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IDEAS FOR POTENTIAL APPLICATION OF PLASTICS IN AGRICULTURE IN THE SUDANO-SAHELIAN COUNTRIES 1/

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INTRODUCTION

The drought which has affected the Sudano-Sahelian area is unique from other droughts which have occurred before, in that on this occasion it is more widespread. The countries affected include Upper Volta, Mali, Mauritania, Niger, Senegal, Chad, Sudan and Ethiopia. These areas, in latitude 11° to 12° North, habitually have dry season periods exceeding six months of the year. Since the rain season is short, the possibilities of development of the vegetation and of pastures is restricted. Whilst the local population has been used to dealing with and surviving in these conditions, it was in 1972 that the shortage became critical and the situation reached devastating proportions, with cropping limited and livestock depleted, famine conditions arose.

Moreover, the extent of the drought produced shortage even in the African tropical zone which has a mean annual rainfall of 500-1200 mm. Additionally, similar climatic conditions have occurred in both the North East of Brazil and in India.

I. FUTURE WEATHER PATTERN

In such a situation it is important to know if this climatic pattern is part of a weather cycle or the beginning of a permanent weather change. In an attempt to find an answer to these questions, Roche (1) of the Office of Scientific Research and Techniques for Overseas (ORSTOM) in France has carried out an objective examination of the current Sahelian drought situation in relation to the climatic and hydrological aspects. Whilst there were other periods of severe drought recorded during 1910-1915 and during 1940-1948, the conclusion was that the existence of a drought cycle (of 30 years or other period) still remained to be demonstrated and this would require a still longer period of observation, at least 60 years more. It was also stated that there was a continuous climatic variation at every point of the globe but the rate of this change was too slow for it to be objectively demonstrated by reference to the limited time series at present available.

II. OJAGADOUGOU PROGRAMME

In September 1973, a meeting of Ministers of State, representing Upper Volta, Mali, Mauritania, Niger, Senegal, Chad and Gambia, was held in Ouagadougou and agreed a plan of action known as the "Ouagadougou programme". This programme sets out the policies which are to be initiated and the short, medium and long term objectives that are considered necessary in an attempt to prevent an occurrence of the famine problems; and to set the future development of the countries concerned on an economic path of progress.

Among the subjects covered by this plan in which plastics applications may be used are:

- hydraulics - for both human and vegetation needs;
- storage and transport.

III. BACKGROUND INFORMATION

Mesnil (2) in a survey of the current situation noted that the present crisis was the result of two interacting and independent factors:

1) A phase of low rainfall, as has occurred in other periods in the last 100 years, but is now more widespread and marked.

2) Human factors, resulting from old causes and cumulative in effect. Degradation of the soil and pastures and loss of fertility with no regeneration. A slowness of diffusion of technical progress coupled with a slow build up of the infrastructure.

He suggested that the following steps were necessary if the famine problem was to be successfully overcome:

(a) irrigation was the only method to ensure future crops. There was a potential of river water for the irrigation of one million hectares. Dams which had been proposed will take 10 to 20 years to build. In the meantime, pumping would provide an intermediate solution as in India and Brazil;

(b) the dry agricultural techniques required to be modernized; Mechanisation of certain of the cultural techniques needed to be implemented;

(c) the formation of a group of Sahelian local experts. The existing group of experts needed to be augmented to study new techniques like irrigation. They should also design new techniques of agriculture in the light of the experience gained during development. To assist this work, it was proposed that an Institute of Sahelian Agriculture should be created. It would perform a training and development function;

(d) the provision of potable water supplies for the people should be of first priority. The general health of the population was the basis on which all future development would rest. There would be a need to mobilize both their energies and creative capacity so that collectively the villages would be able to take progressive charge of their own future.

These points supplement and reinforce part of the total Ouagadougou programme, and provide a useful background against which plastics applications in agriculture will need to be developed.

IV. POTENTIAL APPLICATIONS FOR PLASTICS IN AGRICULTURE

Taking "hydraulics" for first consideration there are a number of obvious areas of potential applications for plastics in agriculture. "Water conservation" covers the broad general description of these applications of which the following are of specific interest in arid and semi-arid desert conditions:

1) Rainfall harvesting and evaporation control
2) Reservoirs
3) Irrigation canal linings
4) Pipes and tubes
5) Trickle irrigation
6) Growing under controlled environment conditions
7) Growing under environment protected conditions
8) Mulching

Storage and transport are of second consideration, and "crop conservation" covers the broad general description of the potential plastics applications.

9) Storage and containers.

V. IMPLEMENTATION OF PLASTICS IN AGRICULTURE APPLICATIONS IN THE SUDANO-SAHELIAN ZONE

While the foregoing are only some of the potential applications of plastics in agriculture they do represent areas of more immediate concern for use in desert agricultural conditions. Past experience indicates that, when applying any plastics in agriculture system in a new location, it is often necessary to make some adaptations to ensure that the system functions successfully in the new environment. In basic terms, the various systems of the agricultural applications of plastics have been developed within a specific situation so as to provide an economic and viable solution to a particular agricultural problem. Established applications in other countries should, therefore, be taken only as a guideline of what can be achieved with plastics to resolve a particular problem in a given set of circumstances. Bahaa el Dine and Persson (3) cover this point particularly well in their summary of a paper on "The Use of Plastics in the Vegetable Production in the U.A.R. with Special Emphasis on Growing Peppers in the Winter Time". They state that in the adaptation of plastics in agriculture applications there is reason to stress that a great number of problems should be carefully studied: problems related to the plastics material itself, the temperature situation in remote areas, the biological reaction of various crops, the economical aspects and so on. To acquire this basic understanding is a pre-requisite of its (application of plastics in agriculture) introduction.

Development Programme

From the foregoing, it will be understood therefore, that the introduction of any of the various applications of plastics which have been suggested for use in the Sudano-Sahelian zone will involve the introduction of a development programme so that the applications may be successfully adapted to the particular and specific needs of the country or zone concerned.

As far as a time scale is concerned, past experience suggests that something of the following order may be needed. One year is required for the initiation of the application utilizing experts in both plastics and agriculture, and extension-work personnel who use this period for their training. During this first year the work is open to farmers/growers and other interested parties to visit and inspect. Informal discussions are usually arranged, illustrated by films or slides, to indicate what is being attempted in any particular scheme.

In the second or third year as the case may be, certain more forward thinking farmers/growers are invited to try the application on their farms under the guidance of both trained extension personnel and experts. During this period, further visits of both local and more distant farmers/growers are encouraged to attend the farms where the applications are in progress, and to freely discuss their reactions to the development. Local knowledge and experience have proved to be of immense value in advancing development of this type.

However, due to the fact that much of the agriculture in the Sudano-Sahelian zone is at subsistence or survival level, it must be expected that the resistance to change of farming methods will be that much greater since no farmer or grower is going to put at risk his only means of survival for himself and family without a very great act of faith. In order to encourage farmers and growers to advance and modernize their growing techniques, it would seem necessary therefore, to introduce some scheme of incentives which would at least guarantee their food supplies against any possible risk of failure.

In the third year more growers over a wider area are encouraged to adopt the application, following its successful use in the previous year, with continued guidance from the extension service. Progressively, in this way, the applications of plastics in agriculture have been developed in many countries.

Demonstration and experimental stations

In order to achieve this type of development programme, it would seem that the establishment of two or three "demonstration and experimental" stations is a prime requisite. They should ideally be dispersed over the countries concerned so that they cover the various climatic and agricultural problems of the zone. If there are in existence some suitable research or extension service stations in the appropriate locations, then these might well be able to offer the necessary facilities such as office accommodation, lecture rooms, workshop and agricultural land, etc.

Co-operation with other organizations

For the development of plastics in agricultural applications to be of real benefit to the Sudano-Sahelian zone it is quite clearly necessary that there should be close co-ordination between UNIDO and FAO. This co-ordination and co-operation will ensure that the developments will supplement the priority objectives of the agricultural programme, and thus maximise the benefits of valuable resources.

Co-operation with local agricultural institutions and universities should be encouraged since this will ensure a wider circle of effective communication and understanding. Co-operation and discussions with local plastics manufacturers (fabricators) or potential entrepreneurs should also be encouraged, since in the vanguard of these application developments will arise a local demand for the correct type and quality of plastics products.

Plastic industry development

The development of a local plastics industry can arise from the agricultural applications, as well as from the domestic needs of the population. The production of blown PE film by the extrusion process will be high on the list of processes to be installed as well as extrusion of rigid PVC pipes in order to provide the plastics products necessary for the applications which have been itemised. It is for these reasons that entrepreneurs should be encouraged to visit and see the development of plastics in agriculture at the experimental and demonstration stations. The development of a local processing and fabrication plastics industry should be encouraged and regarded as part of the total development operation thus making additional contribution to the industrialisation process, apart from any foreign-exchange savings that may also be gained.

VI. IMPLEMENTATION BY UNIDO

The first stage towards the implementation of the suggested development programme must be a fact-finding mission to the countries concerned. It will be necessary to:

1) Discuss with local officials and FAO representatives to determine what are the specific priorities and problems in each country, and to assess what group of countries have common features in this area;

2) Determine what facilities exist that may be suitable for a demonstration and experimental station and if the parties concerned are willing to accommodate such a unit. If there are no facilities then where could such a unit be established and how would this fit in with any other proposed FAO development plans? It would also be important to discuss the necessary funding for establishing such a unit;

3) Determine in which countries the three proposed demonstration and experimental stations should be established. This will mean assessing the relative degree of co-operation that exists between different countries and the advantages and merits of any existing extension service operations. One of the plastics applications is valid only in countries with a coastline since availability of sea water is a necessary requirement for the development. This will additionally involve examining the requirements of these particular countries with relation to this particular type of development - a power-water-food system, discussed in detail later in this review;

4) Determine the extent, nature and capacity of any existing plastics processing/fabrication factories in each of the countries so as to assess what range of plastics products could be produced for the proposed application. To assess the technological level of such factory managements so as to determine if technical assistance may be required to achieve the correct quality of product for the agricultural applications. If there are no such factories then to examine the potential possibilities of either Government or local entrepreneurs being able to set up such factory production facilities.

Once such a mission had reported, it would then be possible to set out a specific project for the development of the demonstration and experimental stations; and if required, projects for technical assistance to the plastics industry.

UNIDO-Romanian Mobile Team

A completely mobile plastics production and demonstration operation is to be fielded by the UNIDO-Romania Centre. This will consist of an extruder and an injection moulding machine, together with suitable personnel who will operate the machines and demonstrate how plastics can be produced and applied in agriculture. The whole assembly of plant and personnel will be totally mobile and will be visiting both Upper Volta and Mali for this purpose. This operation, it is hoped, will arouse local interest in both plastics production and in the application of plastics in agriculture. This demonstration visit will be for a three month period.

It is hoped that a report from a team member will be available for presentation at this 6th International Colloquium on Plastics in Agriculture in association with the UNIDO Symposium on Plastics in Latin America. This should provide some useful first-hand information.

Other suggestions

If, as expected, it is ascertained that there is little or no plastics processing operations being undertaken in the various countries then it may be possible to implement a different approach to producing plastics.

For example, it has been suggested that for the production of rigid PVC pipes it might be better to have a mobile extruder. This could be moved to different centres where the pipe is required rather than to transport the pipe over large areas from a fixed factory. Although the transport of the raw materials would be a lower volume factor, would the costs of this type of operation be viable? The alternative proposition would be to install the extruder and auxiliary equipment in a normal manner in a fixed site factory and to transport the pipe to where it may be required.

In a similar manner, it may be possible to set up a mobile unit for the production of blown PE film, though it is doubtful if this could be used for wide-width film. For wide-width film it may be more economic to set up a fixed-site, multi-purpose production unit of three extruders, which independently can produce normal width lay-flat, but which can separately be brought together to feed one large die for the production of wide-width 6 meter lay-flat film (12 meters opened out to single film). The alternative is to use a large capacity extruder for this production and which, in the circumstances, might be idle for a considerable period of time since there will be no immediate large-scale demand for the capacity which such a unit could produce.

These are some ideas for the plastics production processing operations which could be installed in the area.

Call for comments and criticisms

UNIDO welcomes the views and criticisms of all conference delegates and participants to the ideas which are put forward in this paper. From those with experience in the production of plastics, their views on the practical nature of the possible production process suggestions, or otherwise, are most welcome.

From those who are experienced in plastics in agriculture applications, UNIDO welcomes their views on the application ideas which are proposed and the possible methods of implementation, as well as their alternative ideas.

Within this conference, there will be concentrated a great degree of expertise, knowledge and brain-power on the subject of plastics in agriculture and to an international organisation such as UNIDO, it is vitally important to obtain both individual and corporate opinions on the suggestions covered in this paper.

The International Committee for Plastics in Agriculture (C.I.P.A.) has already published a call for international assistance for the Sudano-Sahelian countries and UNIDO welcomes this co-operation.

The successful use of plastics in agriculture as one step in the programme to overcome the famine problems of the Sudano-Sahelian zone, undoubtedly lies in the effective direction and work of the proposed demonstration and experimental stations. To this end UNIDO will need a team of experts, in plastics in agriculture, to set up and establish these stations. These experts, in bringing to bear their individual experiences in developing the applications of plastics in agriculture, can ensure not only the rapid development of the applications required for the area, but will also ensure the success of the demonstration and experimental stations.

For this purpose, UNIDO would welcome an international effort by experts who are prepared to form part of such a team either on a full-time basis for periods up to three years, or for shorter-term appointments.

Other forms of help and assistance either by individuals or by institutions or companies for the Sudano-Sahelian countries will also be much appreciated and welcomed both by UNIDO and the countries concerned.

VII. DETAILS OF THE PROPOSED PLASTICS IN AGRICULTURE APPLICATIONS

To assist in a fuller understanding of the potential advantages which can be brought to agriculture by the use of plastics a review has been made of the potential application systems. Special attention has been paid to published work which refers to arid, semi-arid and desert conditions as these have specific relevance to the Sudano-Sahelian zone.

A. WATER CONSERVATION

Rainfall harvesting and evaporation control

The harvesting of rainfall has been practiced over many years in arid areas, and ancient desert agriculture in the Negev desert area of Israel was based on the exploitation of surface water run-off from treated catchments in areas having an average annual rainfall of 100 mm.

The reason for the limited use of water harvesting is due to the fact that the structures are too costly. However, various American workers have carried out developments in this area which begin to look attractive. In some early work (4) carried out in the USA in 1960 there was a successful development of constructing a rain-trap utilising butyl rubber lining. This provided an effective means of developing a water supply and appeared to be economic in areas where ample water supplies were not available. It consisted of making a waterproof catchment area for collecting rainfall, and a closed reservoir for storing the water collected, both of which involved the use of butyl rubber sheeting.

Myers (5) carried out most of his water harvesting research in desert regions of the USA with 175-200 mm average annual rainfall. In those areas it appeared that there is little, if any, rain run-off from the soils except during high intensity storms, and little of this run-off ever reached the water storage structure. The technique which was successfully developed involved stabilising the soil surface with asphaltic materials and then covering this surface with a black PE* film, 0.05 mm thick. Further experiments with other types of plastics film were envisaged. It was reported that costs can be materially reduced by this new technique.

One problem noted was that while plastics bags for storing this water offer possibilities against seepage and evaporation losses - unfortunately water storage bags of non-reinforced plastic are subject to damage by a variety of environmental factors including thirsty animals.

* PE = Polyethylene; polythene.

More recently Brent Cluff (6) carried the idea of plastics covering for rain harvesting a stage further. He utilized a gravel overlay to cover the top of a plastics film covering which had been laid on the soil. This was to protect the film from wind and climatic radiation damage. The installation costs were held to a minimum by the use of a mechanical plastic-laying, gravel spreader, which was developed for covering areas larger than one hectare Where gravel had to be carried long distances it was proposed to use a gravel-extracting, soil-sifter which would extract naturally-occurring gravel from the soil profile, lay the plastic film and cover this with the extracted gravel, all in one operation. The biggest cost factor in this water harvesting process was storage of the collected precipitation (rain water). Whilst seepage losses could be controlled by utilizing covered plastics liners, evaporation losses were more difficult to control. Of three systems evaluated, the author favoured a rock (gravel) filled tank (reservoir) suitable for volumes of less than 225,000 litre net capacity. Although the gravel reduced the effective storage capacity by 50 per cent comparative water losses by evaporation, over a six month period, were only 0.25 meters in the tank compared with 1.25 meters from an open water area.

Floating polystyrene foam rafts, and suspended butyl or polypropylene covers were the two other systems tested to control evaporation losses. Brown and Ford (7) in more recent work have examined the feasibility of a floating plastics mesh (net) in conjunction with cetyl alcohol as a means of controlling evaporation. Whilst the experiments were successful, full scale trials remain to be determined.

The estimated life of the Brent-Cluff catchment was stated to be at least 20 years and the cost of installation quoted at $ 0.25 per square meter. Since the efficiency was claimed to be 70 per cent, a cost of water produced in a 300 mm rainfall area would be between US $ 0.135 and US $ 0.066 per 1,000 litres, and these costs would drop in areas of higher rainfall. At today's raw material prices these figures should be increased 50%.

Reservoirs

The use of plastics in various areas of water conservation and usage including pond (reservoir) liners, ditch linings, mulching, drainage tubes, levees and borders was summarised by Edminster and Staff (8). Although this paper dates back to 1960 it contains some useful general background information.

Today, the use of PE film (the word "sheeting" in this context is synonymous) as a waterproof membrane for lining large agricultural reservoirs has become a standard practice. Reservoirs of 100 million litres (22 million gallons) capacity have been constructed by this technique in the South-East area of Spain and in other places.

The basic technique consists of excavating the ground to a predetermined depth, with walls not steeper than 3.5 to 1. This "hole-in-the-ground" is then lined with large sheets of black PE film 0.25 mm thick, 8 meters wide and normally 30 meters long. Jointing between sheets is achieved by means of a specially formulated mastic, and a PE self-adhesive tape acts as a second line of security. The outer peripheral edges of the film are securely anchored by burial in a trench around the reservoir. The whole PE membrane is then covered to a minimum depth of 100 mm and not less than 200 mm for the sides. The nature of the back-fill used for this covering operation is unimportant and the excavated material can normally be used. However, if the material is coarse or contains sharp stones, then a layer of sand or soil should first be spread to act as a cushion. The reservoir is then ready for filling with water.

Both drawings and photographs illustrating the various stages involved in the installation are included in a technical bulletin on water storage (9).

A PE film lined reservoir is known to have been constructed in Sudan (10) a few years ago by a UK company using new techniques to protect against termite attack. It would seem feasible therefore, that such reservoirs could also be constructed in the Sahelian area when there is a specific requirement. The main advantage of the technique lies in its low cost compared to more traditional methods of reservoir construction.

Canal linings

The use of PE film as a waterproof membrane for the lining of canals, so as to make irrigation systems practicable at low cost, has been undertaken in many parts of the world, including Iraq, Pakistan, South America, Australia, Canada and Romania. The purpose of the lining is to prevent seepage and control weed growth. In Canada (9) more than 160 km of canals have been lined with PE film.

In the Rio Negro province of Argentina (11) a large irrigation canal, more than 30 meters wide, has been successfully lined with plastic film to eliminate water losses. The cost was more economic compared to traditional methods of lining.

Pipes and tubes

When a water source has been established it becomes necessary to be able to transport the water to the place of use. Buried pipelines are a conventional method of water transport. Mains-water supply pipes can be of steel, cast-iron, cement types or plastics. The advantage of plastics pipes lies in the fact that they are resistant to corrosion and can therefore be safely used in all types of soil conditions. Joints can be easily made either by solvent-sealing, or patented press-fit joints.

Plastics pipes can be produced in either rigid PVC* or PE. PE pipes, being more flexible than the PVC, can be wound up into reel form. In general PE pipes are produced in diameters of 12 mm to 50 mm, whilst the rigid PVC pipes are produced in diameters of 50 mm to 200 mm. Since both types of plastics pipes are significantly lighter than steel, longer lengths can be easily carried and less joints are therefore required. Pipe fittings, such as T-joints, etc., can be produced by injection moulding and a standard range of fittings is available.

For the Sudano-Sahelian zone perhaps a further advantage lies in the fact that plastics pipe could be produced in the region. Both types of plastics pipe are produced by the extrusion process, though separate units would be necessary for each type. Capital cost indications for a complete PVC pipe plant process, of 1,000 to 2,000 tons per annum capacity, would be of the order of US $ 500,000.

Since irrigation water in the Sahelian area is now being pumped from surface or underground sources, it would be a natural development to move to piped supplies. This would in any case be necessary if trickle irrigation schemes are to be developed.

Trickle irrigation

The principle of trickle irrigation is to deliver to the plant roots only sufficient water for the plant's need, thus achieving a more efficient management of limited water resources. The advantages of trickle irrigation have been detailed by Buclon (12), Chapin and Chapin (13) and Kirkpatrick (14).

They include:

1) Water economy (30-50%) compared to furrow irrigation, thus larger areas can be watered for a given water resource;
2) Improved quality and size of produce;
3) Increased yields of 20-40% compared with furrow irrigation and of 10-20% over spray irrigation;

* PVC = polyvinyl chloride.

4) The possibility of using water with a higher mineral content (saline) since the salt leaches to the periphery of the wetted root zone, permitting root formation within the zone but away from the salt concentration itself;

5) Space between the beds is dry and this assists spraying and harvesting operations whilst undesirable weed growth is greatly reduced.

Various trickle irrigation systems have been designed which are of two basic types. The first type is based on plastics pipes, mostly in LD PE,* to which are fitted adjustable drip nozzles or other devices which ensure a drip outlet. The second type is based on a lay-flat tubing or sheath in which the flow rate of the water is controlled by using water friction to reduce the pressure. This tubing is normally of sufficient flexibility that it can be rolled up and is thus much more suitable for laying by mechanical means. An example of this latter type is a twin-walled, drip-irrigation sheath developed by Chapin and Chapin (13). The inner PE tube contains one orifice outlet for every four outlets in the outer PE tube. This not only ensures a relatively slow discharge of water, but also that the flow pattern along an 80 meter length of tubing is relatively uniform. A more recent development was reported by Buclon (12) of a trickle irrigation system, known as Viaflo, in which a flat sheath was produced from fibrous porous PE such that the water wets the whole surface.

The systems all involve the distribution of water at low pressure of 1-2 kg/cm^2 (14-28 lbs/sq.in.) which is further reduced at the plants to a few hundred of $grms/cm^2$ so that the water emerges drop by drop (trickle), or as a last resort in a very fine stream. Sophistication of the process involves the introduction of metered nutrient solutions into the irrigation system for more economical utilisation of resources.

Initial usage of trickle irrigation was in high-intensity cropping in greenhouses where the system could be automated, and thus lead to a reduction of labour. However, from 1960 onwards various trials have been conducted on open crops, and the system modified to produce satisfactory results under these conditions. The work received an impetus from countries, like Israel and Australia, where there are water resource limitations which hastened this development. From 1970 serious exploitation of this system of irrigation was to be seen not only in Israel and Australia but also in Argentina, Germany, India, Italy, Mexico and the USA.

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* LD PE = Low density polyethylene

Buclon (12) reported that at least 15,000 hectares were now irrigated in the USA by this technique. An indicative cost of the pipe system fitted with drip nozzles was 500-700 US$ per hectare and this particular type of system was used for more widely-spaced crops such as orchards.

Flat sheathed systems were principally used for close-grown crops such as vegetables in open fields, and food crops and flower crops in greenhouses, and here the costs were 600-1,200 US$ per hectare of which 50% or more was made up by the mains and secondary pipes which are used for distribution of the water to the sheaths.

That trickle irrigation or now more commonly called "drip-irrigation" in the USA, has aroused international interest which can be judged by the fact that a Second International Congress on this subject is being held in San Diego, USA on 7-14 July 1974 when some 83 papers are to be presented by representatives from 8 countries.

Hall (15) carried out some controlled comparison trials in 1970/71 of drip and furrow irrigation of tomatoes in California. It was concluded that drip irrigation used less water, and the tomato yields were between 34-45 per cent higher than with furrow irrigation.

In 1971 Oebker and Kuykendall (16) evaluated various methods of trickle irrigation in the Arizona desert for growing pecans and lettuce. The water saved by the use of trickle irrigation was significant. Lettuce was produced with only 25% of the water normally required; and three years old pecans grew with only 20% of the water used in furrow-irrigated plantings. Salt accumulation was less in trickle irrigated plots, and further studies were to be undertaken to find an optimum situation for crop growth.

<u>Growing under controlled environment conditions - for coastal desert areas</u>

Experiments at the University of Sonoro (17) at Puerto Penaso, Mexico, and in co-operation with the University of Arizona, have been concerned with the development of integrated systems that can provide power, water and food on desert sea coasts. With this approach, waste heat from the engine-driven, electric-generator sets is used to de-salt sea water. The fresh water, in turn, is piped to vegetables within controlled environment greenhouses of air-inflated plastics. After successful trials at Puerto Penaso a large scale unit has now been erected in Abu Dhabi.

This very interesting system for growing crops in a controlled environment started as a result of a development for the desalting of sea water. Kassander, Hodges, Thompson and Johnson (18) developed an experimental desalting plant utilizing solar energy and a simple inflated plastics structure of low cost. Independently they had also been working on a closed greenhouse system for special application in areas with water deficiencies. Coupling the two systems together offered some considerable economy.

Hodges, Groh and Johnson (19) reported on the further development of the system to one of packaged power-water-food system. It involved the production of power, water and food for coastal desert areas.

The heart of the system is the power generator, in this case a diesel-electric set. The heat from the engine is fed to a sea water stream, which is the hot salt water source to a distillation type de-salting plant. Some 10% of the water is evaporated and recondensed as pure water. The remaining 90% of the sea water which has been cooled by the process can be fed to the closed environmental chambers for cooling or heating, depending on the time of the year.

The system permits plants to be grown in a totally enclosed space by means of an inflated plastics structure; and by controlling the humidity level within this greenhouse, the plants utilize only 5-10% of their normal water requirement. Since the carbon-dioxide in the closed circuit is quickly utilized by the photosynthesis process of the plants, this is renewed from the carbon dioxide gases emitted by the diesel engine after suitable filtering and cleaning. PE film 12 meters wide, 35 meters long and 0.25 mm thick was used for the inflated structure. As a result of these trials future units will utilize 10 meter wide film of 0.35 mm thickness.

Jensen and Teman (20) carried out cultivation trials in the controlled environment of this power-water-food unit with eighteen different types of vegetables. The vegetables were grown in beach sand that had been leached with desalted water. Certain vegetables matured more quickly, and yields of most crops were much higher when compared to outdoor production. Some disease problems occurred but were held in control with fungicides. It was also noted that some varieties produced abnormal growth, while other varieties of the same kind of vegetable were normal in their growth characteristics.

In the complex which has been erected at Abu Dhabi, Jensen and Eisa (21) have reported on the results of two years work in these units. Daytime temperatures of 34°C and high humidity restricted the amount of cooling that was possible in the summer period, but by shading the greenhouses in the summer, the incoming radiation was effectively decreased.

Warm night temperature has limited the fruit load on the plants, and varieties are being sought for production at high temperature and high humidity. Nevertheless, a wide range of vegetables has been successfully grown; and the two hectares of environmentally controlled greenhouses are now producing one ton of vegetables per day.

Growing under environment protected conditions

As distinct from the totally controlled environment of the Abu Dhabi operation, there are also possibilities of growing under environmental protected conditions. Spice (22) has reported on trials that have been undertaken in Kuwait utilizing both low and walk-in type of plastic covered tunnels. These latter types might be referred to as "greenhouses".

The climatic conditions of the area were severe, with extremes of summer temperatures as high as 50°C and winter ground temperature as low as -8°C. Severe sand storms could also occur and last for several days with devastating effects on the growth of plants. It was to protect against this type of environment that plastics tunnels and greenhouses have been erected, as part of a UNDP-FAO vegetable growing project to reduce the dependancy of Kuwait on imported produce. Also being examined were irrigation techniques and other cultural practices which may improve yield quality and period of availability.

A series of eight conventional, 5 meter wide, 36 meter long tunnel greenhouses were erected and covered with 0,125 mm thick, ultra-violet screened, PE film. Two have been covered with a milk-white translucent PE film to effect some degree of shading.

Two of the tunnels were air-conditioned, using a 120 cm diameter fan at the end of the tunnels, and pulling air in through horizontal, wet-pad units. Cooling is effected by the temperature loss achieved through the evaporation of the water from the wet-pad units. The water for this cooling operation can be either sea water or brackish water.

Low tunnels, covered with PE film, have been constructed using a variety of supporting hoops made from reinforcing-rod and conduit tubing. Experiments to utilize the mid-rib of date palms were being organized. Extension of the growing season is reported, as well as considerable protection against frost, by the use of these tunnels.

Mulching

"Mulching" is the term used to describe a covering on the soil, around a plant, primarily to prevent moisture loss. Traditionally, this mulch could consist of straw or even grass cuttings; however, with plasticulture, it is the use of a plastics film to cover the soil. This primarily prevents water loss by evaporation but also carries with it other benefits. If, for example, the film used is black in colour then weed growth is surpressed. Additionally, fruit from the plants is kept clean and the incidence of plant desease is lower. Mulching can be carried out with either transparent, grey or black films of PE. The choice of film has been the subject of much experimentation depending on the climatic factors involved. Buclon (23) in reporting on the results of 10 years research and applications of plastics mulching in France and in the world stated that when a PE film, 0.03 mm thick, was laid on the soil it modified important production factors such as temperature, humidity, soil structure, presence or lack of weeds, degree of nitrogen, of carbon dioxide and the root system. After reviewing the work carried out on each of these items he concluded that plastics mulching acted on a considerable number of factors:

(a) ground temperature which it increased more or less according to its colour (transparent or black);

(b) soil humidity was regularised, the black film being perhaps slightly more efficient than transparent film;

(c) maintained the ground physical structure, gaseous exchanges were thus facilitated, as well as lateral penetration of rain or irrigation water;

(d) maintained the nitrate fertilisers soluble in the ground at a level which enabled them to be used immediately;

(e) maintained a non-negligeable quantity of nitrate after the crop (harvest);

(f) increased the superficial root system without any water vapour at the level of the stomates;

(g) increased the superficial root system without any modification of the deeper root system.

He noted that these factors were often linked to each other and that there was a synergetic action between all these factors which finally would not only increase earliness but increased yields as well.

Buclon (23) also reported that melons, asparagus, strawberries, tomatoes, cucumbers, lettuce, aubergines, pimento, summer squash, beans, potatoes, maize, tobacco, cotton, pineapple, vine, floral cultivations and arboriculture (coffee, tea) have all been subject to growing under mulch conditions, and he set out the basis for selecting the most suitable type (degree of transparency) of film for mulching.

For tropical arid conditions there is little doubt that it is the moisture retention and prevention of evaporation factors which are most important. Spice (22) reported that there was little difference in the results obtained in Kuwait, between clear or black PE film mulch where squash gave five times greater yields than the adjacent unmulched plants.

B. STORAGE AND CONTAINERS

Crop conservation

Having successfully grown a crop the next stage after harvesting is to ensure its safe storage until it is required for consumption. Hall (24) in his survey of storage and transportation of food commodities pointed out that some 26% of dried fish distributed in developing countries is lost as a result of spoilage during storage. With cereals, oilseeds, vegetables and their products, losses in the tropics can be as high as 30%, a large part of this loss being due to the ravages of mites, insects and rodents. This emphasized therefore, the need to pay special attention to the adoption of suitable storage systems for agricultural produce in tropical conditions.

Storage systems

In all the various types of storage systems in use in the tropics the problems of controlling insect pests are of highest priority, and the method of control ought to be geared to the type of farmer and the design and condition of the container. For this purpose, plastics film has a useful part to play.

Sun drying

The use of plastics sheets could have a wider future for controlled sun drying of crops such as ground-nuts or rice. The UK Tropical Stored Products Centre (24) designed such a plastics type sun-drier which could be used also as a moisture-loss recorder, and a fumigation and storage container.

Pusa bin

In India a "Pusa" bin has/been successfully constructed (24). This is a square shaped mud silo incorporating a plastics film as a sandwich liner within the floor and walls which provides a simple form of air-tight storage for the farmer.

Circular weld-mesh plastic lined silos

Hall (24) reported that the use of circular weld-mesh type silos with plastics liners for crop storage was observed in a few countries in the tropics. Development work, in Europe, on grain storage in such silos has been reported by Hyde (25) who indicated that the increasing use of cereals in livestock rations had led to widespread use of sealed silos to store grain of higher moisture content than is possible in open storage. Experiments with the plastics lined silos gave satisfactory storage of both barley and beans where the grain was to be used for animal feed. The introduction of carbon dioxide into the silo reduced the anaerobic fermentation which developed after the oxygen had been eliminated. Further work in this direction was reported by Riczko (26) who showed that maise with a 30% moisture content could be successfully stored in a plastic lined silo made oxygen-free by flushing with carbon dioxide.

G.R.P* silos

Developments with GRP for the construction of silos hold promise of large scale silos suitable for grain storage use in the tropics. In Hungary, Laszlo (27) has reported the development of filament-wound silos of 20 cubic meter capacity which were filled pneumatically and unloaded by means of a pulley. Other work by Desso (28) concerned the development of GRP silos of 800 cubic meter capacity which have been used successfully for the storage of 600 tons of barley.

Portable warehouses

The development of plastics air-tents as warehouses for temporary storage purposes has been successfully used in tropic conditions (24). One such warehouse with a capacity of 5,000 tons of bagged produce has been used in the tropics, but needed modification to reduce condensation problems. This type of structure was supported completely, and only by air continously blown in a relatively low pressure. The fundamental design factors for this type of building are well covered in a paper by Canham (29) on air supported plastics structures.

This air-warehouse has the added advantage that it can also be used as a fumigation chamber, and can also be rapidly moved.

* G.R.P. = glassfibre reinforced polyester

Fumigation sheets

Central storage of produce usually provides scope for the erection of bag or bulk storage systems. The centres consist of GRP, or metal, or concrete silo installations, and of large warehouses, and involve problems of both insect and rodent control. Where bags are stacked, produce can be disinfected by covering the stack with a plastics sheeting and introducing a fumigant under the sheeting. The plastics sheet performs two functions. It maintains a concentration of gas within the produce for a minimum time, and it also prevents reinfestation while it is left in situ (24). For these applications, both PE film and flexible, unsupported PVC film have been successfully used.

Some indication that fumigation is already in use in the Sahelian zone is given in a French review(30) dealing with French research for the arid tropical zone of Africa. Mention is made of fumigating stocks of grain packed in plastic bags with capsules of carbon tetrachloride. Unfortunately no other details are mentioned.

Sacks

While jute sacks have been used for many years they are gradually being replaced by PP (polypropylene) woven sacks. In this respect, natural fibres with a multiplicity of areas in which micro-organisms can lodge, and capable of holding moisture, provide an environment favourable to the development of bacteria, fungi and insects, with the resultant deterioration of contents. A PP sack has non-absorbent moisture properties and freedom from taint-imparting odours, it therefore, provides a biologically inert wrap for agricultural produce. Variations of this type of sack can involve coating one face of the PP woven cloth with a PE film so as to produce a PE film-lined sack. Hall (24) mentioned a report by the Tanzania Coffee Board to the effect that coffee stored in PE lined bags reduced deterioration, both of raw colour and overall quality in clean coffee. It would appear therefore, that there may be opportunities to be explored in the use of PP sacks in the Sudano-Sahelian zone.

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