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PLASTICS PROCESSING AND APPLICATIONS IN AGRICULTURE IN DEVELOPING COUNTRIES 1/

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Introduction

The development of applications in agriculture in developing countries fundamentally follows the same basic pattern as in the more developed countries. Plastics are used only where a definite economic advantage can be shown when examined over the total system used or where classical materials are unavailable. What is perhaps more marked, are the different problems faced in developing countries regarding the development of both plastics and agriculture.

There is generally a lack of plastics technology and know-how to produce the correct quality of plastics products for agricultural use. In many cases there is often a failure to understand that special raw materials and formulations are required in order to be able to produce the correct quality of plastics material required. Moreover, even where this is understood, then there is sometimes a lack of understanding of the influence of processing conditions on the properties of the finished product. Quality control is seldom practised, as such, although thickness and width dimensions are often measured but not always recorded. All this is primarily due to the fact that entrepreneurs are seldom technical and the size of the plastics operation cannot justify the cost of employing a plastics technologist. Information on plastics processing normally arrives either through friends in the business or through machinery manufacturers who are more concerned to assure the buyer that the equipment is simple and will easily produce whatever plastics product is required.

In the few cases where large scale enterprises have been established, there is generally a better understanding of the needs for quality control and that products, with special performance requirements, are required for both industrial and agricultural applications. Unfortunately, in many developing countries there are problems in knowing where to seek such information. Raw material suppliers, in many cases, are represented by agents who are primarily concerned only with selling and are reluctant to feed back to their principals the technical problems that are raised. Where they do so, and special grades of polymers become involved, then there is the inevitable problem of stock-keeping; tying up capital and warehouse space as well as increasing the product range. In some countries this is further aggravated by import licences and limitations on the quantities which can be imported in any given period. It will thus be seen, that what in a developed country is a relatively simple task of ordering a particular type of polymer which in normal circumstances would be delivered within a matter of a few days, now becomes a major operation in a developing country, especially when their polymer supplies have to be imported.

In developing countries, where polymer is manufactured, the position is normally a great deal easier since there are generally technologists available within the producing company, who are able to advise fabricators and convertors on these matters. However, such polymer production facilities are generally small scale and this necessarily limits the range of polymers that can be produced economically. It is not always possible therefore, to produce the same wide range of grades or types of polymers that are taken for granted in developed countries. In such cases, it is necessary to make a compromise solution that will produce the best result from the different types of polymer locally available, but this is not necessarily the same as the result that could be achieved if the correct type of polymer was used.

From the foregoing it will be appreciated that there is an obvious need in developing countries to improve the plastics technology facilities if the plastics industry is to develop and expand. This is an area in which UNIDO has been providing technical assistance. In these types of circumstances where the majority of plastics fabricators and convertors are unable to afford to employ plastics technologists, then consideration can be given to the establihsment of a central organization to undertake such a work. These central organizations are known as "Plastics Development and Technology Centres" and they have a multiplicity of functions ranging from processing and application development to training of personnel. By such means, developing countries can maximize the benefits of scarce and expensive technical resources in both equipment and manpower, and are thus provided with a sound technological base on which the expansion and development of their plastics industries can move forward. Without this type of technical facility, the development of plastics in agriculture depends largely on the initiative and enthusiasm of individual entrepreneurs or on knowledge brought into the country by a locally operating foreign company.

1. Initial development of agricultural applications

The development of plastics in agriculture in developing countries stems from one of three driving forces:

a) An enlightened and technically competent plastics fabricating or converting company discusses with a grower or farmer on the type of applications that have been established in other countries. From these discussions there usually emerges a trial which the grower is prepared to undertake with plastics which the plastics company often provides either free of charge or at nominal cost.

b) A forward looking grower who has either travelled extensively or has read technical literature, will be aware of many applications of plastics in agriculture. One day he is faced with certain economic problems in his cropping and will realize that plastics might be an answer to his problem. At this point he will try and make contact with a local plastics company to enlist its aid to resolve the problem.

c) The initiative is taken by an agricultural science-based institution or government, whether it be an agricultural extension service or an agricultural department of a University. Here the knowledge of the agricultural problems of the country is often more detailed, but experience shows that the potential of plastics to resolve these problems is not always as well known as might be expected at first sight. However, when the possibilities are known, contact is then made with the plastics companies until one is found who is prepared to co-operate in some development trials.

It is from this type of background that applications of plastics in agriculture have been started in developing countries. As the general interest awakens, a National Committee for Plastics in Agriculture can then be formed, as in Argentina, which was initiated by the plastics industry. It enables the promotion of applications to continue, and for farmers, growers and other agriculturalists to have the opportunity of discussing their problems with the members of the plastics industry. Only by this close co-operation followed by trials, can plastics be successfully developed into the differing economic situations that exist in each country. Membership of the International Committee for Plastics in Agriculture (C.I.P.A.) ensures an ever increasing range of contacts with specialists around the world, and a steady flow of information that enables the industry to have an 'awareness' of what is happening in this particular area of plastics application.

From many developing countries visited, a range of plastics in agricultural applications have been noted that may be of interest to other countries that have yet to exploit this type of application of plastics. The countries visited included Argentina, Chile, Guatemala, Iran, Lebanon, Malaysia, Nicaragua and Singapore.

2. Planting bags

The replacement of the traditional clay-pot by plastics bags for young plants at the nursery stage is perhaps one of the first plastics applications that is adopted by a developing country. This is due to the fact that a simple PE (polyethylene, low density) bag is, in general, considerably more economic as a direct cost than a clay-pot. Moreover, growing trials to prove the effectiveness of the bag are simple to make and involve little cost or risk of financial loss to the grower.

While the following nursery plants have been observed growing in commercial production in PE planting bags, this list gives only an indication of the range of plants that can be grown in such bags:

- tea;
- rubber;
- palm oil;
- oranges;
- apples;
- tomatoes;
- chrysanthemums;
- lilies.

The normal PE film bag is gussetted so that it forms a firm base and stands well when filled with soil. Black bags are the usual colour since they prevent weed growth developing from the sides of the bag and absorb sufficient heat during the day to retain warmth at night, and thus greatly assist the establishment of root growth. In some countries, transparent PE bags are used for this application and the plastics industry has not pursued the matter of establishing black bags as a standard through lack of knowledge.

For the plastics industry, this can be of economic importance since much overun printed film, short-ends and off-colour runs can all be recycled into black film if the melt-index of the materials are not too dissimilar. Providing that suitable master-batches are utilized, the film produced will be of first class quality. It must be stressed that this is not a question of merely adding 'black' master-batch colour. When PE is processed, it is slowly oxidized by the effect of heat and if the oxidation is progressively continued, then the material will gradually become physically weak until in the end it embrittles. It is necessary therefore, to ensure that the master-batch contains effective and sufficient anti-oxidants to prevent this deterioration of properties in the recycling process. Most reputable raw materials suppliers will give specific technical advice on this matter if requested and a number of them provide suitable master batches incorporating both pigment and anti-oxidant for this purpose.

Normally, up to 30% of PE film rework can be processed this way, and depending on the particular type of plant being operated, considerably higher quantities have been successfully reworked. In view of the current situation of polymer supply, this rework operation can be vital to the production efficiency and output of a PE film producer. This technique of utilizing printed PE film and off-colour materials which were otherwise normally dumped or burnt, can effect a product cost reduction of the order of 20%.

3. Rubber plantation

Apart from planting bags there are three other applications of plastics in the rubber plantation industry. They are bud grafting, rubber latex collection and packaging of processed rubber - Standard Malaysian Rubber (SMR).

Bud grafting

In order to quickly establish rubber trees with what are considered to be the most desirable characteristics, and thus ensure an economic plantation with trees of high yield, recourse is often made to the technique of grafting on to an existing young tree, sometimes one, or perhaps two differentparts of another type of rubber tree are utilized. For example, it may be required that the tree should have a short crown, but the high yielding tree variety has a high crown. In this case, it is possible to graft the short crown element on to the high yielding tree and thus rapidly achieve a combination which would take many years by plant breeding techniques.

When the graft has been made, transparent PE film of about 50 cm width and 0.05 mm thickness is wound closely round the graft so that it is protected from infection and insect attack. After a number of weeks when it is observed that the graft has taken, the film can be removed. This method of bud grafting gives up to 90% success compared to 50 to 60% obtained by older and traditional techniques, and the cost of the small amount of PE film is thus more than fully justified.

Rubber latex collection

When the market prices for rubber were dropping to extremely low levels, it became clear that the economics of rubber plantations required close study. One proposal was put forward which could help reduce the labour required in the daily rubber collection and thus reduce part of the labour cost. This was to change from the current system of emptying the cup into which the tapped rubber was collected, to the use of a PE bag in place of the cup. By this means, the bag would only need to be emptied about once in 2 weeks instead of daily cup emptying.

After much experimentation a suitable bag design and quality was developed which could be simply and quickly attached to the tree by means of a wire. The rubber latex ran into the bag at a prepared opening and the bag could be left for two to three weeks before it was required to be collected. The latex in the bag of course coagulated of its own accord, and being totally enclosed was very clean. This cleanliness was a significant improvement on cup collection where insects, particles of air-borne dust and debris easily contaminates the latex.

To prevent rain running down the tree into the bag, trials were successfully carried out using both polystyrene and polyurethane foam as a rain-guard. The foam was fitted spirally above the tapping cut, and the rain was thus channelled away from the bag. Problems of insect infestation in the foam were observed, but the work was not continued.

The fact that the latex coagulated in the bag restricted the types of rubber for which it could be used, but the fact that it was so clean made the rubber of highest commercial quality.

The project was not proceeded with on a large scale since it would have involved a reduction in the total labour force when there was a basic need to ensure the fullest possible employment. Moreover, market prices of rubber have since moved upwards. However, in some remote areas where labour is still scarce, the method is in successful commercial operation.

Packaging of processed rubber

In further attempts to improve profitability of rubber plantations, efforts were also made to modernize the approach to the marketing of the finished rubber. Previously it was baled and packed in sheets of rubber which were liberally coated with talc to prevent sticking in handling.

In the new system that has been developed, the rubber is now compounded into specific and quality controlled grades of compound so that they can be added directly into the mixing equipment at the ultimate tyre factory. A pre-weighed amount of this rubber compound is now compacted into a block and packed into a thin PE bag which carries the compound/grade identification; the whole (rubber and PE bag) can be placed cleanly into the tyre producer's mixing equipment where the small quantity of polyethylene film from the bag is easily dispersed into the rubber. These batches of rubber are later stocked and packed into a simple export case consisting of a cardboard outer lined with sheets of PE film, and reinforced with wooden sheets. This method of marketing has been a tremendous success and has significantly improved profitability.

Some problems of the PE bags splitting open in transit had been reported, but provision of a slightly larger bag and the addition of more "slip-agent master batch" have helped resolve this problem. Altering the conditions for the PE film production so that the physical properties of the film were more balanced, in both length and crosswise directions, also greatly assisted better performance. This necessitated using a different film width/die diameter ratio so that good physical properties were developed in both directions. This type of development work required both access to plastics technology and suitable testing equipment so that the properties of the film could be characterized.

4. Tea plantation (at 1,800 meters above sea-level)

Bottomless PE planting bags

Young tea cuttings are planted in black PE bags. However, the bags are not sealed at the base and are in fact bottomless. A special type of sandy and sterile soil is used for filling the bags, and being slightly moist it consolidates when it is tamped into the PE 'bag'. Thus, it remains intact when the filled bag is lifted.

PE tunnels

The tea cuttings are set in the planting bags, which are then arranged in close-packing rows between the confines of two wooden boards which form the boundary wall of the nursery bed. The plants are then watered and covered with transparent PE film to form a tunnel over them. Bamboo cane, grown locally, is used to make suitable tunnel supporting hoops, set at about one meter distance apart. This tunnel and several similar units are all located under a rustic wood framework about 2.5 m high, over the top of which are laid branches of atap leaves to provide shading.

The tea cuttings are left for thr e weeks under the closed tunnel. After that time the PE film is lifted at the sides to provide ventilation before it is finally discarded after about the eighth week. By this period a vigorous root growth is achieved with a low percentage of failure. The cutting continue to grow in the nursery with part of the atap shading being removed in four stages during the course of the year. The one year old plants are then ready for transplanting into the tea estate.

Soil fumigation

Large sheets of black PE film, 0.125 mm thick and approximately 4 x 10 meters wide, are spread over the ground to be sterilized, and by heaping soil along the other edges, an effective gas seal is made. Methyl bromide is the sterilising agent used and is introduced under the film through a flexible plastic tube. The sheet is then left for 48 hours before being removed and used again for the next section.

Problems were encountered with film embrittlement after a short period of time, and this was undoubtedly due to insufficient anti-oxidant being incorporated into the original formulation. For this type of application where toughness is a prime requirement, then better performance would be obtained if the film were made from PE with a melt index in the range 0.9 to 1.0.

5. Tobacco plantations

Shading

White PE film is used in several countries for the shading of tobacco plants. The white film is semi-opaque and normally transmits between 40 to 60% of the light. The film is secured to a wooden frame over young tobacco plants to prevent too much heat build-up during the critical period of growing.

Large sheets of 0.15 mm thickness are often required for this purpose, approximately 5 x 4 meters width.

In developing countries, there is normally a limited demand for wide PE sheeting and few companies are prepared to invest the large capital outlay required for the necessary die and take-off equipment. It was therefore, particularly interesting to see how one company had resolved the matter, who were equipped to produce sheeting of just over one meter wide lay-flat (2 meters when opened up to single film width).

Using local skills in wood working, they had produced a heat sealing unit constructed mainly of large beam wooden members that made a 4 meter long seal in one operation. By cutting the meter wide lay-flat film into 4 meter lengths and slitting it lengthwise to make single film, it was possible to seal two edges, 4 meters long together - this ultimately became the width of the final shade sheeting at a dimension of 4 x 6 or 4 x 5 meters. Despite this extraordinary length of sealing bar, the sealing was of a satisfactory quality. Admittedly, PE film of 0.15 mm was used to ensure sufficient thickness tolerance on sealing, where otherwise PE film of 0.1 mm would have sufficed , but this did enable the growers to utilize PE sheets for shading in the absence of seamless wide-width PE film. This particular example gives an indication of how, by application of both initiative and determination, problems can be resolved, even if in a somewhat unorthodox way.

6. Banana plantations

Fruit protection

An established use for PE transparent film has been as a protective sleeve over the banana fruit from the time it is first formed to the time of cutting. Perforated lay-flat PE film of 0.05 to 0.1 mm thickness is cut into lengths of about 2-3 meters, sufficiently long to cover the fruit and allow the ends to be bunched and tied. The inside of these cut lengths of lay-flat film is dusted by the grower with insecticide before the fruit is covered. Not only does the film protect the fruit from bird and insect attack, it also promotes higher yields in the fruit and shortens maturity time.

The PE lay-flat can be printed with different coloured stripes so that the sequence in which the fruit is to be cut can be more readily identified in the plantation, and is related to the time when the fruit was first covered.

Work carried out in Australia on the use of coloured translucent PE film for the covering of bananas indicated that blue, green, yellow and red PE films significantly increased the fruit yield and time to maturity, compared to a control which was uncovered. More recent work indicated that a reflective plastic cover performed better than the conventional cover, and also offered a bonus of additional protection from fruit burning during the summer heat.

It would appear that there remains much work to be done by the plastics industry to exploit the results of this development work to the particular conditions of each individual country.

Fruit packing

After the bananas have been washed, graded, treated to prevent premature ripening and weighed, they are then wrapped in perforated transparent PE film and packed in cardboard cartons. These cartons are then ready for immediate overseas shipment.

7. Rice cropping

Protection of nursery rice

Where young rice is grown in a nursery bed so that it can later be transplanted into the rice field, there is often a risk of losses through rodent attack. A simple and effective means of preventing this has been observed. A transparent blue-coloured PE film is erected as a "fence" around the whole of the nursery bed. The bottom edge of the film is anchored into the soil below the water level, and is held in an upright position by means of bamboo canes inserted into soil which are placed alternately on one side and then the other of the film so that a slight tension is developed. This is sufficient to keep the film in a vertical position. Film of 0.125 mm thickness and about 75 cm width is used for this application.

Rodent attack, in this particular case by rats, was prevented as the PE film is too slippery for them to climb up. After one season of successful trials, the method was rapidly adopted by many farmers in the following year.

Enquiries were made to ascertain why blue PE film was used for this application. It transpired that the colour was incidental. The company concerned with this development realized that farmers and growers who were unaccustomed to handling PE film, could not easily distinguish the difference in thickness or the quality of PE film that was available on the market. They therefore introduced blue film to identify the 0.125 mm thickness, and green film for 0.075 mm thickness, since these were the two thicknesses that had earlier been sold for general purpose applications to farmers through retail shops. The idea is simple, effective and had much to commend it in the circumstances prevailing.

Grain shields for hand treshing

In several developing countries, rice is threshed by hand in the rice field. The operation involves striking the sheaf of rice several times against a mesh of wood rods. These rods are positioned in the upper section of a wooden container into which the rice grains drop. To prevent some of the rice grains going over the sides of the container, it was normal practice to erect a cloth screen so that it formed a part extension of three sides of the box. Thus any grain hitting the cloth automatically fell back into the box. Because cloth deteriorates rather rapidly in tropical climatic conditions PE film was tested as a replacement. It was held, simply, in position by attachment to bamboo canes, set within the box. Blue (0.125 mm) PE film has now become standard for this application as experience indicated that it has a much longer life than textile, and is of lower effective cost.

Packaging of rice

Traditionally rice was packed in jute sacks. With the advent of PP* woven sacks in a quality that more than matched the performance of jute and with a clear economic advantage it was inevitable that rice packaging would switch to PP sacks. This has happened rapidly over a period of three years.

PP sacks are manufactured in two basic stages:

a) the production of PP tape for weaving;

b) the weaving of the tape into cloth from which the sacks are then fabricated, and printed, if required.

a) The PP polymer is supplied in compound form by the manufacturer normally with suitable anti-oxidant and other additives incorporated. This compound is then extruded into blown lay-flat film form as by the normal processes used for the production of PE film. Some companies arrange the equipment so that the bubble is blown downwards instead of upwards as normal for PE film production. It is stated that downward extrusion tends to give both better bubble and also thickness variation control of the PP film. However, from observation of both forms of production and

* PP = polypropylene.

from discussion with manufacturers it would appear in practice there are only marginal differences in favour of downward extrusion.

The film is passed, in line, through a hot tunnel, or over a heated metal plate, the essential factor in either method being accurate temperature control. When the film is hot it is stretched lengthwise by a multiple bobbin wind-up unit, and the film is slit into narrow tapes in the width range of 1 mm to 3 mm. This stretching process highly orients the molecular structure of the polymer so that the breaking strength (tensile strength) of the tape is very significantly increased. It is this strength characteristic which ultimately determines the sack load performance for a given thickness of tape, and it is therefore a key element to control in production.

Sacks produced from PP tape tend to be too harsh, in handle, compared with jute sacks which they replace. As a result of extended trials it is now common practice to use mixtures of PP and PE.HD* polymers to modify the 'feel" or "handle" of the final woven fabric. The use of PE.HD while producing a fabric of softer handle, does however have a lower strength characteristic than PP. It is necessary therefore not to add too much PE.HD otherwise the drop in strength could only be compensated by producing a thicker, and therefore more costly product. Up to 25% PE.HD has been used in these polymer blends for sack production.

b) The weaving of the PP tape can take place on standard conventional textile weaving machines. Flat-bed looms operating at 100 picks** per minute are of low capital cost and labour intensive. There is also available a high-speed, flat-bed machine which will produce at twice this speed. Where developing countries are producing sacks for their own internal requirements it would appear that flat-bed looms have certain advantages, particularly in being labour intensive.

However, where it is intended to sell PP sacks for export then other considerations apply. The first and foremost consideration is to be competitive in a world market, and also to ensure repetitive quality products. If it is desired to weave PP cloth for sacks at speeds greater than about 200 picks per minute then it is necessary to examine the use of circular weaving (not knitting) machine. These can produce at rates of up to 400 picks per minute, but are capital intensive. Apart from an ability to produce cloth at high speed, one type of circular weaving machine has another hidden advantage which makes it particularly economic.

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*PE.HD = polyethylene, high-density.

** Picks = number of threads (ribbons) woven per minute.

When using flat-bed looms it is a characteristic of the process that some tapes get twisted, i.e. folded-over on themselves while the cloth is being woven. To the non-technical person this might understandably be dismissed as being of minor importance particularly since the general visual appearance of the cloth is non-critical in the application of sacks. However, it has to be understood that the introduction of a fold (twist) into an oriented PP tape results in a lowering of the actual breaking strength of that tape. Nevertheless, it is possible to produce PP sacks of satisfactory performance standard by selecting a PP tape of higher strength (thicker film) to overcome this defect.

In circular weaving, on a machine specially designed for use with PP, the twisting of the tape is almost totally eliminated. It is thus possible to use a PP tape of thinner film than that required by flat-bed weaving, to produce a cloth of equivalent performance. Since the use of thinner film can result in a saving of raw material of up to 15% it will be realized that this can have a significant effect on the economics of the process. All the more so in present day conditions of higher raw material prices, following the crude oil price increases, and influenced to a lesser extent by a world shortage of plastics polymers. There are other minor capital cost savings which can result from adoption of circular weaving but these do not need to be discussed at this stage.

In any process there are always some positive and some negative points. What then are the negative points in circular weaving? As far as can be judged only one is of significance. In developing countries where circular looms have been installed some companies have reported that their engineers have had difficulty in carrying out routine maintenance and/or service work on these looms, because they are too complex for them to understand. These particular circular looms are sophisticated, modern-engineered machines designed for heavy-duty, high speed operation. It is inevitable therefore that the engineering and therefore the maintenance requires specialised knowledge and skill. Nevertheless, by the correct selection of suitable engineers, and following a specialized course in training on these machines this type of problem has been satisfactorily resolved. The economic benefits of high-speed circular weaving are easily sufficient to justify the expenditures that such a training course entails.

It must at all times be remembered, and it cannot be stressed too often, that the economic production of PP sacks is both a highly technological operation and an industry in its own right. Many types of sacks can be produced for different applications. For example, by the installation of a T-die extruder it is possible to laminate a thin film of PE to one face of the PP cloth. This is suitable for the production of sacks for fertilizers and other fine powdered products. Other applications of PP sacks, each requiring their own specific type of weave construction and strength characteristics, include the packaging of flour, sugar, grain and other agricultural crops.

8. Greenhouses and tunnels

A variety of different types of plastics covered greenhouses and tunnels have been observed in several developing countries.

Greenhouses

Greenhouses have in the main been used for flower cultivation and also tomatoes, whilst tunnels have been used for tomatoes, peppers and strawberries. Carnations, chrysanthemums, lilies and orchids are successfully grown in plastics greenhouses in several developing countries.

The construction of the greenhouses have been in either wood or steel, depending on cost and availability of raw materials in each particular country. In the tropical and sub-tropical areas the greenhouse normally consists of a multi-bay covered roof structure, and uncovered sides. Detachable side panels have also been observed, which could be placed in position when wind conditions make this necessary.

In the tropics, at 1800 metre altitude, the need for covering of tomatoes had little to do with achieving earliness since the climate was one of a continual spring-time, with temperatures of 21-24°C being normal the year round. However, in this particular region the humidity was constantly high, and so mildew and other plant diseases which flourish under such conditions, were endemic. This necessitated frequent spraying for satisfactory crop protection. Due to the fact that this location was also subject to frequent rain, the effectiveness of the spray was so diminished that daily spraying became necessary. By growing under a PE covered roof structure, the period of spraying was significantly reduced to once every two week period.

The cost-saving thus achieved more than repaid the price of the structure and the PE film covering, despite the fact that it had to be recovered three or four times per year. This was due to normal packaging quality PE film being used for the application which was the only quality available. This film was not designed, nor required to withstand exposure to the tropic weather conditions. Since that time, co-operation between the plastic industry and the local university, encouraged by UNIDO, has reached the stage where some specific technological problems are being studied by the university for the plastics industry. As a result of this work, it would now appear possible that an improved PE film will be evolved for commercial production which could have a life of one year under these particular climatic conditions.

This will be of direct economic benefit in the application, and especially so in today's conditions of high raw material prices.

It was also noted that many tomato growers were making use of polypropylene raffia as vertical supports for their plants.

In this location PE film covered roof structures, in units covering more than one thousand square meters are utilized for carnation and chrysanthemum growing. These structures are built by local labour from rough cut timber which form the vertical supports, being some 2.5 meters high and spaced 4 to 5 meters apart. The low angled timber roof framing has purlins spaced at about one meter intervals covered with galvanized wire mesh. The PE film is secured to this roof frame by wooden battens. The wire mesh is used in an attempt to reduce the wind-flapping of the PE film and thus to try and extend its useful life. Improvements in the design of the roof unit can be expected to follow the availability of longer-life PE film.

Metal structures have been used in some countries where iron rod and angle-iron are freely available, and wood less so. Moreover, in such countries it was observed that conventional glasshouse constructions have been in metal so the thinking is oriented in this direction. Some wide span, light-weight designed, metal houses have been observed. In most cases the PE film covering is secured through wooden members attached to the metal work. Very large mobile greenhouses for flower crops have been seen which were constructed of metal, and mounted on rails.

The use of GRP (glass fibre reinforced plastics) corrugated sheets is not wide-spread, as a roof covering for greenhouses. One nursery, specializing in orchids, had one section covered with a GRP corrugated roof and this was to achieve a reduction of light intensity.

Some conventional shaped greenhouses, constructed of rough-cut wood, were observed where the height to the roof apex was only 2.5 meters. These were covered with PE film, in widths of approximately 2 meters and fixed in position by wooden battens. Tomatoes were being grown in these structures to achieve earliness. Frost protection consisted of burning oil in small canisters set at intervals between the closely set rows of greenhouses, while in other locations it was common practice to burn oil-soaked waste in open-ended oil drums within the greenhouses.

The potential use of PE water tubes as a means of protection against a few degrees of frost was unknown. In this technique, short lengths of PE tubular film (about 200-300 mm width layflat) is bunch sealed at one end, either by tying, or heat-sealing. The tube is then filled with water to about half its potential volume and the other end is then sealed in a similar manner. A sufficient number of these tubes of water are then laid alongside the growing plants in the greenhouses, where it absorbs heat from the sun during the day. At night, the heat, built up in the water, now starts to slowly radiate and is sufficient to protect the plants in its immediate vicinity from 1°C or 2°C of frost.

In one area which was visited, where drought conditions had been experienced for some two years, in consequence of a changing weather pattern, a whole valley of some 40-50 km length was devastated. This had previously been a rich and fertile valley devoted to many horticultural crops, orchards and vineyards. In the lower section of the valley, aerial observation showed that irrigation by newly drilled water wells was keeping some small areas in growth; and water-tankers driven further along the valley were providing just sufficient water for some of the vineyards to survive. Higher in the valley three large reservoirs, normally used for irrigation, were virtually empty. Only occasional patches of bright green, amid the brown background indicated some water source. It was in this area that both greenhouses and tunnels, covered with PE film, were observed in scattered locations. By carefully using the limited water resources it had been possible to grow tomatoes in these covered structures and the water condensation on the inside of the film was trapped for further use. The various systems of trickle irrigation that might have been used under such conditions to make even more effective use of the scarce water resources, were unknown to the growers; as also was the use of PE film as a mulch. It would seem therefore, that there still exists a large gap in the communication chain in transmitting information on known applications of plastics in agriculture to developing countries where there are specific needs. Conferences, like the 6th International Colloquium on Plastics in Agriculture in association with the UNIDO Symposium on Plastics in Latin America, are one means of ensuring a wider distribution of knowledge on this subject, but much more remains to be done.

Tunnels

Various types and sizes of tunnels covered with PE film have been observed in several developing countries. The largest size tunnel was one 3 meter wide but only approximately one meter high. This tunnel was constructed on information obtained from Israel. A narrow wooden beam supported on wooden stakes provided the central ridge support of the tunnel. Steel wire hoops were set along the ridge at intervals of about 2 meters. One edge of the PE film was battened to the ridge and then additional wire hoops placed over the outside provided sufficient tension to keep the film in place. This film covered only one half of the tunnel, and a second length of film was similarly attached to cover the other half. This technique enables a wider tunnel to be achieved where only relatively narrow widths (2 meters) of PE film are available. The tunnels were to be planted with tomatoes, and as the plants grew it was inteded to raise the polythene sides, in progressive stage, until such time as the tunnel height restricted the plants. At this point the PE film would be rolled up and tied to the ridge bar. The crop at this point not requiring further protection in the particular climate concerned.

A number of smaller tunnels, of the Nantaise variety, were seen in several countries. Some were used for salad crops, and some for strawberries.

In most cases the PE film was used for only a limited period of crop protection and there were few complaints of the film not withstanding the outdoor exposure. Two years use under such application conditions appeared normal. There is little doubt that improved film performance can be achieved by formulation design. Recent price increase of raw materials may make this more necessary than in the past.

One unusual crop applications was the use of PE film covering small wooden frames which were set over a crop of capers. This was so arranged that while there was very adequate ventilation, it did nevertheless permit a heat build-up in the soil to take place, and also provided some protection from rain damage.

Apart from steel and galvanised wire hoops, bamboo hoops have also been observed in use as tunnel supports. Their use depends on availability and cost relative to wire in any particular location.

9. Mulching

The use of PE film as a mulch does not seem to have yet been developed on any large scale in the developing countries visited. Only the experimental use of both black and white PE film as a mulch has been observed. In this particular case, the use was on a strawberry crop. The black film had been in position for 5 years and the white for one year. This is an area of application where more development work will need to be undertaken, in each country, to fully exploit the potential of mulching.

10. Crop storage

Apart from the use of PP woven sacks for crop storage it has been noted that in one country PE film lined, wire-mesh silos have now also been constructed for the storage of grain. This is a low cost and effective means of rapidly providing additional crop storage facilities. Like all established applications for plastics in agriculture, further development is necessary in each country to ensure the most economic solution to a particular problem. In this particular case the development was undertaken over a three year period to economically adapt and exploit the application to local needs.

11. Water conservation

Only in one country visited has there been any real application of the potential that plastics offer in applications for water storage and transport and distribution, although the water needs of some other countries appeared to be much greater. In this particular case, the development has proceeded because of the initiative taken by the local plastics industry in promoting the applications of plastics in agriculture.

Australian-style, circular ponds for water storage for cattle use are constructed of concrete. They inevitably tend to leak and can lead to large water losses. By utilizing large sheets of PE film, development work has shown how, when building these ponds, they can now be made water-proof at relatively low cost. This is a unique example of a development to a specific local problem.

In the same country, there are large-scale irrigation projects planned which involve cutting new canals for transporting water to particular parts of the area. The use of both PVC* and PE films for lining of canals and reservoirs is well established. In this particular case, it was a very wide canal, and with fairly fast water-flow rates. It was therefore, interesting to learn that the last section of the canal has been successfully lined with PE film using the normal back-filling technique.

The use of flexible PVC hose-pipe, in diameter of 12-30 mm, has been observed in several countries as a standard means of watering flowers as well as for other crops. The use of a 400 mm black PE lay-flat tube as a means of transporting water, over about 1 km distance, was unusual. The film was about 0.08 mm thick and there were only a few pinholes in the length involved. Nevertheless, it provided a low cost system for moving a large volume of water from one storage area to another, under low pressure. This application again illustrates the advantage of local development to resolve specific problems in agriculture.

In one country where irrigation ditches are an essential element in providing water for furrow irrigation a local grower, after hearing about how plastics can be utilised in agricultural applications, decided to line his main irrigation ditch with PE film. The only immediately available film was some clear PE material of 0.05 mm thickness. Despite the fact that this film was hardly suitable for the job some two kilometers of ditch were lined in a few days. When the water was introduced, it was noted that there was quite a considerable volume and flow-rate towards the end of the ditch, which previously hardly had any water due to losses by soil permeation. The grower was very pleased with this improved flow since it enabled him to irrigate a much larger area of land than before. However, no information has been made available regarding the useful life of the film. For this application, there is little doubt that specially formulated black PE film would be more likely to have a useful economic life. There are obviously long-term exposure problems to be resolved to ensure the film does have an economic life in this type of application. Additionally, if systems can be evolved, in which the area of film directly exposed to the weather, and not covered by water, can be reduced to a minimum; this would significantly improve the long-term life of the film. With such systems there is every possibility that this method of channel ditch lining could be made more widespread.

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*PVC = polyvinyl chloride.

However, this is only a part of the total irrigation picture, and the present trend to move to piped supplies, feeding trickle irrigation systems, whilst more capital intensive, does make significantly more efficient use of water relative to plant growth and yields. It is becoming increasingly clear that much more development effort is required in this area to clarify the technology of application in relation to each crop to be grown so as to maximize the benefits obtained. Development of this kind is already being undertaken in some developed countries.

12. General comments

From the foregoing it will be appreciated that a relatively wide range of plastics in agriculture applications have been adopted by a number of developing countries in the tropics and semi-tropic zones. However, it is clear that there are other applications which could be developed as well as making improvements in existing ones; and past experience show the need for plastics technological assistance to resolve some of the problems encountered. In many developing countries, where individual companies are unable to afford to employ the necessary technological skills and equipment for such development to be initiated, then there is need to consider carefully the advantages that can accrue to the whole national plastics industry by setting up a Plastics Technology Centre (PTC) to serve the needs of the industry.

Since the work which such a Centre could undertake can extend to promote the development of agriculture and other industries (packaging, electrical, furniture, etc.), as well as providing specialized training facilities then, in these circumstances, as there are wider national benefits to be obtained, there is a case for the national plastics industry to seek Government assistance in the implementation of a PTC.

However, this pre-supposes that the plastics industry in the country concerned has organised itself into an effective industrial association so that it is able to speak as a corporate and responsible body, and is thus enabled to discuss such requests for assistance with Government.

When UNIDO receive a Government request for technical assistance to aid an industry, this becomes an area in which UNIDO is able to be of positive help. Plastics industry surveys could be undertaken to determine the extent of the facilities which may be required for a PTC as well as setting up specific and detailed project proposals for its establishment. In some cases the United Nations Development Programme (UNDP) may be able to provide some financial contribution to its funding if the project is included in the Country Programme (of development) of the Government concerned. By these means, UNIDO aims to support and encourage the general industrial development of developing countries.

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