CHAPTER 1

INTRODUCTION

1.1. INTRODUCTION

Plastic covering, either framed or floating, is now used worldwide to protect crops from unfavorable growing conditions, such as severe weather and insects and birds.

Protected cultivation in the broad sense, including mulching, has been widely spread by the innovation of plastic films. Paper, straw, and glass were the main materials used before the era of plastics. Utilization of plastics in agriculture started in the developed countries and is now spreading to the developing countries.

Early utilization of plastic was in cold regions, and plastic was mainly used for protection from the cold. Now plastic is used also for protection from wind, insects and diseases. The use of covering techniques started with a simple system such as mulching, then row covers and small tunnels were developed, and finally plastic houses. Floating mulch was an exception to this sequence: it was introduced rather recently, although it is a simple structure. New development of functional and inexpensive films triggered widespread use of floating mulch.

Table 1.1. The use of plastic mulch (ha) in the world (after Jouët, 2001)

	1991	*1999*
World		12,130,000
Africa and Middle East		80,000
Egypt	7,000	30,000
Israel	4,000	26,000
America		200,000
U.S.A.	20,000	75,000
Asia		9,760,000
China	1,400,000	9,600,000
Japan	150,000	160,000
Europe		450,000
Spain	100,000	150,000
France	100,000	100,000
Italy	50,000	75,000

Table 1.1 shows the use of plastic mulch in the world. Wide use in Asia especially drastic increase in China in the last ten years is apparent. China had the largest area of

plastic mulch in the world followed by Japan, Spain, and France in 1999. The European region was second next to Asia, and Spain, France and Italy were the top three countries in Europe.

Table 1.2. The area of low tunnels and floating mulch (ha) (after Jouët, 2001; original data was modified by CIPA data, 2000)

Low tunnels	*1991*	*1999*	*Floating mulch*	*1991*	*1999*
World		882,000	World		86,000
Africa		80,000	Africa and Middle East		6,000
Egypt	15,000	50,000	Egypt		5,000
America		30,000	America		6,000
U.S.A.	5,000	15,000	U.S.A.	1,500	5,000
Asia		170,000	Asia		14,000
China	20,000	85,000	China	1,000	8,000
Japan	53,624	56,500	Japan	4,000	6,000
Europe		90,000	Europe		60,000
Italy	100,000	24,000	United Kingdom	9,000	12,000
Spain	100,000	17,500	France	8,000	10,000
France	50,000	16,000	Italy	3,000	10,000

Table 1.2 lists countries where the area of low tunnels and floating mulch is more than 15,000 ha. Since construction and dismantling of these facilities occur frequently statistical data are less reliable than those for more stable structures such as glasshouses. Again, China had the largest area of low tunnels in the world and Japan was the next. Floating mulch was most widespread in Europe, followed by Asia, America, and Africa and the Middle East.

These data are all from the Comité International des Plastiques en Agriculture (CIPA) in France, which is one of the organizations that publish this kind of worldwide statistical data, but it is not a governmental body and has some difficulty in collecting and updating these data.

The area of plastic greenhouses in the main horticultural countries is shown in Table 1.3 from largest to smallest for areas over 2,000 ha in each region. More than half of the world area of plastic greenhouses is in Asia and again China has the largest area. In most countries, greenhouses are made of plastic and glass; the majority are plastic, although, as is well known, almost all greenhouses are glass in the Netherlands where the greenhouse area is over 8,000 ha. Glasshouses and rigid-plastic houses are longer-life structures, and therefore are mostly located in cold regions where these structures can be used throughout the year. In Japan, year-round use of greenhouses is becoming predominant, but in moderate and warm climate regions they are still provisional and are only used in winter. Double-cropping systems consisting of rice cultivation in open fields and strawberry cultivation in plastic houses on same fields, are common in some regions in Japan.

Table 1.3. The area of plastic greenhouses (ha) in the main horticultural countries (after Jouët, 2001; the original data was modified by CIPA data, 2000)

	1991	*1999*
World		682,050
Africa and Middle East		55,000
Turkey		14,000
Morocco		10,000
Israel	1,500	5,200
Algeria	4,802	5,005
Rep. of South Africa		2,500
Syria		2,000
America		22,350
U.S.A.	2,850	9,250
Colombia		4,500
Ecuador		2,700
Asia		450,000
China	200,000	380,000
Japan	45,033	51,042
Korea		2,200
Europe		180,000
Italy	65,000	61,900
Spain	35,000	51,000
France	9,000	9,200
Hungary	4,000	6,500
Serbia		5,040
Czech and Slovak Rep.		4,300
Russia	4,850	3,250
Greece		3,000
Portugal		2,700
United Kingdom	1,000	2,500
Poland		2,000

1.2. EUROPE AND AMERICA

There is no such steep expansion of protected cultivation area in Europe and America as in Asia, but the total area is not small, and a stable situation exists. Protected cultivation into Europe is classified in three types: Fully automated greenhouses, simple plastic houses, and large-scale greenhouses associated with energy plants. A close look at protected cultivation in northwestern Europe shows that new systems have gradually been installed. Climatic control by digital computers, hydroponic systems, and inter-transportation systems (which can be called agri-robot systems) are spreading in northwestern European countries. In the Mediterranean countries, simple plastic houses are predominant. In the eastern European countries, large-scale glasshouses with energy supplied from nearby power plants are very common; they are normally operated cooperatively, although levels of mechanization are not high.

In the United States, greenhouses are used for farming in long-term structures on the one hand, while row covers and floating mulches are becoming popular on small farms (Schales, 1987; Wells, 1988). Some countries in Central and South America are becoming exporting countries of flowers produced in protected cultivation.

1.3. ASIA

Plastic films are widely used in Korea and China. In Korea plastic houses are also used for temporary protected fruit culture 1) to control low temperature; 2) to avoid diseases and damage by insects and birds; 3) to shut out strong rain and wind; and 4) to improve the fruit quality (Park, 1988). A similar approach is becoming used in more tropical Asian countries such as Thailand and the Philippines (Bualek, 1988; Bautista, 1988).

1.4. AFRICA AND THE MIDDLE EAST

The weather in the Mediterranean region is relatively mild. Turkey, Morocco, Israel, and Algeria are all in this region and rather simple structures are predominant in these countries.

1.5. JAPAN

In Japan, primitive methods using oil paper and straw mats to protect crops from the severe natural environment were used as long ago as the early 1600s. Widespread implementation of protected cultivation in Japan began in 1951 after the introduction of Polyvinyl Chloride (PVC) film, and the benefits of its application to agriculture were quickly appreciated. Paper covered tunnels were rapidly replaced by PVC-film covered ones. Traditional wooden or bamboo frames were replaced with steel first and then with aluminum and plastics in some cases. Mulching with plastics began with PVC film, but later shifted to Polyethylene (PE) after its introduction (Nishi, 1986).

Protected cultivation will be one of the promising ways of supplying food under unfavorable environmental conditions in Japan if the energy problems can be solved. The past and present situation in Japanese protected cultivation is summarized in Table 1.4 and Fig. 1.1. (The data in the figure are only for greenhouses.) This figure shows rather steady expansion of protected cultivation area has continued for years along with the development of new covering materials, but it is clear that the expansion rate of plastic houses flattened during the steep oil price increases in the 1970's. One of the particular trends in Japan was that the area for pomiculture expanded along with that for floriculture, and in the 1980’s the pomiculture area was at one time larger than the area for floriculture. The rapid growth of rain shelter area in the 1980’s and 1990’s is apparent after rain shelters were introduced in 1983 (see Fig. 1.1).

Table 1.4. Estimation of the world consumption of plastic (t) used in agricultural production (after Jouët, 2001)

	1985	*1991*	*1999*
Tunnels	88,000	122,000	168,000
Mulch	270,000	370,000	650,000
Floating mulch	22,500	27,000	40,000
Greenhouses	180,000	350,000	450,000
Silages	140,000	265,000	540,000
PP twine for hay and straw	100,000	140,000	204,000
Hydroponic systems	5,000	10,000	20,000
Micro-irrigation	260,000	325,000	625,000
Others (nets, plastic bags, except fertilizer bags)	80,000	130,000	150,000
Total	1,145,500	1,759,000	2,847,000

Statistics on the use of agricultural plastics in recent years are summarized in Table 1.4. The area of mulching is predominant. Tunnels follow, with more than half using PVC. The most dominant use of PVC is, however, in greenhouses. Direct film covering of crops without the use of frames --floating mulch -- is increasing dramatically because of its higher yields and lower costs. Direct net covering is also consistently being used to prevent crops from damage caused by insects, birds and severe winds. In tropical regions, film covering is used not only for rain shelters but also for weed and soil moisture control. The use of plastic covering in agriculture is based on the light transmission and thermal properties of plastic films, and their effects in the crop environment.

1.5.1. COVERING MATERIALS: PE OR PVC?

Covering materials are more or less common to all systems, from mulching to greenhouses. Glass has been the traditional and ideal covering material for many years, and it still is, for facilities designed for year-round use. When farmers insist on investment in a shorter period or use a facility for only a certain part of the year, soft films are used. The three covering films most often used are PVC, PE and Ethylene Vinyl Acetate (EVA). PVC is most opaque to long wave radiation (second only to glass); next most opaque is EVA, and then PE at the same thickness. PE is most transparent to long wave radiation; often the inside air temperature of a PE house can be lower than the outside due to long wave radiation loss on calm, clear winter nights. The few degrees difference in indoor temperature between a PVC and a PE house is critical if the house is not heated and the temperature is around freezing. Now that IR-resistant PE and EVA have been developed, the difference can be minimized. The long wave transmissivity characteristics of IR-resistant PE are not reported, but the order of thermal superiority would be PVC first, then IR-resistant PE and EVA at almost the same level (Grafiadellis, 1985). The situation is not so critical in heated greenhouses.

In the 1980s, a report indicated that evaporation of Dibutyl Phthalate, which is used as a plasticizer, from PVC films and pipes harms plants inside the house. In Japan, this substance was replaced almost 35 years ago with Di-Ocpyl Phthalate (Di-Ethyl Hexyl Phthalate), a harmless chemical. Deterioration of films is also slower today because of the longer life of plasticizers in films. At the International Seminar on Agricultural Plastics in Korea in 1988, a scientist reported on discharge of chloride gas from PVC film greenhouses. The gas can be generated if the film is burned, but not if the film is at a temperature of less than around 180°C. Not only these chemical properties of the films but also their physical properties entirely depend upon how they are made in each country. In Japan, Japanese Industrial Standards (JIS), similar to DIN in Germany, are used to judge the products. In North America each manufacturer reportedly sets its own standards (Blom and Ingratta, 1985). It is rather difficult to discuss the issue with such different products being produced under the same name.

Rigid polyester rigid film, which has much greater durability as well as transmissivity than PE and PVC, is becoming popular in Japan, although the price is rather high. Its lifetime is said to be 5 to 7 years.

Environmental conditions change the situation, of course. If condensation occurs, the inside surface of PE film becomes more opaque to long wave radiation.

Aging and weathering effects on films are also important factors to consider in selecting films, but this topic is beyond the scope of this book.

1.5.2. GREENHOUSE PRODUCTION IN JAPAN

In Japan, although the area of greenhouses is less than 1% of the total arable land, Table 1.5 shows the extent to which the country depends upon production in greenhouses for its main vegetables. Significant proportions of vegetables such as tomatoes, cucumbers, green peppers and strawberries are produced under protected cultivation.

In recent years, rain shelter greenhouses have been increasingly used in fruit and leaf vegetable production. Because of this recent increase, the area of rain shelter greenhouses is normally separated statistically from the other greenhouse area. However in 1989, the rain shelter area was approximately 10,000 ha, a 10% increase from the preceding year (see Fig. 1.1). Tomatoes and spinach accounted for more than 85% of the rain shelter greenhouse area. The normal open-field growing season is March or April through October or November, when outside temperature conditions are favorable for open field cultivation. With the use of greenhouses, the production area can then be from 200 to 300 m higher in altitude than traditional areas. In summer, day temperature is slightly higher inside, with no significant difference in night temperature. Fruit injury and disease infection due to rain have been drastically reduced: for example, tomatoes are substantially protected from bacterial canker and spinach from downy mildew.

1.5.3. FLOATING MULCH IN JAPAN

Floating mulch was first introduced in Okinawa (southernmost island in Japan) in the 1950s, in order to protect crops against severe weather conditions in summer. It has now become a common method in Okinawa, and has been adopted in other areas of Japan.

Table 1.5. The ratio of vegetable production in greenhouses to total production from 1975 to 1998 in Japan (after JGHA, 2001)

Crop	*1975*	*1979*	*1983*	*1990*	*1998*
Eggplant	32	35	37	38	34 (%)
Tomatoes	34	40	54	68	71
Cucumbers	49	53	57	62	65
Pumpkins*	31	37	37	36	39
Green peppers	60	66	65	68	64
Strawberries	81	85	89	95	99
Watermelons*	63	73	77	83	94
Lettuce*	28	30	32	32	35

* Tunnel cultivation is included.

Floating mulch has various advantages: 1) reduction in damage caused by typhoons, 2) protection from severe swings in weather, and 3) reduction in damage by birds and insects.

Materials for films are the non-woven fabric of Polyethylene Vinyl Alcohol (EVOH), PE, polyester and Polypropylene (PP), and materials for cheesecloth and net are polyester and PVA. The physical properties of these materials are listed in Table 1.6.

Table 1.6. Main physical properties of materials available in Japan for floating mulches (after Takakura, 1988)

Materials	*Light trans-missivity(%)*	*Emissivity (%)**	*Weight (g/m^2)*	*Price ($\$/m^2$)*
Non-woven				
EVOH	95	81	40	0.6 - 0.8
PE	90	13	35	0.4 - 0.5
Polyester	70 - 90	53	15 - 30	0.2 - 0.4
PP	80 - 90	16	20 - 25	0.2 - 0.3
Cheesecloth				
Polyester	70 - 90	53	30 - 50	0.8 - 1.0

* Emissivity of crude materials

1.5.4. PLASTIC WASTES

Waste treatment of used plastics has been one of the biggest problems since the amount of plastic consumption has increased drastically in recent years. In 1985, the total amount of waste exceeded 165,892 tons: 68.7 % was from vegetable cultivation and 12.0 % from field crop cultivation; 55.1 % was PVC and 38.2 % was PE.

Since 1970, plastic wastes have been required to be treated under industrial waste regulations; all users, mostly growers, must be responsible for treating the wastes they generate without producing any air and water pollution. It is illegal to throw away plastic wastes untreated because they form obstacles in rivers and other public places.

The methods of treating plastic wastes in Japan are 1) recycling, 2) burial, and 3) incineration (Table 1.7).

Recycling

Five types of recycling are used. a) Pellets and fluffs are generated from waste plastics. Collected waste plastics, mostly PVC, are first graded, and foreign materials are removed. After a rough crush, they are washed with water, and fine crush and drying make them final products. The recovery ratio from used materials is approximately 50% for PVC. The products are half-materials for plastic tiles, mats, sandals and fillers. b) Collected waste plastics, either PVC or PE, are crushed and then melted without washing. Plastic are extruded to make the final plastic products. c) Collected waste PE is crushed and mixed with sawdust or rice hulls to make solid fuels. Their calorific values vary from 5,630 to 10,050 kcal/kg, which is equivalent to that of coals and cokes. d) Waste PVC and PE can be treated to make hydrophobic materials for under-draining, (*i.e.*, plastic trays and pipes). e) Oil or gas can be regenerated by pyrolysis of waste PE.

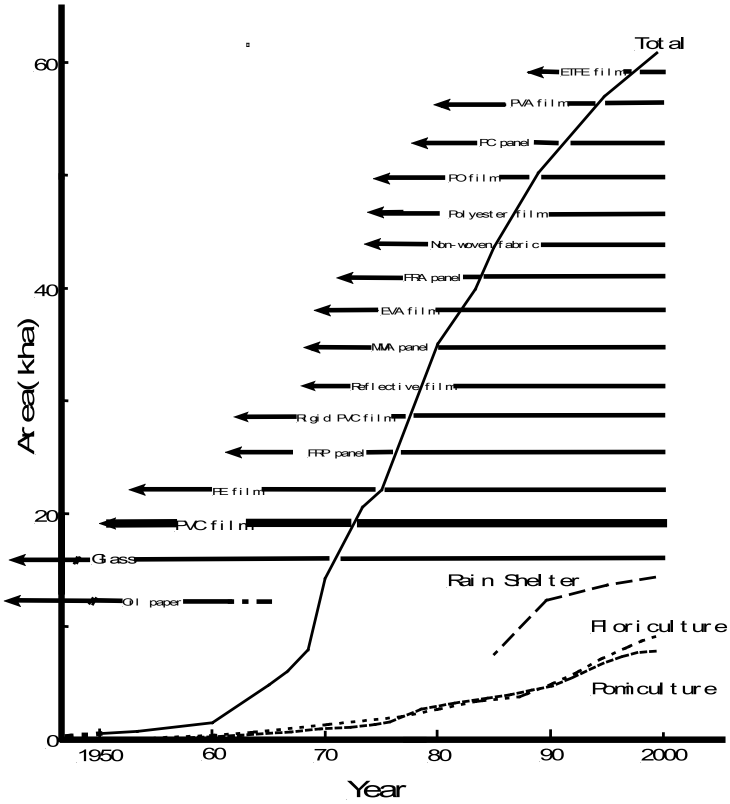

Figure 1.1. Trends in greenhouse development and covering materials in use in Japan (after JGHA, 2001).

Table 1. 7. Treatment of waste plastics in Japan (after JGHA, 2001).

Year	*1983*	*1987*	*1991*	*1995*	*1999*
Recycling	31,058	33,134	42,565	43,238	49,812
Burial	26,832	35,828	41,958	43,238	49,812
Incineration	64,620	75,801	76,090	72,448	31,423
Other*	35,390	29,946	23,303	22,147	35,319
Total (t)	157,900	174,709	183,916	190,515	178,887

* includes collection by companies.

Burial

Waste plastics that are not suitable for recycling must be buried according to the law of Japan, which also regulate the place and method of burial and pre-treatment.

Incineration

Incineration is also regulated by law. It is not recommended, but incineration of up to 100 kg/day at an authorized facility is allowed. More detailed and thorough approaches will be needed both technically and administratively.

PROBLEMS

1. List the concrete advantages of the usage of plastic houses over open field cultivation.

2. Why is air temperature in PE houses in general lower on cold nights than that in unheated PVC houses?

3. List the concrete advantages of floating mulches.

4. Describe briefly the recycling methods for waste plastics.