all contribute to maintaining agricultural productivity. As agriculture depends directly on environmental conditions, climate change impacts on agriculture are becoming immensely evident. Changes in rainfall cycles are impacting on agricultural yields as water availability is decreasing in already arid zones and water excesses (floods) are being experienced in other areas.

Small scale farmers are among the first to feel the impacts of climate change because of their great dependence on the natural environment. Extreme climate variability (droughts and floods) can destroy the economies and welfare of poor rural families because they lack technologies, social protection mechanisms (such as benefits, insurance and savings) and adequate protection for their crops and animals.

1.3 Climate Change and Water Availability

Growing evidence suggests that changes in the hydrological cycles can bring longer droughts and more intense rains making wet regions even wetter and arid areas drier. Changes in rainfall and the disappearance of glaciers will result in a considerable reduction in water quality for human consumption and farming. This in turn will affect agricultural production and food security. Water scarcity is projected to become one of the main causes of social conflict in the developing world (Zhu, 2011).

1.4 Conclusion

It is firmly established that the global climate is changing. This is as a result of the burning of fossil fuels and agricultural land use change (Greenhouse Gas Effect). It is predicted that the earth's temperature is expected to rise between 2^{o}C and 5^{o}C over the next century. Positive proof of global warming is shown pictorially below:

Climate Change will result in the warming of the planet. This will cause changing rainfall patterns, rising sea levels (low lying areas would be affected by salinity) and other unpredictable weather events (floods, droughts, hurricanes, etc).

Agriculture is the sector which is likely to be most seriously affected by climate change. Consequently, there is the need for adaptation measures (Climate Smart Practices) to be employed to ensure that some of the negative effects of climate change are annulled.

2.0 CLIMATE CHANGE AND THE GUYANESE SCENARIO

2.1 Introduction

In Guyana, agriculture is the dominant sector both in terms of foreign exchange earnings and job creation. Agriculture will continue to be important to national and regional development in the future as there is a growing demand for increased agricultural productivity, investment opportunities in agribusiness, etc. Consequently, agriculture has a key role to play in mitigating and adapting to climate change. Therefore, our farmers need to be aware of measures that could be adopted to combat the effects of climate change (Climate Smart Agricultural Practices).

2.2 Facts about Guyana

Based on the studies that have been conducted, the following are the facts to be noted for Guyana with respect to climate change:

1. Records indicated an increase by $1^{o}C$ of the mean annual temperature in Guyana between 1909 and 1998.
2. Sea level rise in Guyana is about 5 times that of the global average.
3. Records show the mean relative change in sea level as 10.2mm per year for the period 1951- 1979.
4. Records indicate abnormal patterns in Guyana: more intense rainfall periods and longer dry spells.

2.3 Future Climate Change Projection for Guyana

Based on the models developed, the following are the future climate change projections for Guyana.

1. Temperature rise: $1.2^{o}C$ – $4.2^{o}C$ rise by the end of the 21^{st} Century.
2. Sea level rise: 0.40m – 0.61m by the end of the 21^{st} Century.

3. Weather conditions: More intense rainfall periods and longer dry periods (Overall drier periods are expected).

2.4 Precipitation Change and Crop Development

Increased temperature will tend to increase crop water demand (evapotranspiration or ET). Many crops in the hinterland such as cassava, spices, etc., are not irrigated, so seasonal rainfall as a result of climate change will be very critical. With the increase in the frequency of high-precipitation events in Guyana, which can be worsened by climate change causing more field flooding, problems will be created for field operations, more soil compaction, and possible crop losses due to lack of oxygen for roots and disease problems associated with wet conditions.

2.5 Evidence of Crop Response to date

As the evidence of climate change has mounted, plant scientists and ecologists have begun examining historical records for signs of biological responses to the warming trend. It is very difficult to determine whether historical crop yield trends can be attributed to climate change because there are so many other factors, such as cultural practices and market forces that affect yields.

2.6 Weeds, Insect and Disease Pests

Crop plants in agroecosystems do not grow in isolation. Weeds, and beneficial and harmful insects, microbes, and other organisms in the environment will also be responding to changes in CO_2 and climate. In general, many of the most invasive and noxious weeds respond more positively to increasing CO_2 than do most of our cash crops.

It is mostly speculation at this time as to which crops and regions will benefit and which will be worse off in the future with regard to weed and pest control.

The optimists can hope that some current crop pests will migrate out of the region, while pessimists will worry with the knowledge that the threat of invasive species will likely increase and approval of chemical control measures may not keep pace with these invasions.

Warmer climate will likely increase the populations of insect species. Some leaf feeding insects appear to do more crop damage to plants under high CO_2 conditions (Hamilton *et al*, 2005). It remains difficult to predict future rainfall patterns, but wetter spells would tend to favour many foliar pathogens (Coakley *et al,* 1999).

2.7 Can Farmers Adapt to Climate Change?

Some farmer adaptation strategies are:

1. Change in planting, harvest dates;
2. Change in varieties grown;
3. Increased water, fertilizer, herbicide, pesticide use;
4. Change in crop species; and
5. New irrigation or drainage systems, other major investments.

2.8 Win- Win Farmer Adaptation Strategies

Some win- win farmer adaptation strategies for Guyana are:

1. Conserving energy and reducing greenhouse gas emissions (increase profit margin and minimize contribution to climate change);

2. Increasing soil organic matter (this not only improves soil health and productivity, but organic matter is mostly carbon derived from CO_2 in the atmosphere [via plant photosynthesis], so it reduces the amount of this greenhouse gas in the atmosphere);

3. Improving nitrogen (N) use efficiency (synthetic N fertilizers are energy-intensive to produce, transport and apply; and soil emissions of nitrous oxide [a greenhouse gas] increases as more N fertilizer is applied to the soil); and

4. Entering the expanding market for renewable energy (eg. wind energy, biomass fuels) using marginal land.

3.0 CLIMATE CHANGE ADAPTATION- CLIMATE SMART AGRICULTURAL PRACTICES

3.1 Introduction

Climate change adaptation is an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or explore beneficial opportunities.

Climate Smart Agriculture is the utilisation of sustainable farming practices which increases resilence and reduces vulnerability to climate change related threats while reducing the negative impacts and greenhouse gas emissions. In simple terms, climate smart agricultural practices refer to practices/technologies, systems, etc., that could be utilised by farmers to adapt to the effects of climate change. In Guyana there are a number of policies which are currently being pursued to mitigate the effects of climate change. Additionally, farmers need to be aware of the climate smart practice that could be employed as adaptative strategies.

3.2 Government Policies

The GOG has implemented the LCDS as a measure to combat the effects of global climate change. Further, the Ministry of Agriculture (MOA) has intensified the Grow More Food Campaign, a market-oriented programme, to enhance food production, not only for local consumption but also for export markets. The implementation of the ADP and READ together with enhanced D&I infrastructure and improved extension services are but some of the measures being undertaken.

Additionally, seed storage facility (for long term seed storage) is being constructed. The esablishmtent of genebanks is also an ongoing activity. Further, the rural diversification programme and the use of alternative energy (hydropower and biofuels) are being implemented.

3.3 Climate Smart Agricultural Practices for Guyana

There are a number of climate smart agricultural practices that are being promoted globally. This has been dealt with extensively by Zhu (2011).

In Guyana, there are a number of general climate smart practices being promoted for use by our farmers as well as specific ines targeting fruit and vegetable cultivation. These are summarised below.

(A) General Climate Smart Agricultural Practices:

i. Familiarity with weather forecasts;
ii. Making use of opportunity days;
iii. Production of quality seedlings;
iv. Identification of areas not subjected to flooding; and
v. Creation of embankments.

(B) Specific Climate Smart Agricultural Practices:

i. Sustainable water use and management (Sprinkler and Drip Irrigation);
ii. Shaded Cultivation;
iii. Hydrophonics;
iv. Integrated Nutrient Management;
v. Crop diversification and new varieties;
vi. Ecological pest management;
vii. Mixed farming (Intercropping);
viii. Seed and Grain Storage;
ix. Mulching; and
x. Use of inocula with beans

4.0 GENERAL CLIMATE SMART AGRICULTURAL PRACTICES FOR GUYANA

The general climate smart agricultural practices outlined below should be practiced by all fruit and vegetable farmers in Guyana. This will ensure year round production of these commodities, thereby ensuring food security and maintaining exports.

4.1 Familiarity with weather forecasts

In the planning of their farming activities, farmers must adhere to the weather forecasts (both short and long-term) provided by the MOA. This will enable them to re-adjust their planting schedules. Farmers are well aware of the time from planting to harvest for various crops.

4.2 Make use of opportunity days (for land preparation, planting and harvesting).

From the forecasts, farmers need to make use of the opportunity days. This simply refers to those days when the weather conditions are optional for land preparation, planting or harvesting. It means that these operations should be extended to beyond the time farmers would normally spend with regards to these operations.

It is important that the recommended varieties of crops are cultivated and the appropriate plant spacings utilized. There are crop varieties that are more resilient to the effects of climate change and these should be used.

Additionally, processing of food crops, especially cassava could be done using mechanical graters (Figuer 4.1) prior to the onset of heavy rains or suspected drought situations. This will ensure that the processed products (farine, flours, bread, cassava, etc.) would be available for consumption.

Figure 4.1: Cassava Grater

4.3 Production of Quality Seedlings (preferably protected seedling cultivation)

Seedling to be transplanted must be healthy and free of pests and diseases. This will ensure that adequate production is obtained. It is recommended that seedlings be produced in seedling trays and preferably in a seedling house (Figure 4.2).

Seedlings in Seedling Tray

Seedling House

Figure 4.2: Seedling Cultivation

4.4 Identify areas for production that are not subject to flooding

If the weather forecasts predict unusual weather patterns, especially unseasonal rainfall, farmers must choose areas that are not subjected to or less prone to flooding for establishing crops. Alternatively, some form of empoldering may be necessary. Access to pumps is also needed.

4.5 Creation of Embankments

It is recommended that some form of embankment (‘meres’ or mounds) be constructed around cultivated fields. This would prevent excess water from flooding the fields. It would also be necessary to have pumps on standby to get rid of excess water should the needs arise.

5.0 SPECIFIC CLIMATE SMART AGRICULTURAL PRACTICES FOR GUYANA

Agriculture, the backbone of the Guyanese economy is the sector which is likely to be most affected by climate change and must therefore undergo a significant transformation in order to meet the related challenges of food security and climate change. Consequently, our farmers need to be aware of measures that could be adopted to combat the effects of climate change. Apart from the general guidelines provided in Chapter 4, it is important that specific climate smart practices be utilised to meet these goals.

5.1 SUSTAINABLE WATER USE AND MANAGEMENT

It has been predicted (IPCC WG 11, 2012) that during the next decade, billions of people, particularly those in developing countries will face changes in rainfall patterns that will contribute to severe shortages or flooding resulting in negative impacts on agricultural production. Enhancing water availability through adaptive technologies for sustainable water use and management is therefore a key strategy for increasing agricultural productivity and for ensuring food security. Two such adaptive technologies applicable to Guyana are the use of Sprinkler and Drip Irrigation.

5.1.1 SPRINKLER IRRIGATION

Sprinkler Irrigation is a pressurised irrigation system which applies water to the soil surface using mechanical/ hydraulic devices that stimulate natural rainfall (water distributed from overhead). The various types of sprinklers are shown in Figure 5.1.

Figure 5.1 SPRINKLER IRRIGATION SYSTEM

5.1.1.1 HOW DOES SPRINKLER IRRIGATION CONTRIBUTE TO CLIMATE CHANGE ADAPTATION?

- Support farmers by making more efficient use of their water supply;
- Uses less water than irrigating by gravity;
- Provides even application of water to cultivated plot;

5.1.1.2 ADVANTAGES OF SPRINKLER IRRIGATION

The following are the advantages of sprinkler irrigation systems:

- Makes more efficient use of water for irrigation in agriculture;
- Reduces water conveyance channels (reduces water loss);

- Distributes water evenly across crops (avoiding wastage);
- Shows increases in crop yields;
- Suited for most crops (row, field, tree);
- Suitable for all types of soils except heavy clay;
- Soluble fertilizers can be used in the system;
- Reduces soil erosion; and
- Improves crop productivity (more income generation employment opportunities and food security).

The main disadvantages of the system are:

- The initial cost to install and the effect that the winds can cause
- Winds can affect effectiveness (altering distribution pattern of water droplets).

5.1.2 DRIP IRRIGATION

Drip Irrigation is based on the constant application of a specific calculated quantity of water to soil and crops if use of pipes, valves and small dippers (emitters). A typical layout of drip irrigation system used in Guyana is shown in Figure 5.2.

Figure 5.2: Drip Irrigation Emitters

5.1.2.1 HOW DOES DRIP IRRIGATION CONTRIBUTE TO CLIMATE CHANGE ADAPTATION?

- Provides efficient use of water;
- Provides water directly to the plants when required;
- Can utilise fertigation (allows nutrients to be utilised efficiently);
- Uses less water than sprinkler; and
- Not affected by wind or rain

5.1.2.2 **Advantages**

The main advantages of drip irrigation system are:

- Helps use water efficiently;
- Reduces water run-off through deep water percolation or evaporation to almost zero;
- If water consumption is reduced, production costs are lowered;
- Less favourable conditions are provided for the onset of diseases, including fungus;
- Agricultural chemicals can be applied more efficiently & precisely with drip irrigation;
- N is less subject to losses by leaching;
- Nutrient, applications better timed to meet plants needs; and
- Efficient in sandy areas with permanent crops & vegetables.

5.1.2.3 Disadvantages

The main disadvantages of drip irrigation systems are

- Initial cost to set up is high;
- Unexpected rainfall can affect drip system (moving pipes and clogging emitters); and
- Can be damaged by tractors, etc.

5.2 Shaded Cultivation

Cultivation under shade (using mesh or plastic) is a technique that is currently being adopted as a climate smart agriculture practice by farmers, who have recognised the numerous benefits from this system. There are different combination that could be used (Figure 5.3). It is also necessary for raised beds to be employed.

Figure 5.3: Different Types of Shaded Cultivation System

Two systems that are recommended for use in Guyana are protected seedling production and cultivation under shade with a strong organic component (organoponics).

5.2.1 Protected Seedling Production

Traditional seedling production techniques can present limitations in output, because the major production of seedling is done during the wet season. Owning to heavy rains, which occur with high frequency and intensity in Guyana seedling production is subject to excessive moisture, physical damage as well as inefficient pest and disease control. Another factor have to be taken into account is high solar radiation.

Protected seedling houses are economically designed structures using plastic film as roofing material to reduce the high levels of sunlight and rainfall that affect seedling production.

In protected seedling production, it is important to note that at transplanting time you have a secure plant and this system is used to plant the majority of agriculture.

5.2.1.1 Construction Details:

- The entire roof should be covered with plastic film and shade mesh should be placed 1 m above the plastic film;
- The sides should be covered with insect proof netting;
- The unit should be closed with one entrance containing a disinfectant point and a double door;
- Two tables should be located inside. Dimensions 8 m in length and 1.05 m in width; and
- These examples are the same as found in NAREI.

5.2.1.2 Compost Substrate

In selecting suitable compost, candidate substrate must have the following characteristics:

- Be physically uniformed;
- Free from weed seeds, Nematodes and Pathogens;
- Have pH between 6.0 and 7.0;
- Have E.C. (Electrical Conductivity) should be below 0.8 dsm^{-1};
- Free flowing to fill the cells uniformly;
- Provide a uniform rooting medium;
- Excellent moisture holding characteristics, while providing sufficient aeration to the actively growing and respiring root system;
- Micro and Macronutrients required during the propagation period; and
- Low cost

5.2.1.3 Organic Material that can be used

Locally available organic material available, such as:

- Earth worm humus
- Composted pen manure
- Filter press mud
- Peat
- Rice husk

5.2.1.4 Technology is applied in four stages

1. Preparation of substrate
2. Tray filling and seeding
3. Germination
4. Growing of seedling

Figure 5.4: Preparation of substrate

5.2.1.5 Mixture of Substrate

(Substrate 1- without soil)
60% of Earth worm humus.
30% of Composted pen manure
10% of Rice husk

(Substrate 2- with soil)
- 30-40% of Soil.
- 30% of Composted pen Manure.
- 30-20% of Earth worm humus.
- 10% of Rice husk.

- Other substrates such as Zeolitas y Micorrizas(PROMIX) can also be used.

- Substrate used can be varied depending on real conditions, but these substrates can be enriched using TSP, for each Kg of substrate 10g of TSP should be applied.
- It is important that once disinfected the substrates should not touch the soil and should be used after disinfection or stored in a clean place with a concrete floor.

Figure 5.5: Mixture of Substrate

5.2.1.6 Tray Filling and Seedling

Tray filling

- Trays should be properly disinfected with formalin at 2% or Bleach and rinsed. It should have one tank with formalin or bleach solution and another tank with water for rinsing;
- Once disinfected store in a dry and clean place where it doesn't touch the soil;
- Tray is then filled;
- Remove surplus substrate by hand;
- The center of each cell is marked at the same depth it is ideal to use a marker to obtain uniformity when planting: 2mm for small seeds and 5mm for medium seeds (cucurbitace family);
- The trays used vary in the number of cells; those used here are 1228 cells; and
- The trays will be planted on tables avoiding contact with the soil.

Seeding

- The seeds used should be treated to avoid contamination;
- One seed per cell and two seeds in the short extremes of the tray;
- Cover seed with fine grade of substrate;
- Water the seed trays and if required apply fungicide;
- Water should be applied with a spray can to avoid seed movement (once planted seeds should not be moved from their position;
- The amount of water should be applied until a slight dripping in seen from the holes in the bottom of the trays;
- One irrigation should be sufficient until germination;
- This first irrigation should be applied with rain water to favor rapid germination; and
- Stack trays, move trays carefully to a dark room where humidity is permitted for necessary germination of the seeds.

5.2.1.7 Germination.

Germination time vary for different seeds, there is no scheme in which it is done but periodic checks should be done (Figure 5.6).

Examples in conditions of Guyana:

Crops	Days of Germination
1) Pack- Choy, Broccoli	1
2) Cauliflower, Cabbage	
3) Tomatoes and Lettuce	3

4) Sweet and Hot Peppers 7-9
5) Celery 11

Figure 5.6: Germination for Different Seeds

5.2.1.8 Economics of production of Protected Seedling house 9m x 4m

Capital cost	Quantity	Cost
Construction of seedling house	1	$471,238
Seedling Trays	120	$ 84,000
Water can	1	$1,500
Spray can	1	$15,000
Spade	1	$3000
5 gallon buckets	2	$1000
		Total= $ 575,000

Operational Cost for one Year

Expenditure for one year	Quantity	Cost $
Substrate	2080kg	104,000
Water		10,000
Foliar fertilizer	3 liters	4500
Insecticide	1liter	2000
Fungicide	250 g	1500
Bleach	16liters	3200
Seeds	4 kg seed	30,000
Labour	1	300,000
		Total cost =455,200

Production Parameters for seedling House 9m x4 m

# of trays per batch	**# of plants per tray**	**Duration of batch**	**# of seedling per batch**	**Mortality rate per batch**	**Total # of seedling per batch**	**# of batches per year**	**Total # seedling per year**
104	128	4 weeks	13312	10 %	11980	11	131,780

- ☐ If the average price per seedling is $7.00 then gross yearly income =$922,460
- ☐ *Net Yearly Income = gross Yearly Income – Expenditure =$922,460- $455,200 = $467,260*
- ☐ *Expressing Net yearly income as a percentage of your capital investment ($467,260 X 100 = 81 %*
  575,000

- ***In one year you would have recovered 81% of your Capital Investment***

5.2.2 Shaded Cultivation Incorporating Organoponics

5.2.2.1 INTRODUCTION

There are a number problems associated with the cultivation of vegetables in Guyana. Owing to heavy rainy periods and high solar radiation, vegetable crops are subjected to excessive humidity and physical damage, as well as the frequent occurrence of plant pest and diseases.

Intensive vegetable production under semi protected conditions referred to as organoponics, offers a solution to these problems. This system (Figure 5.7) utilizes raised beds containing a suitable mixed growing medium with high levels of organic matter and protected at the side with wooden material.

5.2.2.2 SELECTION OF THE SITE

- Should be built as close as possible to final market site, thus reducing deterioration during transportation.
- Should be built in areas with good superficial drainage and avoid areas prone to flooding.
- Should ensure sufficient water for irrigation.

5.2.2.3 CONSTRUCTION DETAILS

- The entire roof should be covered with shade mesh.
- The unit should be closed with one entrance containing a disinfectant point.
- The beds should not be more than 30m in length, width 1.2m and height 0.3m. Concrete blocks or wood may be used as lateral protection. The space between beds should be 0.6m.
- Beds should be filled with 70% soil and 30% organic material. Sandy soils are preferable.
- The dimensions of the Organoponic are: Southern height-3m / Northern height-2.5m/ Width-8.6m / Length-32m. ((Check the drawing in annex)

(a) Outside view of the Organoponic **(b) Inside view of the Organoponic**

Figure 5.7: Outside & Inside View of the Organoponic System

The substrate achieved should have the following characteristics:

- High water holding capacity;
- Good drainage;
- Sufficient available nutrients;
- Low salinity (below 1.2ds/cm-^{1});
- Free of weed seeds;
- Free of disease and nematodes;
- Low cost; and
- Well mixed

Organic Material to be used:

Locally available organic materials such as:

- Earth worm humus or vermicompost;
- Composted pen manure;
- Composted sugar cane bagasse; and
- Other composted material.

5.2.2.4 Planting

Before planting, thoroughly mix the soil and the organic material (properly decomposed), level beds, followed by deep irrigation and later planting.

For planting distance and type of planting, expected yield, approximate biological cycle of crops planted. (Check table in annex).

To obtain best results:

- The entire area, including walk ways and 1m around the unit, should be maintained free of weeds;
- No less than 95% of plant population should be established;
- To maintain good soil fertility, apply 10kg of properly decomposed organic material per square meter throughout the year, preferably in 3 applications;
- In direct planting; seeds should be covered preferably with earth worm humus and plants thinned out when they are 4 to 5 cm high; and
- Crops, such as: tomato, cucumber, cabbage and sweet pepper (principal crop), should be intercropped with short cycle crops such as: lettuce and pakchoy (secondary crop), this will maximize use of planting area.

5.2.2.5 Intercropping must have the following

- Intercrop plants of different botanical families and that are not susceptible to the same diseases (Figure 5.8);
- The harvest cycle of the secondary crop must be shorter than the principal crop;
- Husbandry of secondary crop has to be subordinate to the practices of the principal crop; and
- The primary and secondary crop should have similar irrigation needs.

Intercrop tomato with lettuce   Intercrop sweet pepper with pakchoy

Figure 5.8: Intercropping

5.3 IRRIGATION

In general, water should be applied daily, preferably in the morning; the quantity of water applied would be dependent on the stage of the crop and weather conditions.

5.3.1 Techniques of Integrated Pest Management that can be used.

- **Coloured traps:** This method functions well when associated with other control procedures and is based on utilizing the attractive influence of colour on some insects e.g. white fly, grasshoppers and leaf miners are attracted by the yellow colour. Thrips are attracted to colours such as blue and white. Plastic or wooden strips of colour can be used; strips should be covered with a thin layer of grease. Insects are attracted by the colours and are trapped by the strips and die. Yellow coloured traps should be dominant; traps should be placed in beds at the top of the crop (Figure 5.9).

Figure 5.9: Yellow colour traps

- Insect repellant plants: These plants are planted at the head of the beds, but never on the beds ; the following species can be used (Figure 5.10).

    1. *Ocimum bassilicum Lin*. Purple Basil
    2. *Ocimum sanctus Lin.* White Basil (Married man pork)
    3. *Coleus amboinicus Lour.* Thick leaf thyme.

- Crop rotation should always be practiced.

White Basil; *Ocimun sanctus Lin* Thick leaf thyme; *Coleus amboinicus Lour.*

Figure 5.10: Insect Repellant Plants

5.3.2 Advantages of the System.

- The Organoponic can be built in areas that are not conducive to the cultivation of crops either because the required soil type is not available or because the present soil is lacking in some way or the other which will affect proper growth of the crop.
- The Organoponic can be built close to the final distribution point which would help to reduce spoilage and enable the supply of fresh produce to consumers.
- It is resistant to minimal flooding.

Figure 5.11: Minimal Flood Control

5.4 Hydroponics

5.4.1 Introduction.

Hydroponics is the growing of crops without soil (Figure 5.12). Inert materials such as white sand could be used as the substitute for the growing of a wide variety of crops. Specialized structures could be constructed for large scale hydroponic cultivation. In Guyana, this system could be practiced by home growers.

The use of vegetable materials such as plastic containers makes this technique very environmentally friendly. Further, no production occurs on the 'ground', the effects from flooding would be minimal.

Hydroponics

Cultivation under shade

Figure 5.12: Hydroponics & Shaded Cultivation

5.4.2 Advantages of Hydroponics

- The possibility of obtaining more produce in less time than using traditional agriculture;
- Growing plants more densely;
- Cultivating the same species repeatedly because there is no soil depletion;
- More produce/surface unit is obtained;
- Production can be timed more effectively to satisfy market demands;
- Soil bourne pests and diseases can be eliminated;
- The need for weed control is eliminated;
- Reduced turnaround time between planting as no soil preparation is required; and
- Pests and diseases are easier to get rid of because container mobility.
- Cleaner and fresher produce can be reaped.

5.4.3 Disadvantages of Hydroponics

- Commercial scale requires technical knowledge as well as a good grasp of the principles;
- On a commercial scale the initial investment in relatively high; and
- A constant supply of water is required.

5.4.4 Production System

- **OPEN SYSTEM:** the nutrient solution is mixed and applied to plants, instead of being recycled some examples are: growing beds, vertical and horizontal pvc pipes, individual containers e.g. Pots, plastic sacks and old tires (Figure 5.13).

Figure 5.13: Open System - Grow Beds

- **CLOSED SYSTEM:** The nutrient solution is circulated continuously, providing the nutrients that the plants required e.g. Floating roots, Nutrient Film Technique (NFT), PVC channel (Figure 5.14).

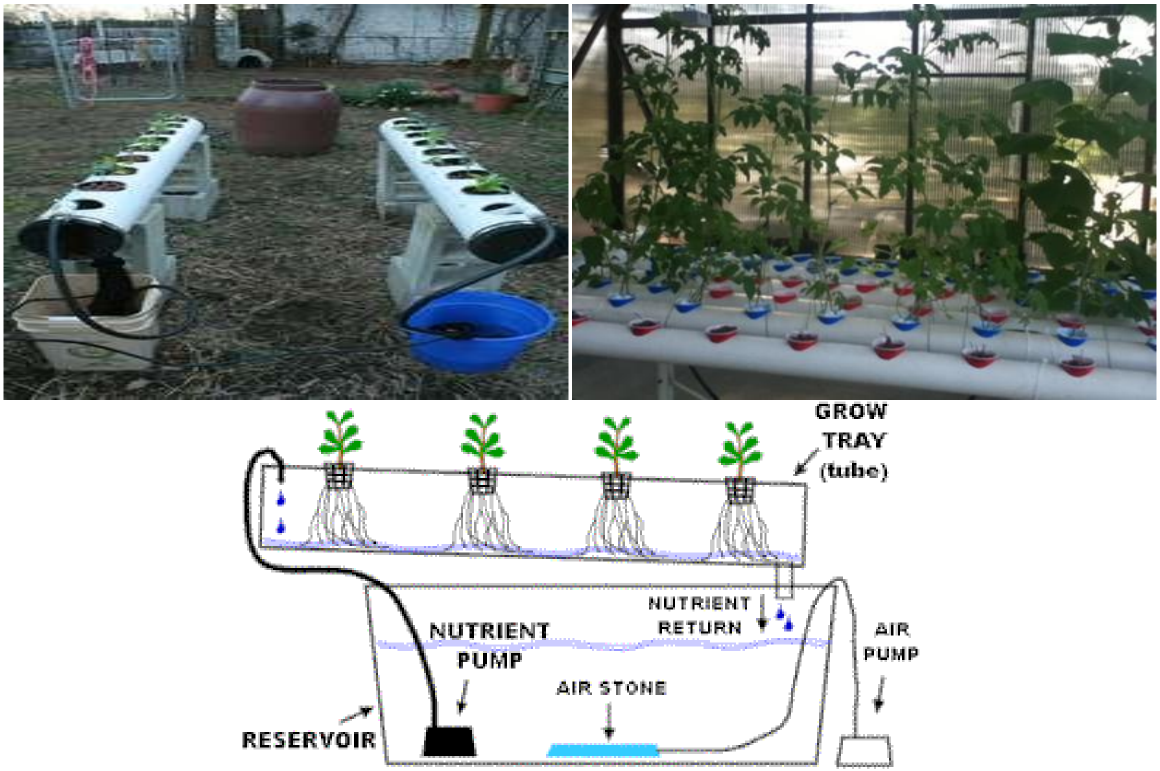


Figure 5.14: Closed System - NFT System

5.4.5. Location of Hydroponics

- Avoid heavily shaded and windy areas
- Keep area projected from domestic pets and animals
- The area must receive a minimum of six hrs of sunlight
- Must be close to source of water source and where nutrients are kept.
- It must be kept from contaminated water
- It must be kept far from trees and other plants that are affected by pest and diseases.

5.4.6 Appropriate Containers for Hydroponics

CHARACTERISTICS OF APPROPRIATE CONTAINERS:

- Dark and opaque since algae develop better in clear containers
- Water proof to prevent loss of nutrient rich water
- Made from chemically inert materials
- Must haves holes to drain excess water and allow for aeration.

Some examples are shown in Figure. 5.15.

Figure 5.15: Appropriate Containers for Hydroponics

5.4.7 The Substrate

CHARACTERISTICS OF A GOOD SUBSTRATE:

- Material should be inert
- Must be made of particles no longer than 7mm or smaller than 2mm
- Must be capable of maintaining moisture and drain excess water
- Must not decompose easily
- Must not hold microorganism hazardous to humans or plants
- It must be readily available
-

The recommended substrate mixtures are:

- 50 % RICE HULL: 50% GROUND VOLCANIC STONES
- 60% RICE HULL : 40% WHITE SAND

- 60 % RICE HULL: 40 % GROUND CLAY BRICKS
- 80% RICE HULL : 20 % SAW DUST
- CLEAN WATER

5.4.8 Pest Control

- Various pest control strategies may be employed in this system such as:
- The use of botanicals e.g. garlic, neem, pepper etc
- The use of coloured traps, insect screens etc
- Limited use of synthetic pesticides

5.4.9 Recommendations

Hydroponics is suitable as an urban farming activity where space may be a limitation or for household use. The recommended crops for use in hydroponics include lettuce, celery, eschallot, pakchoi and tomatoes.

For commercial farming, the use of shaded cultivation is recommended. A small component for hydroponics could be done in shaded conditions on a needs basis.

5.5 INTEGRATED NUTRIENT MANAGEMENT (INM)

It is well known that the soil provides plants with anchorage, water and nutrients. When the nutrient supply is inadequate, this is replenished with the addition of fertilizers. These fertilizers could either be mineral or organic in nature. It is imperative that the use of mineral fertilizers (most widely used) be promoted through Integrated Nutrient Management (INM). INM aims at optimal use of nutrient sources on a cropping- system or crop- rotation basis. This encourages farmers to focus on a long- term planning and making greater considerations for environmental impacts.

5.5.1 CONTRIBUTION OF INM TO CLIMATE CHANGE ADAPTATION

Excessive rainfall, etc. resulting in soil erosion causes the depletion of nutrients in the soil. By increasing soil fertility and improving plant health, INM can have positive effects on crops in the following ways:

- Crops which are supplied with adequate amounts of N, P and K show greater resistance to pests and diseases.
- Balanced nutrition enhances root development. This enables roots to penetrate deeper layers to access water.
- Under increasingly saline conditions, plants can be supplemented with K to maintain natural growth.

5.5.2 ADVANTAGES OF INM

The advantages of INM are:

- Enables the adaptation of plant nutrition and soil fertility management to site characteristics by combining the use of organic and inorganic nutrient resources.
- Empowers farmers by increasing their technical expertise and decision- making capacity.
- Promotes land use changes and encourages crop rotations, etc.

5.5.3 DISADVANTAGE OF INM

The main disadvantage of INM is that the INM approach is sensitive to climatic conditions and could produce negative effects if crop and soil nutrients are not monitored and changes to fertilizer practices made accordingly.

5.5.4 **Crop Diversification and New Varieties**

The introduction of new cultivated species and improved varieties of crop is a technology aimed at enhancing plant productivity, quality, health and nutritional value and building crop resilience to diseases, pest organisms and environmental stresses.

Crop diversification refers to the addition of new crops or cropping systems to agricultural production on a particular farm taking into account the different returns from value- added crops with complementary marketing opportunities.

5.5.5 RATIONALE FOR CROP DIVERSIFICATION

Major driving forces for crop diversification include:

- Increasing income on small farm holdings;
- Withstanding price fluctuation;
- Mitigating effects of increasing climate variability;
- Balancing food demand;
- Improving fodder for livestock animals;
- Conservation of natural resources;
- Minimising environmental pollution;
- Reducing dependence on off-farm inputs;
- Depending on crop rotation, decreasing insect pests, diseases and weed problems; and
- Increasing community food security.

5.5.6 INTRODUCTION OF CROP SPECIES

Farmers are responsible for the introduction of new and improved varieties in response to environmental stress conditions. Agricultural researchers are also expected to identify new varieties that may be better adapted to changing climatic conditions.

Farmers cross select seeds from plant varieties that demonstrate the qualities they seek to propagate to develop new varieties with the characteristics they desire.

5.5.7 CONSIDERATIONS IN INTRODUCING NEW CROP SPECIES

1. Availability and quality of resources including irrigation, rainfall and soil fertility.
2. Access to technologies such as seed, fertiliser, water, marketing, storage and processing.
3. Household related factors covering food and fodder self- sufficiency requirement as well as investment capacity.
4. Price and market related factors including output and input prices as well as trade policies and other economic policies that affect these prices either directly or indirectly.
5. Institutional and infrastructure related factors covering farm size and tenancy arrangements, research, extension and marketing systems and government regulatory policies.

5.5.8 CONTRIBUTION TO CLIMATE CHANGE

These include:

1. Breeding new and improved crop varieties which enhance the resistance of plants to a variety of stresses that could result from climatic change:
    - Ensuring that agricultural production can continue and even improve despite uncertainties about future impacts.
2. Varieties with improved nutritional content can provide benefits for animals and humans.
    - Reducing vulnerability to illness and improve overall health.

5.5.9 ADVANTAGES

1. Introduction of adapted and accepted varieties strengthen farmers' cropping systems:
    - Increasing yields, improving drought resilience, boosting resistance to pests and diseases and also by capturing new market opportunities.

2. The products of the research process become more relevant to the needs of smallholder farmers:
    - Research contributes to the knowledge of new crops that are introduced into the cropping system.
    - Identify crops and varieties that are suited to a multitude of environments and farmer preferences.
    - Increase the validity, accuracy and the efficiency of the research process and its outputs.
3. Provides better conditions for food security.
4. Enables farmers to grow surplus products for sale.
5. Enables farmers to gain access to national and international markets with new products, food and medicinal plants.
6. Diversify from the monoculture of traditional staples which can have important nutritional benefits for farmers.
7. Support a country to becoming more self- reliant in terms of food production.
8. It manages price risk, on the assumption that not all products will suffer low market prices at the same time.
9. Management techniques for diversified crops consist of more sustainable natural resource practices.

5.5.10 DISADVANTAGES

1. Farmer experimentation using only native varieties limit the benefits and responses that are amongst the materials being tested.
2. Introduction of exotic species may become pests.
3. Achieving high yields in terms of tons per hectare in a mixed farming system.
4. Access to national and international markets may be limited-
   Government policy including subsidies, the price and supply of inputs, infrastructure for storage and transportation.
5. Poor economic returns if the crops are not selected based on a market assessment. For example, drought tolerant crop varieties may fetch a low market price if there is not sufficient demand.

5.6 ECOLOGICAL PEST MANAGEMENT

Ecological Pest Management (EPM) is an approach that increases the strength of natural systems to reinforce the natural processes of pest regulation and improve agricultural production. Also known as Integrated Pest Management (IPM), this practice uses several methods in a compatible manner to maintain pest populations below economically damaging levels and at the same time, it protects against hazards to human, animals, plants and the environment.

5.6.1 COMPONENTS OF EPM

The key components of EPM are Crop Management, Soil Management and Pest Management.

5.6.1.1 CROP MANAGEMENT

This includes the selection of appropriate crops for local and climatic conditions.

1. Select pest resistant, local, native varieties and well adapted cultivars.
2. Crop rotation.
3. Legumes to improve soil fertility and favourable conditions for healthy plants that can withstand pests and diseases.
4. Cover Crops
5. Green manure to reduce weed infestation and pest and disease attack.
6. Intercropping and agro-forestry systems.
7. Crop spacing and pruning to create unfavourable conditions for pests.

5.6.1.2 SOIL MANAGEMENT

This includes maintaining soil nutrition and pH levels to provide the best chemical, physical and biological soil habitat for crops.

1. Healthy soil structure;
2. Longer crop rotations;
3. Enhances soil microbial populations and break disease, insect and weed cycles;
4. Use of organic manures, earthworm castings, colloidal minerals and soil inoculants;
5. Microbes help to improve water absorption and air exchange; and
6. Alleviating soil compaction to reactivate soil nutrients.

5.6.1.3 PEST MANAGEMENT

This is the usage of beneficial organisms that behave as parasitoids and predators:

1. Releasing beneficial insects and providing suitable habitat;
2. Managing plant density and structure to deter diseases;
3. Weed control; and
4. Managing field boundaries and in-field habitats to attract beneficial insects, and trap or confuse insect pests.

5.6.2 CONTRIBUTION OF EPM TO CLIMATE CHANGE ADAPTATION

1. EPM is regarded as ‘clean’ technologies;
2. Provides a healthy and balanced ecosystem;

3. Combines the life cycle of crops, insects and fungi, with natural external inputs (i.e. bio-pesticides);
4. Allows good harvesting in difficult conditions of pests and diseases;
5. Promotes a diversified farming system; and
6. EPM builds farmers' resilience to potential risks such as damage to crop yields.

5.6.3 ADVANTAGES OF EPM

1. Reduce cost:
    - Pesticides
    - Fuel
    - Equipment
    - Labour

2. Increase production levels

3. Reduce pesticide usage, e.g. specific controllers for a determined pest.

5.6.4 DISADVANTAGES OF EPM

1. 'Biological Controller' (BC) which is an insect that destroys it, is not identified
2. Not a 'quick fix';
3. BC takes years to establish a population;
4. No single BC works in every situation;
5. A BC may work in one soil type but not in another soil type;
6. One type of BC may be needed to achieve uniform control across a variety of different situations and land types; and
7. EPM is not easy to implement and requires substantial knowledge and monitoring for the combined components of the system to be successful.

5.7 MIXED FARMING

Mixed farming is an agricultural system in which a farmer conducts different agricultural practices together, such as cash crops and livestock. The aim is to increase income through different services and to complement land and labour demands across the year.

5.7.1 CONTRIBUTION OF MIXED FARMING TO CLIMATE CHANGE ADAPTATION

Mixed farming contributes to Climate Change Adaptation in the following ways:

- The diversification of crops and livestock allows farmers to have a greater number of options to face the uncertain weather conditions.
- Gives a more stable production.

5.7.2 ADVANTAGES

The advantages of mixed farming are as follows:

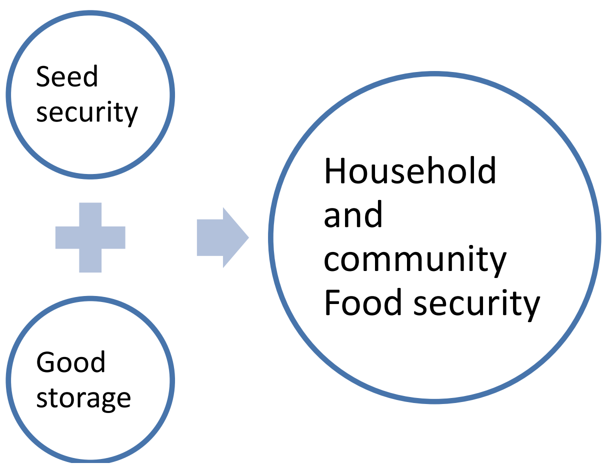
- Allows greater food security and household nutrition levels
- Maintains soil fertility by recycling nutrients

5.7.3 DISADVANTAGE

The main disadvantage of mixed farming is that production levels could be lower than specialised systems (monoculture).

5.8 SEED AND GRAIN STORAGE

The importance of seed and grain storage is summarised below.



The basic objective of good storage is to create environmental conditions that protect the product and maintain its quality, thus reducing product loss and financial loss.

5.8.1 CONTRIBUTION TO CLIMATE CHANGE ADAPTATION

Grain storage:

- Helps to prepare for droughts, hunger and malnutrition;
- Ensures feed is available for livestock; and
- Seed stock is available in the event of poor harvests due to drought

Efficient harvesting can reduce post- harvest losses and preserve food quantity, quality and the nutritional value of the product.

Innovations for addressing climate change include technologies for:

- Reducing waste of agricultural produce; and
- Establishment of safe storage for seeds and reserves of food and agricultural inputs are used as indicators of adaptive capacity in the agriculture sector.

5.8.2 ADVANTAGES

- Establishment of safe, long- term storage facilities;
- Ensure that grain supplies are available during times of drought;
- Store food after harvest so as not to be compelled to sell at low prices; and
- Use appropriate storing techniques to prolong the life of foodstuffs and protect the quality, thereby preserving stocks year- round.

5.8.3 DISADVANTAGES

- Failure to adequately clean and dry grain can lead to excess moisture, foreign matter and pest infestations;
- Over- drying of grains can negatively impact seed quality;
- Losses of seeds from insects, rodents, birds and moisture uptake can be high in traditional bulk storage systems; and
- Controlling or preventing pest infestation may require chemical sprays. Some markets will not accept seeds and grains treated with these chemicals.

5.9 MULCHING

Mulching is a practice which involves the application of materials such as dried grass and leaves, which are placed on the surface of the soil. This practice aids in the conservation of soil moisture and the suppression of weed growth. This is a very useful practice on sandy soils during dry periods.

5.9.1 Maintain Soil Cover (Mulch)

The maintenance of soil cover is essential to minimize evaporation losses during dry periods. This is especially so for orchards where a grass cover should be always be present. However, this should be kept at a low level.

Mulching, which is the application of materials such as dried grass or any other suitable material around plant roots is necessary during dry periods (Figure 5.16). This helps to "cool down" the root area as well as prevent losses of moisture. It also reduces the number of times the plants need to be watered.

Additionally, synthetic plastic mulches could be used. An appropriate irrigation system would need to be used with synthetic mulches. These systems considerably reduce weed growth and thus there is no need for the use of herbicides.

Figure 5.16: Synthetic Plastic Mulches

5.10 Use inocula with beans

The trend these days is to reduce as far as possible the quantities of nitrogenous fertilizers being used. There is no need to use nitrogenous fertilizers with legumes (bora, red peas, etc.) once inoculums is applied to the seeds prior to planting.

There is also a 'carryover' effect on crops to be planted the following season, which causes a reduction in the amounts of nitrogenous fertilizers to be applied. This has been demonstrated at Moco Moco where red pea was rotated with rice.

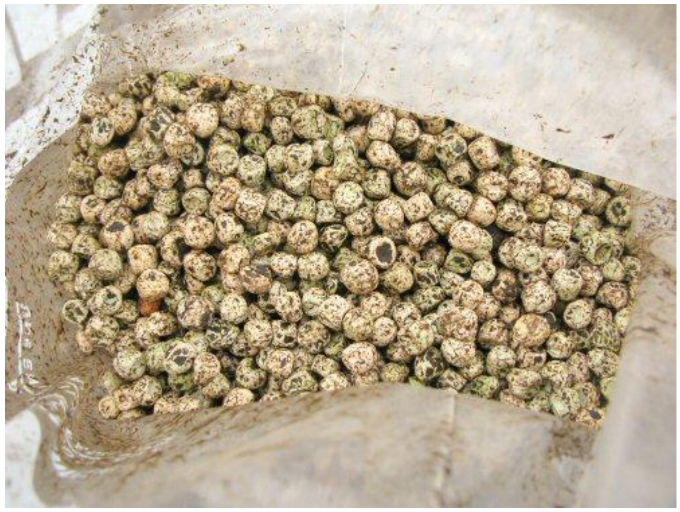


Figure 5.17: Rhizobia on Seeds