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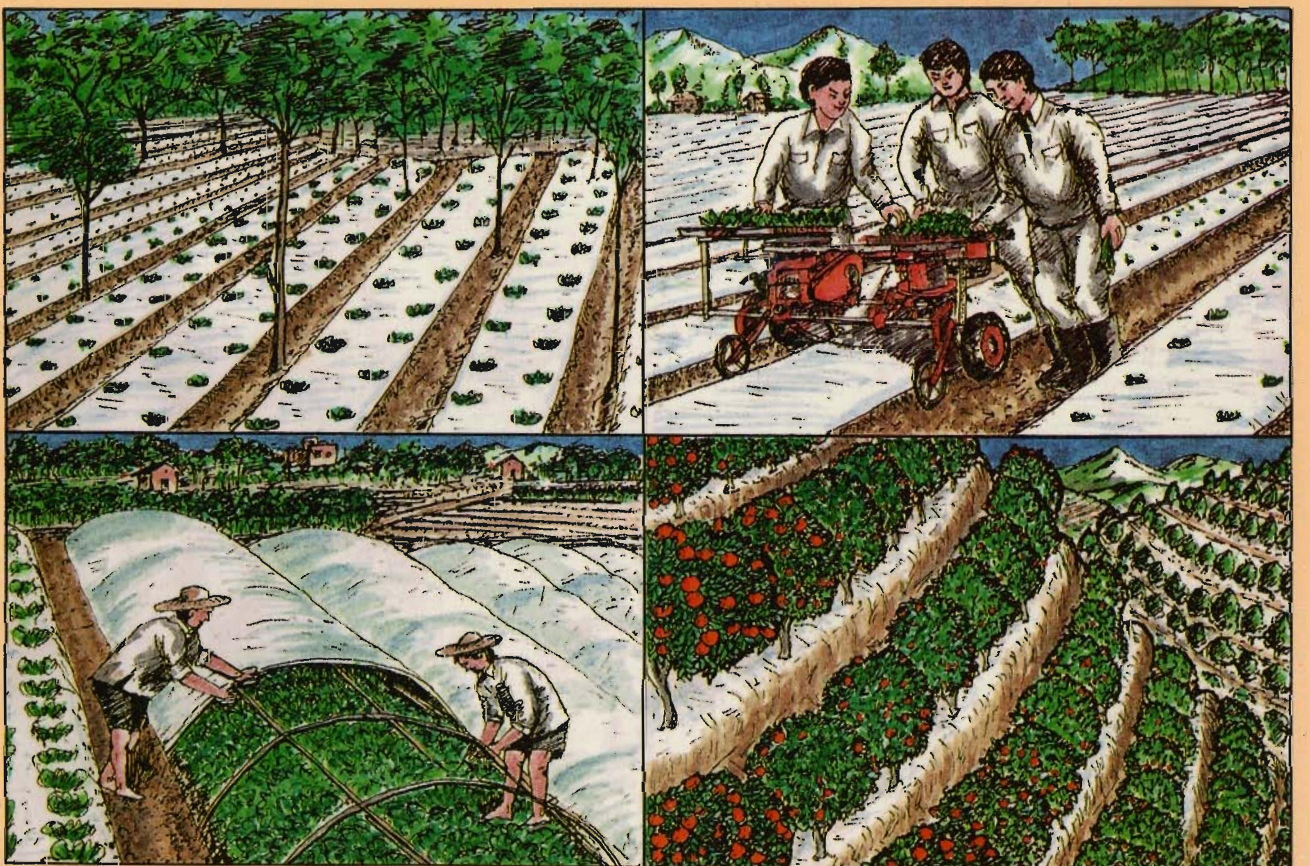
THE APPLICATION OF PLASTIC FILM TECHNOLOGY IN CHINA



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THE APPLICATION OF PLASTIC FILM TECHNOLOGY (PFT) IN CHINA

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FOREWORD

The International Centre for Integrated Mountain Development (ICIMOD) was established in 1983 to promote an ecologically sound development process in the Hindu Kush-Himalayan Region. An important mandate of the Centre is identification, documentation, and information exchange on promising technologies for sustainable mountain development.

Traditionally mulches of straw, leaves, ashes, and other agricultural residues have been used throughout mankind's agricultural history to modify the growing environment of food crops and other agricultural and horticultural crops. In more recent times, greenhouses have enabled farmers to advance and shorten the growing season of many crops.

The relatively new plastics' and polythene industry has made a modern version of a traditional technology possible. The 1950s saw the introduction of the use of plastic film into agriculture. It was soon found that use of this new material helped to increase temperatures, retain moisture, and promote seed germination and growth of young seedlings. It was also found to accelerate not only the growth and development of roots, but also of the whole plant; achieving high yields and good crop qualities. In short, a synthetic material was provided that was able to improve the results achieved with traditional mulches. Polythene film also reduces the need for large amounts of organic material for mulching.

In 1978, plastic film technology was first introduced into China and, at present, the technology is used in 29 municipalities, provinces, and autonomous regions, indicating its application in a wide range of climatic and soil/terrain conditions.

A technology that can modify the microclimatic growing conditions of food and other crops is highly relevant to the farming systems of the Hindu Kush-Himalayan Region where extreme weather conditions put severe limitations on producing adequate supplies of food. It is hoped that the present document will be a stimulus and incentive for agricultural research scientists and development workers in the other Regional Member Countries of ICIMOD to test and demonstrate the replicability of this technology.

Professor Lu Rongsen has gathered together Chinese experiences in the application of plastic film technology. It is a commendable piece of work and I gratefully acknowledge the commitment and technical analysis that has made this information available to a readership outside China.

Egbert Pelinck
Director General

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Grateful thanks are also due to all the technical reviewers who carefully appraised the document and made useful suggestions for its improvement.

Lu Rongsen

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I. Introduction

What is Plastic Film Technology?

For a long time, agricultural production has been constrained by low temperatures, drought, short frost-free periods, over-abundant precipitation, waterlogging, saline-alkali effects, and other adverse impacts.

From ancient times, farmers have used traditional mulch technology to overcome these adverse conditions, for example, by spreading straw or fallen leaves on the ground to protect the roots of crops and by putting stones near the plants to increase the temperature of the soil and reduce evaporation. These methods are useful, but they have many limitations which result in them not being very effective in overcoming the problems mentioned above; they also cannot be used throughout all regions and on all crops.

In the 1950s, plastic film was introduced into agriculture as a new film material which brought about great changes. Plastic film technology is considered to be an important breakthrough, transforming traditional agriculture into modern agriculture.

Plastic Film Technology (or Technology for the Promotion of Root Cultivation) uses plastic film (usually polythene film) for plant cultivation.

In Plastic Film Technology (PFT), the surface of the earth is covered with polythene film (0.014 ± 0.003mm) in order to increase temperature, retain moisture, promote seed germination and emergence, accelerate the growth and development of roots and of the whole plant, and achieve high yields and good crop qualities.

Following the introduction of this technology in China in 1979, it has been used over large areas, has proved suitable for many crops, has increased yields by considerable margins, has been highly lucrative, and has become so popular with farmers that it has compared favourably with other agricultural technologies. At present, this technology is used throughout China in 29 municipalities, provinces, and autonomous regions. According to Chinese farmers, "it is a white revolution".

Global Use of Plastic Film Technology

Plastic Film Technology developed along with the petrochemical and high polymer chemical industries. Many countries have successfully applied PFT in agriculture. Japan, which started to use PFT in the 1950s, is one of the earliest countries to take a lead in the use of PFT and is still the leading country in developing new covering materials, manufacturing varieties of polythene film, and introducing technological innovations. The United States, France, Germany, Italy, and Spain have also made significant achievements in studying, applying, and developing covering materials.

At present, PFT is very popular in Japan and it has become an indispensable, agricultural cultivation method. PFT was first used in greenhouses, in plastic canopy cultivation, and then on open land. Many crops, such as seasonal vegetables, peanuts, sweet corn, tobacco, rice, potatoes, sweet potatoes, soyabeans, sesame, tea, mulberries, citrus fruits, apples, pears, peaches, and grapes, have been cultivated using PFT. Out of these tobacco, sweet corn, strawberries, garlic, and lettuce are exclusively cultivated by using PFT. PFT helps prevent damage from insects and diseases, improves the quality and maturation of products, promotes earlier maturation, and increases yields by 30 to 50 per cent and sometimes by 100 per cent or more. By using PFT, many thermophilic crops can be successfully cultivated in the northern areas where such crops have never been cultivated. It has been proven that PFT can be used in arid areas (because it retains moisture and increases soil temperature), in cold areas with short frost-free periods (because it increases soil temperature and effectively prolongs the growth period), and in wet areas with high temperatures (because it protects crops from waterlogging and controls the loss of nutrients from the soil).

In Japan in 1975, PFT was applied in the cultivation of vegetables, peanuts, tobacco, and rice, over an area of 158,00 hectares. In 1977, this increased to more than 200,000 hectares, accounting for 16.7 per cent of the total area (except for orchards and pasturelands). During this period, plastic film application machines were popularised in Japan. Large or medium-sized machines could be drawn by tractors and small-sized machines were suitable for manual operation.

In order to promote the development of PFT, an Association of Rice Cultivation with PFT was formed in 1965 and the name was changed to the Japanese Association of Plastic Film Technologies in 1969. The association is responsible for research, demonstration, and extension through the organisation and mobilisation of agricultural institutions, universities, factories for manufacturing PFT products, and households specialising in PFT. These institutions have carried out a series of experiments and demonstrations on environmental changes caused by the application of PFT, studied the effects on the growth and development of various crops, and devised operating technologies for different crops. They have also studied the spectrum of various polythene films and their effect on the enzymatic activities and photosynthesis of roots. They have studied the effect of capturing and avoiding reflex light from different types of polythene films and the effect on the colour and quality of fruit. Through these efforts, Japan has been making improvements in the application of PFT.

The United States, which is not comparable to Japan in crop species and area, has considerable achievements to its credit also. It has carried out research on PFT and developed new covering materials. For example, the U.S.A. has studied and applied seedling-protective film in the field, disinfectant film to prevent diseases, biodegradable polythene film (which can be absorbed by the plant after use), and porous film sheet made of decomposable cellulose which can be used to protect seeds and soil from erosion.

R.L. Carolus of Michigan University carried out extensive experiments on vegetables by using black PF. The results of eight years' research (1954-1962) have proven that PF can promote the growth of vegetables in the early stages, increase the early stage yield, and increase total yields which vary according to species and varieties. For example, musk melon and cucumber are sensitive and respond better than tomatoes and sweet pepper; the early stage yield of pumpkins is higher than contrast crops by 18 per cent, and the yield of "Baby Hybrid" muskmelon, grown during cool seasons, increased by 76 per cent in comparison with contrast crops. The early stage yield of "Fireball" tomatoes covered with PF (with irrigation) increased by 109 per cent in comparison with contrast crops. R.L. Carolus considered that the advantages of black PF were that it is inexpensive, is durable, protects crops from weeds, saves labour, increases yields, improves the quality of crops, and has great potential.

California is the foremost State for strawberry cultivation in the United States. When the strawberry fields were covered with PF (black PF or black-white PF), strawberry yields reached 104 tonnes per hectare. In Hawaii, for pineapple cultivation, the land is first covered with black PF, holes are punched in the PF, and finally the seedlings are planted through the holes. It is believed that black PF can kill weeds and increase yields and that results are even better in arid areas.

G.J. Hoenmuth (1983) studied the effects of black PF and ridge farming on sweet potato cultivation in northern America. The production of American sweet potatoes is concentrated in the south mostly, but a well-known area for sweet potato cultivation stretches along the Atlantic coast from New Jersey to Georgia. In the north, e.g., New England, natural conditions are unfavourable for sweet potato cultivation. In this experiment, the "Gem" variety of sweet potato was cultivated by ridge farming and covered with black PF. The results showed the leaf area, the leaf number, and the total dried weight of viticulae of the experimental plants to be higher than contrast crops. The yield of tubers reached 18.6 tonnes per hectare. The number of first-grade tubers apparently increased. The experiment proved that it was possible to increase the yield of sweet potatoes in the northern areas.

PFT is not only used in semi-arid areas, but also in countries where sufficient water resources exist, e.g., the Mediterranean countries. In 1961, PF was used to cover only several hundred square metres of cucumber fields in France, but, after 10 years, the PF-covered areas had reached 2,500 hectares and cucumbers, muskmelons, tomatoes, strawberries, lettuce, grapes, and asparagus were cultivated by the application of PFT. In 1965, Italy began to use PF to cultivate cash crops such as vegetables, strawberries, pineapples, tobacco, and coffee. From 1978 to 1980, a trial was carried out in Britain on cultivating potatoes by using PF and the yield of potatoes increased to six to seven tonnes per hectare and matured seven to 14 days earlier than before. At present, three kinds of polythene film (Coverall, Sanfilm, and Blanker) are popular in Britain.

In the CRS (the former USSR), in early spring when temperatures and humidity levels are lower, PF is used to increase the soil temperature and retain moisture. According to experiments using PF during 1974 to 1977, the maturation of strawberries was four to six days earlier than on open land. The leaf area, the number of stolons, the percentage of fertile fruit, and the yield were also higher. On the other hand, as the fruit did not touch the soil, the incidence of mould rot was lower than without PF, and the economic benefit was evident. The results of other experiments with PF showed that when the strawberry fields were covered by a small canopy above the ridge, the temperature in the canopy increased by 309.3°C, the relative humidity increased by 20 to 30 per cent, the percentage of fertile fruit increased by 26.5 to 78.4 per cent, and the total yield increased by 67.5 to 78.9 per cent.

In recent years, PFT has been applied and popularised rapidly in different countries. In Bulgaria, milk-white PF is used for tank agriculture (nutrient solution cultivation) and black PF is used for strawberry cultivation. The PF is replaced every three years. In Morocco and Algeria, the area of commercial vegetable gardens using PF has been increasing year by year. In the Netherlands, a comparative experiment on apple trees, which were grafted on to one-year old dwarf stocks covered by black PF and cultivated through sod culture, was carried out in News Station. After several years, the results showed that the yield of apple trees covered by black PF increased 1.5 times more than the yield of those cultivated using sod culture. In addition, the apple trees covered by black PF had advantages in terms of a strong root system and more lateral and small roots; less weed growth and protection from frost; and therefore savings in labour and cost. In Portugal, it was found that young pear trees covered by PF increased their trunk girth by 48 per cent. In Spain, newly-planted young citrus trees covered by PF compared favourably with other trees in terms of the damage caused by tilling and weeding. The PF also retained moisture and controlled weeds around the young citrus trees. In Tunisia, when a citrus orchard was covered by black PF, the yield increased by 50 per cent, the water for irrigation was saved by 30 per cent, and weeds were also controlled. In Cape Verde, it was found that less irrigation water was needed when PF was used in banana orchards.

According to the statistics of the Council of International Plastics for Agriculture (CIPA), every year the member countries of CIPA consume more than one million tonnes of plastic resin (excluding packing materials), 70 to 80 per cent of which is used to manufacture products to develop modern agriculture. Table 1-1 shows the areas using PF in different countries (1980-1983).

Table 1-1: The Areas Using PF in Different Countries

Unit: hectare

Country	1980	1983	Country	1980	1983
China	1,667	6,286,700	Hungary	1,000	-
Japan	175,000	207,441	German	1,775	-
American	80,000	-	Belgium	1,000	-
France	35,000	48,000	U.K.	300	1,000
Spain	26,000	32,600	Portugal	1,800	2,000
Italy	9,000	-	Czechoslovakia	320	500
Israel	2,000	-	Mexico	400*	-
Bulgaria	1,000	-	Argentina	400*	-

Source: Chinese Association of Plastic Film Technology : A Complete Value of Plastic Film Technology, 1988

Use of Plastic Film Technology in China

The petrochemical industry developed later in China than in the western countries. From the end of the 1950s to the beginning of the 1960s, PF was used to manufacture small canopies for vegetables to promote earlier cultivation in the suburbs of Beijing, Shanghai, and Tianjin. It was also used for rice seedling cultivation in some southern areas of China. In 1966, the first big PF canopy was used in Changchun, Jilin Province. In 1978, the area covered by big PF canopies reached about 5,400 hectares and parts of used PF canopies were used as ground covers, bringing evident economic benefits. But this technology did not become popular on a large scale because the PF used was very thick (about 0.1mm) and could not nestle close enough to the earth, therefore it was unable to increase temperature and retain moisture. In addition, every hectare needed about 1,500kg of PF, making it very expensive for and unaffordable by farmers.

In 1978, several PF technologies (including agronomic methods, special PF, and complete covering machines) were introduced from Japan into China. By means of comprehensive studies and demonstrations, PFT was gradually popularised throughout the whole country. In order to disseminate this technology over a wider area, and to promote the exchange of existing knowledge, some organisations were established to study and domonstrate PFT. In 1980, the Liaoning Association of PFT was formed. Under the association, several study groups conducted research on the following topics: vegetables, cotton, peanuts, tobacco, rice, and PF. As a result of the activities of the association, by the end of 1981 the area using PF reached 4,700 hectares, accounting for one-third of the total area using PF in the country. Since then, many study groups, associations, a united experimental group, and cooperative agencies have been set up in 17 provinces, greatly accelerating the development of PFT. In 1984, the Chinese Association of PF Research was founded in Beijing. Nine special study groups were formed for various crops and inputs: cotton, peanuts, vegetables, melons, tobacco, rice, sugar crops, PF, and PF machines, and, through experiments and demonstrations, PFT was further developed. At the same time, information on PFT and its applications was disseminated. These efforts were successful in popularising PFT over a wider area and in imparting training to personnel.

Over the years, the application of PFT in diverse areas and on a variety of crops increased rapidly and breakthroughs were also achieved in research. In 1979, the total demonstration area reached 1,600 hectares and, in 1982, it totalled 118,000 hectares. Again in 1984 and 1985, it reached 1.33 million hectares and 1.47 million hectares respectively. In 1986, it reached 1.80 million hectares, making China the world leader in terms of the extent of PF usage (see Table 1-2). In 1991, the total PF application area reached four million hectares.

In other countries, PF is mainly used to cultivate horticultural crops such as vegetables, strawberries, and melons, but, in China, it has been used successfully to cultivate more than 80 species, e.g., vegetables, cotton, peanuts, tobacco, and melons as well as for rice seedling culture, dried rice cultivation, sugarcane, beets, mustard, fibre crops, mulberries, tea, sunflowers, fruits, herbs, and medicinal plants. It is used extensively in nurseries, and more than 40 species have performed very well and yielded good profits.

Concomitantly, basic research on the effects of PF has been carried out by Chinese scientists. They have carried out comprehensive research on the effects of PF on the growth and development of crops, the function of metabolism in roots, enzyme activity, photosynthesis, formulation of yield, absorption and transportation of nutrients, and other physiological and biochemical problems. They have also studied the effects of light, heat, water, air, and fertilisers, while using PFT, on the germination of seeds, vegetative and reproductive growth, and the development of individual plant and crop population. They have put forward a theory of the "Relatively Stable Effect of PF on the Environment." The important conclusions are that the effective accumulated

Table 1-2: The Total Area of Crops Covered with PF in China (1979-1986)

(Unit: Hectare)

Year	The Total Area	Cotton	Vegeta- bles	Peanuts	Rice Cul- tivation Seedlings	Melons	Dryland Rice Culti- vation	Sugarcane	Beets	Tobacco	Maize	Other Crops
1979	442		433	07								02
1980	1,667	53	1,500	67		13						33
1981	20,733	3,927	7,147	2,513	1,400	327	37					0,050
1982	118,333	57,067	20,667	20,113	13,920	4,820	0,440					1,307
1983	629,133	437,980	50,527	39,200	72,333	20,933	1,093	3,000	0,320	1,180		2,567
1984	1,333,333	853,333	58,000	92,000	187,333	58,667	1,500	6,320	4,067	1,193	16,667	54,253
1985	1,466,667	589,333	99,333	266,000	212,000	143,333	5,400	14,200	5,533	7,200	40,667	83,667
1986	1,800,000	466,000	142,333	265,667	302,000	319,533	9,333	20,667	3,800	17,333	98,000	155,333
Grand Total	5,369,913	2,407,693	379,553	685,56	788,987	547,627	17,807	44,187	13,720	26,907	155,333	297,213

Source: Chinese Association of Plastic Film Technology: A Complete Value of Plastic Film Technology, 1988 temperature of each growing season can be increased by 200° to 300°C by using PF. Crops grow and develop seven to 10 days earlier because the PF helps to retain heat; PF enables some crops to be cultivated further north by about 2° to 5° in latitude, i.e., northwards by 500 kilometres. These conclusions provide a new scientific basis for the rational distribution of crops and rational land use.

Research on and manufacture of PF and its application machines advanced at a rapid pace. In 1979, PF of a special kind was developed for covering cultivated crops. Following this, new types, such as various shades of PF, light-reflex PF, weed-killing PF, light-degrading PF, long-lasting PF, and PF with slits, were manufactured. In 1983, two types of ultra-thin PF (HDPE and L-LDPE) were developed and these ultra-thin PFs enabled farmers to reduce the required amount of PF per unit area and also to reduce the cost. In the same year, the Ministry of Light Industry of China promulgated the standard of PF manufacture, through which the quality of PF was guaranteed and PF became easily available in the market. In 1980, the first application machine was manufactured and, in 1984, more than 60 types were developed, one after another, and, by the end of the year, the total number of application machines was more than 12,000. These machines increase efficiency tenfold. In addition, they can guarantee good operating quality, save the amount of PF required, and ensure that seasonal farming activities are carried out on time. These machines have been widely adopted on some big State farms in the northwest and the north of China. By the end of 1984, the area on which PF machines were used reached 133,333 hectares, accounting for 10 per cent of the total PF applied area.

Economic Benefits of Plastic Film Technology

Generally, PFT enables various crops to mature five to 20 days earlier than normal, increases the yield by 30 to 50 per cent, and increases output value by 40 to 50 per cent. By using PF, vegetable yields can be increased by 1,1250 to 22,500kg per hectare and the harvest period can be shifted or prolonged by 40 to 60 days. Cotton plants also bear more bolls before the hot summer days and more flowers before the frosty period, if PF is used. The cotton fibres also grow longer than normal. Peanuts grow vigorously and bear more fruit and seeds when PF is used. Compared to other methods, the yield of peanuts can be increased by 1,125 to 1,875kg per hectare with PFT. When water melon fields are covered with PF, the fruit matures 10 to 20 days earlier than normal and the sugar content increases by one per cent. When orchards are covered with PF, fruits, such as apples, grapes, and peaches, mature earlier and the quality also improves. For example, sugar content and Vitamin C increase and the colour of the fruit is better. It is found that when PF is used in rice nurseries, the quality of young seedlings improves and the cost is one-sixth of that of nurseries using small canopies.

The direct economic benefits from PFT accrue to farmers, extension workers, and decision makers. Table 1-3 shows the direct economic benefits obtained by farmers in two provinces of China.

When these seedlings are transplanted into the rice fields, their restoration period is shortened, more tiller seedlings are produced, and rice yield increases by 450 to 600kg per hectare. In forest nurseries, if PF is used, the percentage of successive

Table 1-3: The Economic Benefits due to Polythene Film Technology (PFT) from Different Crops in China

Unit : US$

Crops	Using PFT Output Value/ha	Without PFT Output Value/ha	Polythene Film Cost/ha	Net increased Value/ha	Ratio Input: Output
Yunnan Province			1985-1987		
Maize	411.6	184.8	48	136.8	1:2.85
Maize	688.8	450.0	60	178.8	1:2.98
Rice	468.8	300.0	48	120.8	1:2.50
Sugarcane	2044.8	1644.5	48	380.3	1:6.92
Watermelon	2586.6	1707.2	63	816.4	1:12.96
Tobacco	1191.6	744.5	60	387.1	1:6.45
Peanut	672.1	264.5	48	359.6	1:8.49
Jiangsu Province			1980-1982		
Potato	760.0	140.7	108	511.3	1:4.73
Cucumber	2978.4	1709.7	108	1160.7	1:10.74
Cucumber	1628.4	946.0	108	820.4	1:7.59
Chilli	2237.8	1385.7	108	746.6	1:6.88
Kidney bean	1146.0	828.0	108	213.0	1:1.97
Cowpea	918.2	622.9	108	187.3	1:1.73
Radish	665.1	230.9	64.8	369.4	1:5.70

Source: Collected by the author from various Chinese documents

seedlings can be transplanted earlier than normal. Plastic Film has been found to increase the output and value of sugarcane; because PF encourages the growth of stubble cane sprouts, the yield of sugarcane also increases by 4.5 to 15 tonnes per hectare. If PF is used, the yield of beet increases by 30 to 80 per cent without a reduction in the sugar content and the extracting season for beet is brought forward. Plastic Film raises the yield of food crops such as corn, wheat, Chinese sorghum, potatoes, and sweet potatoes by large margins.

From 1982 to 1984, the total PF area in the whole of China reached 2,095,000 hectares. When PF was used, the yield of ginned cotton increased by 407,000 tonnes, peanuts by 229,500 tonnes, vegetables by 1,896,500 tonnes, rice by 1,115,000 tonnes, and melons by 1,048,500 tonnes. PFT application also promoted the transformation of traditional agriculture into modernised agriculture, resulted in better crop zonation, in wider distribution of varieties, and improved the use of land resources. A few examples are given below.

In northern, northeastern, and northwestern China, the climate is characterised by inadequate rainfall and short frost-free periods. In order to promote the early maturation of cotton, peanuts, and corn, the farmers used to grow varieties having short maturation periods, or the early-middle varieties for which the yields and qualities were not good. After these crops were covered with PF, the accumulated temperature increased and the growing season was prolonged. The middle or middle-late maturing varieties, for which the yields and qualities are much better than the early varieties, could be grown on large areas, and the use of PF greatly increased the total output of these areas. In other words, various crops, which were not cultivated there before, can now be cultivated in the north, thereby making fuller use of land resources.

Earlier, farmers adopted the wild flooding irrigation method in which a lot of water was wasted and the crops were infested by insects and diseases. As PF conserves soil moisture and enables the root system to penetrate deep into the soil, PF is drought-resistant and its use can reduce water requirements and also the frequency of irrigation. Thus, water resources can be used fully and effectively.

Formerly, in order to retain moisture, farmers used to plant crops on low ridges. This had drawbacks such as making the soil hard and impervious, lowering soil temperatures, and inhibiting development of the root system. Plastic Film can be used to cover the ridges in high ridge farming, thus retaining the heat and moisture. Fertilisers are mainly applied on the ridges and the soil can maintain its wet, porous condition. Therefore, high ridge farming with PF can promote the emergence of seeds, accelerate the growth of plants, and cause crops to mature earlier.

How to improve and exploit saline-alkali soil is a complex agricultural problem. At present, effective measures are being used to improve saline-alkali soil, e.g., using lots of water for irrigation, mixing the soil with sand, digging deep furrows, and cultivating crops by transplanting seedlings. All these measures are successful, but the application of PF on saline-alkali soil produces better results because it effectively restrains salts and protects seedlings.

The information provided in this chapter gives cited evidence of the effectiveness of PFT. This technology requires quite low investments and yields rapid results with high benefits. It is considered to be a very significant innovation in agricultural development. Because of its multiple effects, it is suitable for application on diverse crops, therefore, it can be used not only in the plains and mountains, but also on low-lying, saline-alkali land and where rainfall is insufficient, or where drought frequently occurs. At present, this technology is rapidly becoming popular in both developed and developing countries. It has been successfully applied in Japan, the United States, Germany, France, and China. It is and will be an indispensable and important link in the development of cultivation technologies and will play an important and stabilising role in sustainable agriculture as a whole.

II. The Basic Principles of Plastic Film Technology

PF can transform solar energy absorbed by the soil increasing into thermal energy, thereby increasing the evaporation of water from the soil and facilitating the activity of soil microorganisms, thereby decreasing the rate of fertiliser use and improving the soil's physical properties. In comparison to open land, both the soil and the environment of the land covered by PF improves considerably. This integrated effect strengthens the physiological functions of crops and accelerates its growth and development processes, resulting in high yields and good quality.

Enhancement of Reflex Light and Increase in the Intensity of Photosynthesis

Enhancement of Reflex Light

Crops use solar energy in photosynthesis. Through this process, organic compounds (especially carbohydrates) are formed from carbon dioxide and water, resulting in the liberation of oxygen from chlorophyll-containing plant cells. The growth, development, ripeness, yield, and quality of crops depend on the hours of sunshine and the intensity of sunlight. When sunlight is received by the leaves on the surface, it is reflected among the rest of the leaves. In vigorous crops, the middle and lower leaves wither quickly because they do not receive enough light. By using PF, this additional light can be received from the reflex light of PF and from the drops of water which are trapped by the PF, thus enabling more light to penetrate between leaves and between rows.

According to research carried out by the Department of Horticulture of the Northeastern Agricultural College, China, 15cm above the earth surface the reflection from fields covered by PF is 14 per cent, but the reflection from open land is only 3.5 per cent, i.e., an additional 10.5 per cent of light energy will be used in photosynthesis with the use of PF. In 1981, Shanxi Institute of Cotton Cultivation observed that the reflection from cotton fields in which PF was used was higher by 28.2 to 40.8 per cent in comparison to open land. The Vegetable Institute of the Tianjin Academy of Agricultural Sciences discovered that the intensity of light reflected differed owing to altitudes and the width of ridges.

In the case of narrow high ridges, 20, 40, 60, 80, and 100cm above the bottom of the ridge, the reflection intensities are higher by 13, 98, 31.7, 12.1, and 9.2 per cent respectively and in the case of wide high ridges, they are higher by 91.6, 142.2, 116.4, 78.8, and 63.4 per cent respectively. It was concluded that the land between rows and plants received more sunshine on high wide ridges than on high narrow ridges.

PF can evidently increase the amount of sunshine received by crops, especially at 30 to 35cm above the earth's surface. At this point, the intensity of light reflected from PF is higher in comparison by 1,000 to 1,500lux. This increased sunshine not only accelerates the maturation of wheat and increases the weight of grains, but also facilitates the early emergence of cotton seedlings that are bigger and stronger.

The intensity of light reflection differs according to the colour of PF used. According to research carried out by Cao Xiao Zhi, the Horticultural Department of the Zhejian University of Agriculture, the highest intensity is received from silver PF and the lowest from black PF.

Usually, fruits growing inside the crown of a tree receive less sunshine. When orchards are covered by PF, the light reflected improves the colour and quality of apples, peaches, and grapes.

Prolonging the Effects of Light

Photosynthesis in crops can take place only under a certain intensity of light, the minimum intensity of light being the compensation point. With increasing intensity photosynthesis is strengthened and more organic matter synthesised. However, when the intensity of light crosses saturation point, the effects of photosynthesis do not increase and the crops will be harmed by the too strong light. PF not only increases the amount of sun-shine received by the land between rows and plants but also gives added light reflection and fuses scattered light, enabling crops to attain maximum light intensity and also preventing the light from decreasing to compensation point. In other words, PF can prolong the duration of efficient light, increase the intensity of light, and promote the utilisation ratio of light. Thus, the effects of photosynthesis are enhanced. Hence, PF can increase crop yields and promote earlier ripening.

Enhancing Photosynthesis and Strengthening Crop Functioning

The intensity of photosynthesis depends upon the duration of light, the intensity of light, the concentration of carbon dioxide, the amount of absorbed inorganic salts, the temperature of leaves, and the chlorophyll content. PF can enhance photosynthesis by providing more energy through increased intensity of reflected light and prolonged duration of light.

According to an experiment conducted by the Department of Horticulture of the Northeast Agricultural College, when a tomato field was covered by PF, the pure intensity of photosynthesis was 50.82mg while in the control field it was only 27.61mg. PF increased the intensity of photosynthesis by 23.21mg, i.e., 85 per cent in comparison to the control field.

According to another experiment conducted by the Department of Horticulture of Northeast Agricultural College, when a tomato field was covered by PF, the total area of the leaves was $94.15dm^2$ (sq. dm.) and the coefficient of the leaf area was 4.49, while in the control area the same were $75.22dm^2$ and 3.58 respectively, i.e., 23 per cent and 25 per cent less respectively. The content of chlorophyll increased by 25 per cent, the total sugar content by 26 per cent, and the ratio of C/N by 23 per cent. PF improves various physiological processes, strengthens the synthesis of organic matter, and increases the accumulation of dried materials, thereby enabling crops to increase their yields and to ripen early.

Effect of PF on Temperature

One of the important effects of PF is the increase in land temperature. PF provides thermal energy for the emergence of seeds, the growth of root systems, and for microbacterial activity in the soil.

Effect of PF on the Heat Exchange of Soil

The heat exchange pattern of soil covered by PF differs from that of open land. On open land, when solar radiation penetrates the soil, light energy is transformed into thermal energy. Thermal energy heats the air near the soil by exhausting efficacious radiation from the soil surface, enhancing the temperature of the soil surface, and evaporating water from the soil. During the night, thermal energy in the soil is emitted into the air by means of long-wave radiation. When the soil is covered by PF, the exchange and balance of natural thermal energy changes. During the day, sunlight penetrates the soil directly through PF and increases the temperature of the soil surface, consequently thermal energy shifts to the lower soil layer. Obstructed by PF, thermal energy is not emitted into the air and the amount of heat exhausted by the air flowing near the surface decreases, meanwhile, evaporated water is trapped by PF and the heat of gasification also decreases. This thermal energy is deposited in the soil and shifts to an under layer. So soil under PF receives more thermal energy than open land and the temperature in the cultivated soil layer also increases.

Effect of PF on Temperature and Its Changing Patterns

It has been proved by experiments and practices in different places (see Table 2-1) that PF can increase temperature. The degree of increase depends upon soil type, weather, season, region, and the growth stage of different crops. The increase in temperature range, resulting from the use of PF, is restricted by the kind of ridge constructed and the quality and kind of PF used.

According to an experiment carried out by the Institute of Cotton Research of the Chinese Academy of Agricultural Sciences, when slight and mid-saline-alkaline soil were covered by PF, the average temperatures were higher than on open land by 3.9°C and 2.7°C respectively. When flooded sandy soil, sandy loam soil, and slight sandy loam soil were covered by PF, the average daily temperatures were higher than on open land by 3°C, 3.3°C, and 43°C respectively. With increase in temperature by using PF, the rate of emergence and the stability and healthy growth of seeds can be enhanced. When PF is used to cultivate cotton, problems such as low temperatures of saline-alkaline soil in the first seasonal stage, plants that fail to emerge, late emergence, delayed maturation, and low yields of cotton can be solved. The Jingzhou Institute of Agricultural Sciences found that, notwithstanding the weather conditions, the temperature of the soil layer cultivated with peanuts increased when PF was used.

Different colours have different effects on temperature. According to research carried out by the Department of Horticulture of Zhejian Agricultural College, the range of temperature increase for various colours of PF was one to four degrees centigrade; e.g., opal PF, bi-coloured PF, and green PF can increase the temperature by two to three degrees centigrade; black PF and PF that is black on one side can increase the temperature by one to two degrees centigrade; and silver light reflecting PF can reduce the ground temperature by one to two degrees centigrade at noon within a five-day period but can increase the ground temperature by two degrees centigrade in the morning and evening. During the middle to late growth stage, when plants grow vigorously and shade the ground, PF does not increase the temperature of the soil, but, on the contrary, it decreases the temperature by one degree centigrade compared to open ground.

Table 2-1: Effects of Plastic Film on Soil Temperature

Increase in Soil Temp. (°C)	Test Time	Depth of Soil Layer (cm): 0	(0+5)/2	5	(5+10)/2	10	(10+15)/2	15	(15+20)/2	20	Average Temp. Increase (°C)
Plastic Film	8:00	33.6		28.5		25.2		24.5		23.6	3.3
Open Land		27.8		25.0		22.4		22.0		21.6	
Value of Increased Temp.		5.8	4.7	3.5	3.2	2.8	2.7	2.5	2.2	1.8	
Plastic Film	14:00	41.2		33.2		30.3		25.7		25.8	3.8
Open Land		33.0		29.5		27.4		23.5		23.7	
Value of Increased Temp.		8.2	5.9	3.7	3.3	2.9	2.6	2.2	2.2	2.1	
Plastic Film	20:00	26.9		28.0		27.4		26.4		24.6	3.0
Open Land		22.3		24.4		24.3		24.1		23.0	
Value of Increased Temp.		4.6	4.1	3.6	3.4	3.1	2.7	2.3	1.9	1.6	
Increase in Temp. per Day		6.2		3.6		2.9		2.3		1.8	3.4
Range of Variation of Increased Temp.		3.6		0.2		0.3		0.3		0.5	
Difference between Adjacent Layers			2.6		0.7		0.6		0.5		

Source: Northeastern College of Agriculture 1980

Accumulated Temperature

Crop growth and development take place under certain temperatures. Ground temperature influences the germination of seeds and affects the adhesiveness of solutes in soil solution. In other words, ground temperature has a very important influence on the growth, maturation, yield, and quality of crops because it affects the absorption intensity of water and inorganic salts through root synthesis and the physiological functions of roots. Therefore, ground temperature is more important than air temperature.

According to the experiment carried out by the Department of Horticulture of the Northeastern College of Agriculture, PF can effectively increase the accumulated temperature by 15°C which means that PF can increase the days of high temperature. For example, when kidney bean fields are covered by PF, the active accumulated temperature is higher by 190.9 per cent than on open land and it enables the plant to emerge 10 days earlier (see Table 2-2).

Table 2-2: Growth Period of Kidney Beans with and without PF Use

Growth Period	Sowing-Emerging		Emerging-Flowering		Flowering-Fruiting		Fruiting Harvesting		Total Days
	Date	Days	Date	Days	Date	Days	Date	Days	
Plastic Film	29 April - 7 May	8	7 May - 28 May	21	28 May - 29 June	7	4 June - 29 June	24	60
Without Plastic Film	29 April - 17 May	18	17 May - 4 June	18	4 June - 11 June	7	11 June - 3 July	23	66
Difference in Days		+10		-3		0		-1	+6

Source: North-eastern College of Agriculture 1980

The increase in active accumulated temperature can provide enough thermal energy for the emergence of seeds and the growth and development of crops so that they mature and bear fruit earlier. In this way, PF increases the yield of kidney beans and promotes early maturation. In the areas of early-maturing cotton in Liaoning Province, the active accumulated temperature from the date of sowing to the middle of July increased by 23°C, and this accelerated the emergence of seeds and the growth of young seedlings despite the damage caused by cold to the young seedlings in early spring. PF can provide precious thermal energy for early emergence, accelerated growth, and increased cotton yields.

The results of a trial carried out in maize fields in Hanghe County, Inner Mongolia, are given in Table 2-3.

From this table, it can be observed that the use of PF in maize fields can promote early emergence, strengthen the root system, accelerate growth, make full use of light and thermal energy in the early stage of growth, and overcome the effects of inadequate heat and of damage caused by cold, thereby increasing maize yield.

Previously, peanuts could not be cultivated on open land in Yichun, Heilongjiang Province, and Changtu, Liaoning Province. With the use of PF, peanut cultivation became possible; yields reached 2,250 to 3,000kg per hectare, and the area under peanut cultivation is gradually increasing.

In the north of Daqingshan, Inner Mongolia, watermelon did not ripen in many cases because of an inadequate accumulated temperature and a short frost-free period. The use of PF not only enabled the maturation of watermelon but also increased its yield.

As PF can facilitate a stable increase in accumulated soil temperature of 300°C, it is possible to cultivate improved, high-yielding varieties, increase the yield per unit area, and expand the area under thermophilic crops in northern China. Therefore, PF is

Table 2-3: Effect of PF on Accumulated Soil Temperature and Maize Yield

	Date of Sowing	Date of Emergence	Accumulated T. in 0 to 5cm Soil	Daily Average T.	Yield/ha
Maize Field with PF	4 May	15 May	295.0°C	24.6°C	10,470.3kg
Maize Field without PF	4 May	15 May	455.5°C	20.3°C	7,307.5kg

Source: Wang Yaolong et al. 1988

very useful in the exploitation of natural resources, appropriate use of land, and in the regional distribution of crops.

Acceleration of the Mineralisation Process of Fertilisers and Improvement in Soil Fertility

PF can maintain a wet, loose (porous), warm, and fertile environment by adjusting the balance of water, fertiliser, air, and heat. As a result, the activity of microbes in the soil is strengthened and the process of mineralisation of fertilisers is accelerated. The available nutrient elements and fertiliser efficiency also increase. PF enables the maintenance of a high level of soil fertility and provides a favourable environment for the growth of crops.

The Agricultural Bureau of the Xingjiang Autonomous Region has determined that, after using PF, the content of nitrobacteria and anaerobic bacteria in the soil increases ten times and the content of actinomycetes increases by 80 per cent. As the activity of these microbes increases and the mineralisation process of organic matter is accelerated, the available nutrients in the soil increase considerably during the early stages of growth. In an experiment carried out by the Institute of Vegetable Research, Shandong Academy of Agricultural Sciences, the content of available nitrogen in the fields in which PF was used was 165ppm in comparison to 110ppm in the control field, i.e., an increase by 50 per cent. The phosphorous and potassium content also increased when PF was used.

The nutrient content of a field covered by PF is evidently higher than that of an open field in both the full bloom stage and in the fruit-bearing period, and the exhaustion rate of nutrients is also higher than that of open fields. Therefore, it is necessary to apply more basic manure, additional fertiliser, and to maintain a high level of soil fertility to overcome the premature decay of crops and obtain sustainable high yields.

Reduction in Water Evaporation from the Soil and Maintenance of Moisture Content

The Law of Movement of Soil Water

Irrigation, precipitation, and groundwater are the water sources of soil. The main causes of water loss are evaporation from the soil surface, transpiration of crops, seepage of water into the ground, and less runoff on the soil surface. PF can change the natural distribution and movement of water in the soil and form a special law of distribution and movement. Firstly, it controls the evaporation of water from the soil surface and deposits the evaporated water under the

PF. This water that is deposited in the narrow space between the PF and the soil increases the atmospheric pressure of water and the saturation deficit is reduced. When the dew-point temperature increases, the water-drops are condensed and absorbed by the soil, especially in the mornings and evenings. With increase in temperature, they evaporate and, when the temperature decreases, are condensed again. This special water-cycle is constantly maintained with the use of PF.

When PF is used, more water is deposited in the cultivated soil layer, and this is absorbed by the crops. Secondly, due to capillary action the water in the deep layer rises to the cultivated soil layer through the capillaries. Rain or irrigation water cannot seep perpendicularly into the ridge that is covered with PF, but it can seep horizontally into the place where the roots are distributed. Generally speaking, this process lasts 24 hours. During this period, damage and/or crop failure caused by water-logging are prevented by the timely drainage of water. PF can also prevent the alluvial loss of soil nutrients caused by perpendicular water seepage. Water loss under PFT is mainly through the transpiration process. A certain amount of water runoff occurs from the crop holes on the PF (from the ridges). Therefore, retention of water evidently depends on the size and quality of PF.

Maintaining Water Content

Maintaining the water content of the soil is one of the main attributes of PFT, and this has been proved through practice. So PFT can be considered to be a drought relief measure that is simple and easy to deal with.

An experiment that was conducted in Helan by the Institute of Cotton Research of the Chinese Academy of Agricultural Sciences revealed that, before sowing, the water content in the soil was 20 per cent, and thirty days later, in the soil covered with PF, 1.3 per cent of the water was lost; in the soil in which PF was not used, 2.8 per cent was lost; and from 0 to 5cm under the soil covered with PF, 6.8 per cent was lost. Plastic Film evidently maintains the moisture content of the soil. It was also determined that, after 10 days of sowing 0 to 40cm under the soil, the open land lost 1.2 per cent water but the land covered with PF did not lose water. On the contrary, water increased by 1.2 per cent, showing that PF can make water rise from the deep soil layer to the upper layer.

In Lianing Shanxi, Inner Mongolia, the rate of soil evaporation is two to three times higher than that of precipitation. The effect of PF on water retention is very evident in these provinces.

According to a three-year research programme carried out by Liaoning Institute of Cotton-flax Research, during May, evaporation is very strong and the water content 0 to 5cm under the soil covered with PF is from 4.1 to 6.9 per cent higher than on open land at 10cm. Under soil covered with PF, it is 1.2 to 5.1 per cent higher than on open land. From 20cm under soil covered with PF, it is 0.58 to 2.31 per cent higher than that on open land. The tendency of water to rise from the deep soil layers has also been proved. It seems that if PF is used, contrary to natural law, the water content in the soil decreases progressively from the surface of the soil to the lower layer.

Water-saving Irrigation

Plastic Film can conserve moisture as well as increase moisture content. PFT can be applied to develop new methods of water-saving irrigation, leading to the economic use of water.

According to an experiment carried out by the Tianjin Institute of Vegetable Research, PF not only saves water but also increases yield. In the cooperative experiment carried out by China and Japan during 1986-1987 in Beijing, Shanghai, Shenyang, and Dalian respectively, vegetables were grown on ridges. The surface of the ridges was covered with PF and, above the ridges, there was a big canopy made of plastic film. Under the PF, vegetables were irrigated by drip irrigation and thus 20 to 40 per cent of water was saved. In addition, PF increased the intensity of photosynthesis, decreased moisture under the canopy, and prevented the occurrence of diseases and pests.

Improving the Soil's Physical Properties

As PF can prevent soil erosion caused by wind, rain, and irrigation and can reduce the hardening and imperviousness of the soil caused by treading by man or machine, water can seep into places where the root system is distributed along the sides of ridges, thus keeping the soil in a loose and ventilated condition. Three phases of soil can be changed by the use of PF. In other words, the volume of the solid phase reduces the volume of the liquid phase and the volume of the air phase increases. Soil covered with PF is evidently less compact and low than that of open land. This ensures a sufficient supply of oxygen for the growth of the root system and enables the root system to penetrate deep into the soil layer. A strong root system helps maintain a high absorption capacity enabling plants to resist drought. It also provides a good foundation for the growth and development of crops above the soil, increases yield, and promotes early maturation. However, if the soil is too loose, tall crops may lodge.

Effect of Keeping a Full Stand of Seedlings by Restraining Salts

The salt movement in soil is always facilitated by water. On open land, when water evaporates, salt is carried up to the surface of the soil where it gradually accumulates. Once the seeds emerge, the saline-alkaline soil causes the death of many young seedlings. As stated earlier, a special water-cycle is maintained under PF which washes the salt into the deeper soil layers. This results in a cultivated layer with lower salt contents on the soil surface, creating relatively favourable conditions for the emergence of seeds. Although PF cannot reduce the total content of salt in the soil, it can change the salt distribution pattern. As a result, it has the effect of keeping a full stand of seedlings by restraining salts and resulting in soils with slight and medium degrees of saline-alkaline contents.

According to an experiment carried out in Jiangsu Province, the salt content was reduced by 53 to 89 per cent after the field was covered with PF, and the percentage of full stand string bean seedlings raised from 62 to 66 per cent. Full stand Chinese wax gourd seedlings increased from 94 to 98 per cent but, on open land, full stand Chinese wax gourd seedlings reached only from 12 to 23 per cent even after filling up spaces by transplanting seedlings twice.

According to an experiment carried out by the Liaoning Institute of Cotton-flax Research, on low-lying saline-alkaline land with 0.2 to 0.4 per cent salt content, PF helped reduce the salt content by 27.2 per cent, full stand cotton seedlings reached 96 per cent in a field where cotton could not be cultivated in the past, and the yield of ginned cotton reached 1,575kg per hectare. This successful technology was popularised over 66.6 hectares of cotton fields, and the average yield of ginned cotton reached 1,350kg per hectare. Another experiment, which was carried out by the Institute of Cotton Research of the Chinese Academy of Agricultural Sciences in saline-alkaline fields, showed that, when a cotton field was covered with PF, the salt content under the soil from 0 to 5cm was reduced by 19.6 per cent and from 0 to 20cm it was reduced by 48.9 per cent. Similar results were also obtained in slight, medium, and heavy saline-alkaline soil.

Effect of PF on Diseases and Pests

PF changes the ecological condition of the soil, bringing about changes in the growth patterns and in the patterns of infestations by diseases and pests. Some damage is prevented, some exacerbated, and some delayed or accelerated. The inspectors of the China Cotton PFT Group found that PF can prevent damage by cotton blight and also prevent damage caused by cutworms and cotton aphids in the early stages. But heavy damage is caused by cotton bollworms, red mites, thrips, and aphids in summer.

According to experiments and observations made over a period of two years by the Institute of Cotton Research, Shangdong Academy of Agricultural Sciences, PF can reduce the incidence of cotton blight by 37.43 per cent and the mortality rate of young plants by 26.32 per cent, and it can increase the yield of ginned cotton by 25.2 to 70.69 per cent.

According to data collected by the Beijing Agricultural Bureau, when sweet pepper and tomato fields are covered with PF, it reduces viral diseases by 1.9 to 18.0 per cent, the disease index by 1.7 to 20.7 per cent, and tomato late blight and tomato leaf mould by 20 to 30 per cent. Downy mildew in cucumber is reduced by 10 to 15 per cent and egg plant blight by 20 to 30 per cent. This happens because PF controls disease-producing germs that are spread by rainfall.

Virus disease in tobacco fields is a very serious problem. According to investigations carried out by the Institute of Tobacco Research of the Chinese Academy of Agricultural Sciences, PF accelerates the growth of tobacco, and therefore the peak period when aphids occur is avoided. The occurrence of viral diseases of tobacco in the open field is about 30 to 40 per cent, sometimes reaching 90 per cent. But covering the field with PF can reduce it to five per cent because it is aphids that cause viral diseases.

Effect of PF on Weeds

There are two reasons why PF can control or kill weeds. Firstly , once the field is covered with PF and the planting holes are tightly sealed, the air temperature between the PF and the ground surface can reach 50° to 60°C during the day, and this definitely scorches or burns the young weeds. Secondly, black, one side black, light-reflecting PF, and green PF reduce the sunlight seeping through, or change the components of light, so as to restrain or kill the weeds. For example, in the Institute of Pomology of the Chinese Academy of Agricultural Sciences, when light-reflecting PF was used to cover apple orchards, the results showed that 91.7 per cent of the weeds were controlled. According to another investigation carried out by the Agricultural Bureau of Wanrong County, Shanxi Province, before the maize fields were covered with PF, there were 105.4 weeds per square metre in May. After one month, with the use of PF, most of the weeds were scorched and only 4.8 per square metre remained. This implies that weeds are destroyed at the rate of 95.4 per cent.

III. Application of PF in Food Crop Cultivation

Cultivating Rice Seedlings with the Use of PF

Cultivating good rice seedlings is a key measure and the basis of high yield in rice production. In southern China, during the season when rice seedlings are cultivated, the weather varies a great deal. Cloudy and rainy days occur very frequently and this inclement weather can spoil rice seedlings, prolong the period of rice transplantation, and hinder the growth and development of rice.

PF creates favourable environmental conditions which protect seedlings from spoilation, and it is an effective and economic method of cultivating strong seedlings. PF has proved to be an effective measure of guaranteeing early sowing, early transplantation, early maturation, and high yields.

Increased Yields

The advantages of using PF to cultivate rice seedlings are lower costs, higher economic benefits, and easy application. According to practice, the required amount of PF per hectare is about 150kg, which is 1/6 of the amount required for canopy-covered land and the benefit is four times that of canopy-covered land. Since 1981, this technology has been used in rice production. By 1986, 788,987 hectares of rice seedling fields were covered with PF. If PF is used, rice seedlings become very strong and they take root early after transplanting. They also ripen early, and forced ripening does not occur from the effect of high air temperatures during the heading period - in double-crop rice regions, or where there are double-crop systems, PF protects rice from damage caused by the cold in mountain areas.

According to data collected from 166 demonstration plots in six provinces of China (see Table 3-1), yields increased on 162, or 98 per cent, of the plots. From these plots, the average increase in yield was 495kg per hectare, i.e., 7.9 per cent. Yields decreased on four plots (2%). On these plots, the average decrease in yield was 373.5kg per hectare, i.e., 6.2 per cent.

In the double-crop rice region, PF not only increases the yield of the first crop, but also provides extra time for the second crop. For example, if PF is used, the first crop ripens five to seven days earlier, and the second crop can be transplanted five to seven days earlier. This prolongs the effective date of tillering for the second crop and lightens or prevents the damage caused by cold during autumn in the tillering-ripening stage. Finally, the second crop yield increases. Experiments carried out in Hubei and Anhui provinces show that, if the second crop is transplanted one day earlier, the yield can be increased to 150kg per hectare.

Cultivation Methods

i) <u>Ground Preparation and Fertiliser Application in Rice Nurseries</u>. The rice nursery should be flat. The width of PF used to cultivate rice seedlings should be 180 to 200cm, therefore the width of the rice nursery should be 150 to 170cm. On two sides of the nursery, 12 to 15cm of PF should be sealed with mud. If PF is used to cover the rice nursery, the film clings easily to the soil.

Table 3-1: Rice Seedling Yields in Demonstration Plots

Province	Number of Plots	Ratio of Increased Plots to Decreased Plots	Yield Increase			Yield Decrease		
			Yield Per Hectare	Increased Yield Per Hectare		Yield Per Hectare	Decreased Yield Per Hectare	
			(kg)	(kg)	(%)	(kg)	(kg)	(%)
Jiangxi	58	58:0	6358.5	630.0	8.87			
Hunan	4	4:0	7399.5	409.5	5.86			
Hubei	-	-	-	450.0	7.00			
Zhejian	22	18:4	5914.5	397.5	7.83	5707.5	373.5	6.15
Anhui	24	24:0	-	421.5	7.93			
Guizhou	58	58:0	6676.5-8889.0	663.0	9.93			
Average	166	162.4	6586.5-7183.5	495.0	7.9	5707.5	373.5	6.15

Source: Chinese Association of Plastic Film Technology 1988

If the PF clings too closely to the soil for three days, the young seedlings will die. So the correct method of tilling and preparing the nursery is to work on a fine day, three to five days before sowing, and to flatten (or level) the surface by irrigation. In this way, the nursery will be soft, loose, full of oxygen, and permeable.

The following principles should be adhered to in applying basic fertiliser in rice nurseries. Firstly, as PF decreases the loss and volatility of soil nutrients, an adequate amount of fertiliser is available in the soil. In order to avoid absorption of excess nitrogen by young seedlings, organic manure should be predominant in the base fertiliser used, and it is better to apply more phosphorous and potassium fertiliser; it is not convenient to apply these afterwards. The amounts of fertiliser needed are as follows: 18.8 to 22.5 tonnes per hectare of human/animal excreta, 113 to 150kg per hectare of potassium chloride, 450 to 750kg per hectare of calcium magnesium phosphate, and 300 to 450kg per hectare of calcium super phosphate. Thirdly, organic manure and potassium fertiliser should be applied when the land is tilled or the nursery is prepared and the manure and fertiliser have to be mixed thoroughly with the soil. Phosphorous fertiliser should be applied when the nursery is already flattened or levelled and the seed is sown.

ii) Sowing Period and Sowing Rate. The sowing period depends on the temperature (the minimum temperature needed for the growth of rice seedlings is 12°C), the local conditions of light and heat, and the effect of PF on increase in temperature. According to experience, when the average diurnal temperature stabilises at nine degrees centigrade, the conditions are favourable for sowing cultivated rice seedlings by using PF.

Sowing should be carried out on a fine day. Usually, the sowing period is one week earlier than on open land.

If PF is used, the emergence of seedlings is 15 to 20 per cent higher. The sowing rate depends on the size of the seedling, e.g., when a seedling with three leaves is transplanted, the sowing rate should be 3,000 to 4,500kg/hectare; when a seedling with three to five leaves is transplanted, the sowing rate should be 1,125 to 1,500kg/hectare; and when a seedling with more than five leaves is transplanted, the sowing rate should be 600 to 900kg/hectare. In the case of hybrid seeds of early season rice, the sowing rate should be 225 to 300kg/hectare and, in the case of hybrid seeds of mid-season rice, the sowing rate should be 150 to 187.5kg/hectare.

iii) Seed Decontamination and Soaking. If PF is used to cultivate rice seedlings, diseases easily occur because of high temperature and high humidity caused by the film, so the seeds have to be carefully treated with chemicals. The normal treatment methods are as follows: the seeds are soaked in one per cent of lime solution for 48 hours; in areas affected by rice blast, the seeds are soaked in Formalin solution (0.5kg of Formalin mixed with 25kg of water) for three hours or in Kitazine solution (one kilogramme of water-dispersible powder of Kitazine mixed with 200 to 400kg of water) for 24 hours; in areas where there is rice bacterial blight, the seeds are soaked in Streptomycin solution (one ampule of 0.5 million unit Streptomycin mixed with 2.5kg of water) for 48 hours.

The decontaminated seeds have to be washed in order to remove the chemicals. After that, the seeds have to be soaked in water for three to four days, enabling them to absorb sufficient water (the saturation capacity of water is about 4% of the seed weight). Under proper temperatures, the soaked seeds can germinate well and emerge evenly.

iv) Covering Method and Separating Materials. Usually, in practice, PF is spread flat on the bed. In order to prevent the plastic film from sticking to the muddy bed after sowing seeds, it is necessary to spread a thin layer of plant ash mixed with husk so as to separate the PF from the muddy bed. The separating materials could be crop ash, excrement of animals, and crop sticks and husk, or a mixture of all these materials. These separating materials not only prevent the PF from sticking to the muddy bed, but also increase temperature, protect roots, and enhance the effects of fertiliser. After the separating materials are spread, it is time to cover the bed with PF. Normally, the suitable covering period is for about 15 to 20 days, depending upon weather conditions, the maturation period of varieties, and the required leaf age of seedlings. The appropriate time to remove the PF is when the daily average temperature reaches 14°C, when the minimum temperature is not less than 10°C, and when the seedlings have reached the required leaf age.

v) Care of Seedling Beds during and after PF Application. The main precautions that should be taken while using PF are to ensure that the seedling beds are sealed by PF, to prevent PF from sticking to the muddy beds, and to protect the seedlings from withering so as to increase the rate of emergence and promote a strong and dense growth of seedlings.

When it rains, the water that accumulates on the PF should be drained away in good time. The water that accumulates on the PF should not be kept for more than two days, otherwise the seedlings will suffocate or will be pressed down. With increase in leaf age, the resistance of seedlings will gradually decrease under the high temperatures brought about by the use of PF. When the seedlings have grown a couple of leaves, the PF cover should be removed to ventilate the seedling beds and decrease the temperature, so that the seedlings can adapt to the natural environment outside. According to research, when the daily mean temperature on a fine day is more than 25°C, the extreme maximum temperature of the PF can reach more than 40°C. In practice, when the temperature under PF reaches 32°C, the two ends of the PF should be drawn back to ventilate the seedlings and decrease the temperature during the day and then be replaced again in the evening.

After the PF is removed, additional fertiliser should be applied to the seedling beds. Usually, it is necessary to apply urea and potassium chloride at the rate of 60kg and 75kg per hectare respectively or to apply thin dung water at the rate of 6,000 to 7,500kg per hectare. Five to seven days before, urea should be applied at the rate of 60kg per hectare so that the seedlings can develop new roots. In the case of hybrid seeds, as the seedlings need more tillers, fertiliser should be increased one or two-fold.

Low temperatures and cold may damage the seedlings after the PF is removed. If this occurs, the seedlings should be covered with PF again or the seedling beds should be irrigated to protect the seedlings from damage caused by cold. The surplus water should be drained off after the temperature rises.

Cultivating Upland Rice with PF

It is possibile to shift rice cultivation from the traditional water fields to dry land by using PF, and this is called upland rice cultivation. It is thought that, where annual rainfall is more than 600 to 700mm pf, especially if there is more than 300mm of rain during the two months before head sprout, upland rice cultivation under PF does not require a planned irrigation system. When rainfall is inadequate, upland rice cultivation under PF is possible and a good harvest can be expected. During the key period of rice growth, irrigation should be carried out twice or thrice.

The Economic Benefits

According to experiences over a long period in the Liaoning and Jilin provinces of China, where, for most of the time during the whole season of growth, PF-covered upland rice fields were not provided with irrigation facilities, rice yields still reached 5,250 to 6,000kg/hectare. In 1985, in the three north-eastern provinces of China, the weather was characterised by low temperatures, little sunshine, serious droughts and floods, and a considerable decrease in the water on irrigated rice fields. However, the upland rice yields from a 5,333 hectare area reached

5,625kg/hectare when PF was used. In some places, the yields even exceeded the yields of wetland rice. For example, in Union township, Shuihua city, Helongjiang Province (N-47°), PF was used on 67.3 hectares of upland rice. The yield from 11.1 hectares reached 6,493.5kg/hectare, and this was higher than the normal yield of wetland rice (5,836.5kg/ha) by a factor of 11.3 per cent. It was estimated that, if the cost of PF was less than 375 *yuan* (about 69.4 US$) per hectare and the yield of upland rice under PF reached 3,000kg/hectare, PFT could be considered economically beneficial. In practice, a yield of more than 5,250kg per hectare is possible if PF is used to cultivate upland rice.

Cultivation Methods

Places that are suitable for cultivating upland rice by using PF are low-lying land, easily flooded land, mountain land with adequate rainfall, and sloping land. Heavy saline-alkaline land, clayey land, soil that leaks water, land that is waterlogged throughout the year, and regions with little rainfall and without irrigation facilities are not suitable for upland rice cultivation under PF.

i) <u>Preparing the Ground and Fertiliser Application</u>. Ploughing, harrowing, and constructing ridges can be carried out during autumn or spring, but it must be ensured that the ground is fine, flat, and tight. Stones, root residues, weeds, and wasted PF should be removed.

As it is difficult to apply fertiliser after the land is covered with PF, application of basic manure is necessary and it should be carried out after the first harrowing. Harrowing should be carried out again to ensure that the manure is mixed evenly. In the first year, excess nitrogen and chemicals should not be applied in order to avoid overgrowth, diseases, and lodging.

During the later stage of rice growth, if the rice plants lack fertiliser, proper application of additional fertiliser is necessary. One method of application is to mix the chemical fertiliser in water when rice plants are irrigated. The other method is to apply chemical fertiliser on the PF before rainfall, so that the fertiliser can be carried by rain to the plant beds.

ii) <u>Treatment of Seeds</u>. Before sowing, the seeds have to be exposed to the sun for two to three days. In order to improve the quality of seeds, they have to be soaked in salt water or ammonium sulphate water. The solution is prepared by adding 10 to 11kg of salt or 10 to 12.5kg of ammonium sulphate to every 50kg of water. The amount of seeds poured into the solution should not be more than half of the solution, and they should be carefully stirred. After a while, the shrunken seeds and other impurities float to the surface and these should be removed from the solution. The plump seeds that sink to the bottom should be selected for sowing and have to be washed twice in clear water.

The selected plump seeds should be decontaminated by soaking them in a caustic lime solution. If the temperature of the solution is 10 to 15°C, the seeds should be soaked for six days, and if the temperature is 15 to 20°C, four days are enough. It has been demonstrated that if seeds are soaked in Topsin solution (70% of water-dispersible powder is mixed with

800-1,000 times of water) for 72 hours, or in Bavistin solution (10% of water-dispersible powder is mixed with 300 to 500 times of water) for 48 hours, rice blast can be prevented. The decontaminated seeds have to be soaked in warm water to hasten germination. If the temperature of water is more than 15°C, four to six days are enough. When the seed husk is broken, the time is right for sowing.

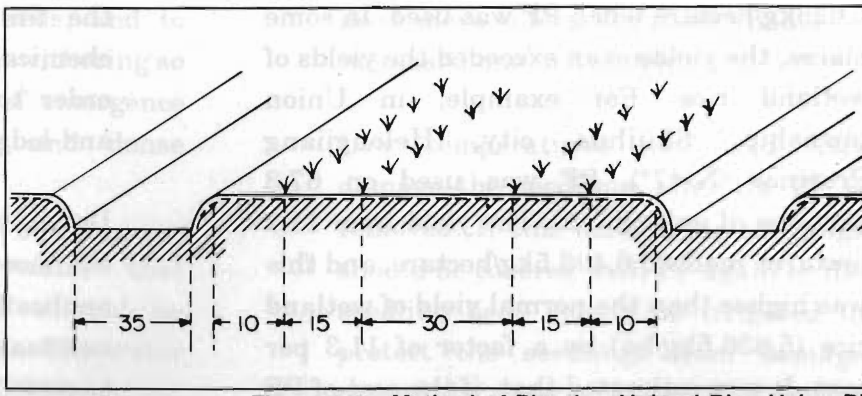

Figure 3-1: Method of Planting Upland Rice Using PF (Unit: cm)

iii) Planting Method. At present, plantation of four lines per ridge is practised (see Figure 3-1). Common plastic films are one metre wide, so the width of the ridge should be 85cm. On the ridge, the space between double lines should be 30cm and the space between the two lines should be 15cm. The distance between the edge of the ridge and the sideline should be 10cm and the distance between two plants should be 10 to 15cm. The walking furrow should be about 35cm. The method of planting and the density of plants can vary, depending upon the features of the plant variety, soil fertility, planting season, and method of cultivation.

iv) Sowing Seeds. After the flat ground is ready, sowing should be carried out according to the planned distance between rows and plants. When the mean temperature over a ten-day period reaches eight to nine degrees centigrade, the temperature of the soil surface under the PF should be more than 12°C and is suitable for sowing. The current practice is to sow the seeds first and then to cover the seeds with PF. Seeds are either sown by hand or with a planter, and eight to 10 seeds are planted in each hole. After sowing, the holes have to be covered with one to two centimetres of soil and pressed tightly. In order to control weeds, weedkillers should be applied before covering the seeds with PF.

v) Controlling Subterranean Pests. Moles, crickets, and grubs are the main pests that damage the seedlings, sometimes they almost destroy the whole rice field. Experiments have proved that Thimet (phorate) is effective in controlling these pests. Usually, 22.5 to 30kg of five per cent Thimet granules are mixed with 225kg of fine sandy soil on one hectare of rice field. This mixture can be applied within rows, or evenly spread on the ridges. If these pests occur again, when the seedlings grow three or four leaves, the same pesticide mixture can still be used by mixing it with 300 to 500 times the amount of water and pouring it into the holes where the seedlings grow. In this way, 95 per cent of the pests can be controlled. Dylox (dipteryx) can be used as a poison for the effective control of pests.

vi) Controlling Weeds. Cultivating upland rice under PF can fail if weeds are not controlled. When the rice field is covered with PF, it is impossible to carry out inter-cultivation and weeding. The only way to control weeds is to sprinkle weedkillers before covering the field with PF. Application of a mixture of Nitrofen and Saturn (the commercial names of weedkillers) has proved to be effective; the former has a broad-spectrum effect and the latter's effects are prolonged over a longer period. When they are mixed together, the joint effect is better than that of any single weedkiller. If the ground is carefully prepared, weedkillers can be sprinkled evenly. To make the application effective, the soil should not be moved and covered immediately with PF. If some weeds do grow and push up the PF, earth should be placed on the PF. This will cause the weeds to die under the high temperatures.

vii) Covering the Soil. There are two ways of covering the soil with PF, i.e., manually or by machine. Depending upon the width of the ridge, shovel enough earth to press the edges of the PF, make two furrows on the two sides of the ridge, and then roll and spread the PF tightly against the surface of the ridge. The two sides of the PF are placed on the furrrows and earth is shovelled on to press them down. Finally, shovel some earth on to the surface of the PF at the required distance in order to prevent the PF from being torn off by the wind. The other method is by machine. After preparing the ground, use manpower, animal power, or tractor to roll and spread the PF on the ridge. Meanwhile, make furrows on two sides of the ridge and cover the edges of PF with earth. Some machines can carry out a series of operations such as ploughing, applying fertiliser, sprinkling pesticides, and spreading PF.

viii) Removing Seedlings. In most cases, the seeds are first sown and then covered with PF, therefore, the seedlings have to be removed after emergence. In order to maintain heat and save labour, it is reasonable to remove the seedlings twice. As the seedlings are heat tolerant, they should first be removed when 70 per cent of them emerge and removed again when all the seedlings emerge. In some places, seedlings are removed only when all of them emerge. Seedlings can be removed by making an "X shaped" hole with a knife or with fingers. It should be ensured that when the hole is made, the seedlings are not damaged. The hole should not be too big and, when the seedlings are taken out, some wet earth should be immediately put around the hole to seal it and prevent moisture from escaping.

ix) Irrigation. There are two water-sensitive stages during the growth of rice. During these two stages, adequate water content in the soil is required, otherwise the growth and development of rice is negatively affected. These two stages include the date of revival from transplanting and one month before heading and flowering. During these two periods, if the water content in the soil is less than 60 per cent of the maximum field capacity, proper irrigation is needed. If there are no irrigation facilities, in order to stop the loss of rainwater it is necessary to construct some checkdams at a certain distance from the walking furrows. If there is too much rainfall, these checkdams can be dug to divert excess water flow.

Maize

Maize is one of the most important food crops, especially for mountainous areas. Maize is also a high yield crop. In 1981, globally, the average yield per unit was 3,360kg per hectare, but, in China, it was 2,985kg per hectare. It is a big challenge to increase the unit yield. Application of PF in maize cultivation is one effective measure of increasing yield. During the last 10 years, maize yields have increased greatly as a result of PFT.

The Biological Characteristics of Maize and Its Adaption to the PF Environment

Maize needs a lot of water; 368 units of water are necessary to produce each unit of dry material. The need is less than those of cotton and wheat but more than those of sorghum and millet. During the period of vigorous growth, a single plant consumes 2.5kg of water every 24 hours. Every kilogramme of dry grain consumes 1,000kg of water during its lifetime. In northern China, water supplies are inadequate during certain stages of maize cultivation. In the seedling stage, over a ten-year period, drought occurs during nine of those years at that stage; in the growing stage, summer drought occurs; and annual evaporation is four times that of rainfall. In dealing with these unfavourable factors, PF has the advantage of being relatively waterproof and airtight, and this can be effective in preventing water vapour from escaping. In spring, when maize fields are covered with PF, water melts and can be maintained under the PF. This provides sufficient water for seed germination and emergence.

On the other hand, the most natural precipitation is stopped by PF and the water flows into the furrows which are not covered with PF. The water then flows crosswise and soaks the soil under the PF, consequently being absorbed by the maize roots.

Maize originated in middle and southern America and is a thermophilic plant. Normally, the growth period of early maturing varieties is about 80 to 95 days and they need an accumulated temperature of 2,100 to 2,300°C; the growth period of middle-maturing varieties is about 95 to 120 days and they need 2,400 to 2,600°C of accumulated temperature; and the growth period of late maturing varieties is about 120 to 140 days and they need 2,600 to 2,800°C of accumulated temperature. Seeds begin to appear between 8°C to 10°C and the minimum temperature required for emergence of the crop is 10° to 12°C. Below 0°C, the seedlings would be damaged. During the period of vigorous growth, the daily average temperature should be 22° to 26°C. If the temperature during the day is below 17°C and at night below 12°C, it would delay the growth of maize. If the temperature is higher than 32° to 35°C, and drought occurs, it would hinder the normal pollination process and if the temperature is lower than 16°C, and rain occurs, it would also hinder pollination and the subsequent growth of grain.

The minimum temperature that is required during the period from sowing to emergence is 0°C and the accumulated temperature is 75° to 120°C. When the maize fields are covered with PF, the required accumulated temperature is reached earlier than in the open field. Compared with the open field, the date of emergence may differ, but the accumulated temperature is almost the same. PF increases the active accumulated temperature. According to research, if PF is used, the accumulated temperature is maintained at 3,105°C from the date seeds are sown throughout the growth period and the daily average temperature is 20.7°C, whereas that of open land is 2,797°C and 18.6°C respectively. This means that PF increases the accumulated temperature, at five centimetres' depth, by 308°C, i.e., a daily increase of 2.1°C. In other words, PF prolongs the season of growth by one month. Figure 3-2 shows the difference in temperature at a depth of five centimetres with PF and without PF.

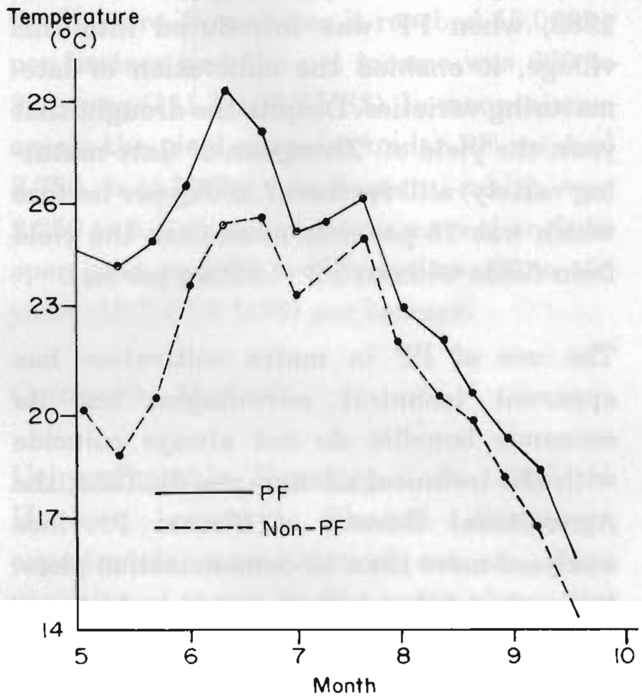

Figure 3-2: Temperature at a Depth of 5cm with PF and without PF

The remarkable feature of PF is that it promotes the early emergence and stable and strong growth of maize seedlings. Because of early emergence, the other processes of development, such as growth of stems, ears, grains, and maturation, are earlier. A significant point is that PF enables the filling stage of maize to coincide with the local season when temperatures are high. Usually, suitable temperatures for the filling stage range from 25° to 26°C. As temperatures during the period of sowing and emergence are lower on open land, the process of growth is delayed. When the maize plant reaches the filling stage, the daily average temperature might decrease between 20° to 24°C and can be sometimes lower than 16°C. Grains cannot develop well and are sometimes damaged by frost if the stage at which grains develop does not coincide with the season when the temperature is high.

If the maize fields are covered with PF, the damage caused by weeds can be reduced. According to an investigation carried out in Lobei Village, Datong County, Shanxi Province, in spring the temperature under PF reached 40° to 50°C and the maximum was 62°C. As a result, most of the annual weeds withered or died; Indian lovegrass *(Eragrostis pilosa)* and palmate meadow sweet *(Filipendula palmata)* were evidently controlled; amaranth *(Amaranthus tricolor)*, purslane *(Portulaca oleracea)*, common knotweed *(Polygonum aviculare)* became yellow and gradually withered; and hispid burnyard grass (*Echinochloa crusgalli* var. *hispidula*), yellow Elsholtzia *(Elsholtzia flava)*, and common reed *(Phragmites communis)* did not die but were controlled.

In addition, in Yanggao County, Shanxi Province, PF helped to reduce the incidence of dust brand disease that affects maize. The incidence of disease in the maize fields under PF was one per cent but in open maize fields it was seven per cent.

It was also discovered that PF can help to restrain salt movement in the soil. According to research carried out by Jinzhong Agricultural School, Shanxi Province, in May the salt content at a depth of 0 to five centimetres of soil layers under PF was 0.292 per cent but that of soil without PF was 0.438 per cent. Maintaining a lower content of salt in the surface layer is advantageous to the emergence and growth of young seedlings. When maize fields are covered with PF, a special "microclimate" is formed under the PF, and this microclimate is favourable for the biological characteristics of maize.

The Economic Benefits of Using PF

In 1979, this technology was first introduced in Lober village, Datong county, Shanxi Province. The yield per unit with PF was 9,495kg per hectare and the yield per unit without PF was 7,500kg per hectare. The rate of increase was 57 per cent. Encouraged by this successful experiment, the area of maize cultivation under PF expanded to 26,000 hectares in Shanxi Province in 1986. In 1985, Hubei Province popularised maize cultivation under PF in mountainous areas and the total area reached 22,600 hectares. The yield per unit under PF reached 4,980kg per hectare, compared to control (2,040kg per hectare) and the rate of increase was 1.4 times.

In 1985, in Bayanlour, Inner Mongolia, 680 hectares of maize fields were covered with PF. The yield was 11,385kg per hectare, compared to 6,150kg per hectare on open land, and the rate of increase was 84 per cent. In pastureland at high altitudes and with cold weather, where it is difficult for maize to ripen, 427 hectares of experimental maize fields were tested and the yield reached 8,100kg per hectare, more than in the fields without PF by 6,300kg per hectare. The rate of increase was 3.5. At Baoyintusamu fodder farm, at an altitude of 1,450m, and with an annual average temperature of only 3.9°C, PF was used on 6.3 hectares of maize field and the yield reached 9,564kg per hectare.

According to research conducted in Shanxi Province, maize covered with PF had the following features: the seeds were plump, the weight per ear was 200 grammes, and the weight of a thousand grains was 330 grammes, which was greater by 1.9 per cent and 13.8 per cent respectively than maize grains from open fields; available ears per plant totalled 1.21 pieces, which was greater by 0.17 pieces than the control; and the per cent of sterile plants was 1.8 per cent, which was lesser by five per cent than the central plot.

In Wanquan County, Hebei Province, there is a village called Houqizhuan which is located at 1,130m where the frost-free period is 120 days. Formerly, only the middle-maturing varieties could be grown there. In 1983, when PF was introduced into this village, it enabled the cultivation of late-maturing varieties. Despite the drought that year, the yield of "Zhongdan-2" (late-maturing variety) still reached 7,650kg per hectare which was 78 per cent more than the yield from fields without PF (4,290kg per ha).

The use of PF in maize cultivation has apparent technical advantages, but its economic benefits do not always coincide with the technical advantages. In 1984, the Agricultural Bureau of Shanxi Province analysed more than 40 demonstration plots. It was found that both the yield and income of nearly 80 per cent of the plots increased, yields increased on some plots but income remained the same, and some plots increased their yield but the income decreased. Further study showed that the absolute increased yield was more than 1,875kg per hectare, i.e., the output was more than the input. It can be stated that both the yield and the income increased. In Inner Mongolia, similar results were obtained, i.e., the ratio of input and output was 1:3.42. In Hubei Province, it was calculated that the investment of maize cultivation under PF was 858 *yuan* (159 US$) per hectare, the total income was 1,554 *yuan* (288 US$) per hectare, and the net profit was 699 *yuan* (129 US$) per hectare, which was 528 *yuan* (98 US$) more per hectare than maize cultivated without PF.

Since PF showed great potential for increasing the yield of maize, this technology became popular very quickly. In 1989, the total area in China reached 57,466 hectares, the average yield was 6,395kg per hectare, and the increased yield was 2,772kg per hectare. In 1991, the total area of maize cultivation under PF in China reached 1,155,667 hectares, or twice that of 1989.

Usually, in the plains, the yield of maize covered with PF reached 6,000 to 7,500kg per hectare. Sometimes it reached 15,000kg per hectare and the net income was 600 to 900 *yuan* (111.1-166.7 US$). In mountainous areas, the yield of maize under PF reached 3,750 to 4,500kg per hectare, which was 2,250 to 3,000kg per hectare more than from open land, and the net income was 90 to 450 *yuan* (16.7-83.3 US$) per hectare.

Cultivation Methods

<u>Using Suitable Varieties.</u> In 1989, in Heshun county, Shanxi Province, experiments were carried out on three varieties of maize in the same place. The varieties were "Jidan-101", "Liguan-4", and "Yinglizhi". They were cultivated under PF, and all three varieties performed very well, but the yields differed. The increased yields per hectare were 3,165kg, 2130kg, and 2,190kg respectively. The difference in increased yield between "Jidan-101" and "Yinglizhi" was 975kg, accounting for 44.5 per cent of the latter. The results showed that selection of suitable varieties was of primary importance.

<u>Preparing the Ground and Basic Fertiliser Application.</u> After ploughing, the maize fields should be irrigated to ensure that the soil contains about 15 per cent water. When the maize fields are covered with PF, it is difficult to apply fertiliser, therefore careful preparation of the ground has to be combined with the application of basic fertiliser. Basic fertiliser should mainly consist of organic manure and proper chemical fertiliser. In Shanxi Province, the maize yield under PF on irrigated fields reached 10,500kg per hectare and the maize yield under PF on upland areas reached 6,000kg per hectare. To obtain these yields, 60 to 70 tonnes per hectare of organic manure, 600 to 750kg per hectare of ammonium bicarbonate, and 450 to 600kg per hectare of calcium superphosphate are required. All these fertilisers should be applied simultaneously when the ground is being prepared.

According to another study conducted in Shanxi Province, to produce 100kg of maize seeds, the plants have to absorb 4.25kg of nitrogen, 1.59kg of phosphoric acid, and 3.51kg of potash oxide (5:2:4) from the soil. If the expected yield is 7,500kg per hectare, the total fertiliser should consist of 375kg of nitrogen and 105kg of phosphoric acid. From the stage when joints appear to the stage when ears appear, the maize plant needs additional nutrients which can be provided by the soil only if PF is used.

<u>Early Sowing and Increasing Plant Density.</u> If PF is used, seeds can be sown four to seven days earlier than on open land. When the temperature of soil stabilises at 10° to 12°C, the time is appropriate for sowing. To derive full benefits from PF, it is necessary to determine the time when the local, daily average temperature is higher than 20°C, and this is essential during the silk advancing and the earing stages of maize. This affects the increase of ear weight and seed weight. Usually, the density of plants under PF is 52,500 to 60,000 plants per hectare, greater by 7,500 plants per hectare than plants cultivated on open fields.

<u>Using Weedkillers.</u> It is not possible to use PF to control weeds over large areas. Despite the fact that PF can control weeds and make

them yellow and withered, the weeds would consume water and nutrients and sometimes they would puncture the PF and emerge. It is better to apply weedkillers before covering the soil with PF. Common weedkillers, such as Lasore, Atrazine (Ametryne), and Simazine (Simetryne), can be used on maize fields. Care must be taken to apply the required amount, because usually the amount required on maize fields under PF is less by one-third than that needed on open fields.

Covering the Soil with PF, Sowing Seeds, and Removing Seedlings. The seeds should be sown and then covered with PF or vice versa. Either method can be used. Usually, the seeds are sown and then covered with PF because it is simple and advantageous if the soil moisture is retained while sowing the seeds. When the ridge is ready, a furrow should be made on the ridge. The distance between the bottom of the furrow and the PF should be about three to five centimetres. The seedlings can grow for seven to 10 days in furrows covered with PF. In this way, the seedlings are prevented from being withered and from damage caused by late frost. The PF has to be spread tightly on the ground and the edges of the PF should be pressed by wet soil (at least 10cm) so as to prevent it from being blown off by the wind.

The seedlings should be taken out after the late frost is over. Before taking them out, it is necessary to make holes in the PF (one hole should be 40cm) to let the hot air out. Sometimes, the temperature under the PF reaches 60°C. These holes lower the temperature and temper the seedlings. When the seedlings turn green and the weather is cloudy, it is time to take the seedlings out.

Economical Use of PF Material and Machine Spreading. As mentioned before, the success or failure of cultivating maize under PF depends not only on increasing the yield but also on increasing income. If farmers cannot realise substantial benefits, this technology cannot be popularised on a large scale. Decreasing the cost of PF is one way of popularising it. Firstly, it is necessary to determine the width of the ridge and furrows in the maize fields, because the amount of PF required per hectare depends on the coverage rate of PF, and the coverage rate depends on the width of the ridges as well as of the furrows. Experiments show that it is more economical and effective if the ridges are 40 to 45cm wide and the furrows are 100 to 120cm wide. In this case, if the width of PF is 70 to 75cm, the coverage rate of PF would be 65 to 75 per cent. Maize should be planted on the ridges covered with PF and other crops such as soyabeans should be planted in the furrows. Secondly, it is necessary to select appropriate PF material. In 1984, in Shanxi Province, a new PF named Linear Low Density Polyethylene (L-LDPE), with a thickness of 0.007mm and a weight of 6.44 grammes per square metre, was tested. Forty-five kilogrammes of L-LDEE is adequate to cover one hectare, therefore farmers can easily afford such PF.

Machines have been used to spread PF in some places. In Yijing Xiang (township), Yingxian, Shanxi Province, out of 800 hectares of maize fields which had to be covered with PF, machines were used to spread them on 355 hectares. According to investigations and calculations, machines were seven times more efficient than the manual method. When the PF was spread by machines, it was pulled taut, saving about eight per cent of the PF.

Wheat

Experiments on the use of PF technology in wheat cultivation were carried out in the beginning of the 1980s in China. After two years of (1980-1981) experiments, the Agricultural Extension Centre of Gaocheng County, Hebei Province, proved that the use of PF in wheat cultivation could greatly increase the yield. After that, similar experiments were carried out in Hebei, Henan, Shanxi, and Beijing and some positive results were achieved. From 1983 to 1984, wheat cultivation under PF was carried out on 430 demonstration plots which were located in 77 counties of Hebei Province. The wheat yield reached 5,466kg per hectare, which was 1,702.5kg per hectare more than on open land, i.e., 43.8 per cent more. In 1983, in the Luoyang area of Henan Province, wheat cultivation under PF was carried out on 38 experimental plots which were located in 13 counties. In the wheat fields covered with PF, the average increased yield per hectare was 255 to 3,120kg, and the increase rate was from five to 53.5 per cent.

The Biological Characteristics of Wheat and Its Adaptation to PFT

Wheat is the second staple grain crop in China, and its cultivated area, which is only less than that of rice, accounts for between 1/4 to 1/5 of the total area of grain crops in the whole country.

Emergence of wheat requires a temperature of 15° to 20°C, loose soil, and sufficient oxygen and water. Under these conditions, wheat seedlings emerge after seven days. For the tillers of wheat to emerge, a temperature of 13° to 15°C is required and, if the temperature is lower than from two to four degrees centigrade, tillers cannot grow. When the soil water capacity is equivalent to from 70 to 80 per cent of the saturated soil water capacity, the primary roots grow well and conditions are also favourable for the growth of wheat tillers. If seeds are sown too late, the temperature of the soil will be low and the accumulated temperature will be insufficient for wheat tillers to grow before winter. In spring, the wheat tillers grow again. Usually, these tillers are not productive and the head sprouts do not grow well. If seeds are sown too early and too densely, the seedlings spindle; do not take secondary roots and tillers; fall over easily; cannot resist cold; and eventually die during the period of overwintering.

Winter wheat will sprout heads only after the vernalisation and photophases. During the vernalisation stage, winter wheat requires a temperature of from zero to five degrees centigrade for 35 to 50 days. If temperatures are not satisfactory, winter wheat cannot sprout heads and flower. Spring wheat requires a temperature of from five to 20°C for five to 15 days during the vernalisation stage. When wheat undergoes stem growth, its endurance to cold evidently decreases. Suitable temperatures for wheat flowering are from about 15° to 20°C and suitable temperatures for filling and maturing are from about 20° to 22°C.

The purpose of cultivating wheat under PF is to create favourable conditions for germination, emergence, and growth of seedlings and tillers. PF increases the soil temperature. According to investigations carried out in Henan Province, the overwintering period of wheat is about 51 days. Under the PF, the accumulated temperature on the surface of the soil increases to 102°C, that under five centimetres of soil increases to 96.9°C, and that under 10cm of soil increases to 102°C. Doubtless, the increased accumulated temperature has a positive effect on the emergence, growth, and tillering of wheat. On the other hand, the PF also provides the root system of the wheat with a relatively stable and wet environment. According to investigations carried out in Ehijiazhuang, Hebei Province, 111 days after covering with PF, the water content in from 0 to 20cm of soil was higher than in soil on open land by two to four per cent. Another investigation was carried out in Shanxi Province, and it was found that the water content in from 0 to 10cm of soil under PF was higher by 2.9 to 5.5 per cent compared to that of soil on open land. It was also discovered that, under PF, water had a tendency to move from the lower layer towards the soil surface, and this is advantageous for overwintering wheat and for the growth of tillers.

Changes in soil nutrients under PF were studied by the Institute of Crop Research, Hebei Academy of Agricultural Sciences, and it was observed that decomposition, release, and consumption of nutrients in the soil were promoted and increased if the period under PF cover was prolonged (see Table 3-2).

Besides the availability of nutrients in the soil, the use of PF also brings about conditions that are favourable for the growth of the root system of wheat, e.g., loose soil and good air permeability.

Table 3-2: The Changes in PF Covered Soil Nutrients during Different Seasons

Soil Nutrients	Layer of Soil (cm)	Before PF (6 Dec. 1983)	After PF is taken away (5 March, 1984)			
			Contrast	Autumn Covering	Winter Covering	Spring Covering
Organic matters	0-20	2.15	2.16	1.88	2.07	2.22
(%)	20-40	1.85	2.11	1.29	1.47	1.27
Alkali hydrolysed	0-20	94.8	104.9	90.9	105.6	94.8
Nitrogen (ppm)	20-40	85.1	96.2	65.0	76.0	64.7
Available	0-20	11.7	61.3	47.6	70.0	51.3
Phosphate (ppm)	20-40	10.4	46.4	22.7	29.5	29.0
Available	0-20	247.5	187.5	210.0	163.8	181.3
Potassium (ppm)	20-40	187.5	148.8	115.0	138.8	113.8

Source: Chinese Association of Plastic Film Technology 1988

The Substantial Effects of PF on Wheat Cultivation

From 1983 to 1984, the Shanxi Institute of Crop Research investigated the overwintering period of wheat. It was found that the mortality rate of wheat seedlings without PF was 30 per cent but no seedlings died under PF. In spring, PF could decrease the mortality rate of seedlings by 18 per cent. In 1984, the Chaoyang Institute of Agricultural Sciences, Beijing, carried out a similar investigation and it was discovered that, during the period of overwintering, the mortality rate of wheat stems on open land was seven per cent and that no stems died under PF. According to an investigation carried out in Qianan county, Hebei

Province, in 1984, the average mortality rate of seedlings collected from 88 open plots was 22.9 per cent and that of seedlings collected from 32 plots under PF was 14.7 per cent. This meant that PF could decrease the mortality rate by 8.2 per cent.

Some investigations showed that PF was useful for forming strong seedlings, e.g., in Wanrong county, Shanxi Province, wheat was sown on the 13th of November, which was 50 days later than the normal sowing period, but those under PF emerged eight days earlier than normal and tillers started to grow 76 days earlier than normal. The Institute of Crop Research, Hebei Academy of Agricultural Sciences, discovered that, in the case of "Jimai-20", plants under PF had one more tiller, two more leaves on the main stem, 0.9 more secondary roots, and 91.6 square centimetres more leaf area than the control and in the case of "Jimai-7", the plant under PF had 1.3 more tillers, two more leaves on the main stem, 2.8 more secondary roots, and 61.8 square centimetres more leaf area.

Under PF, the respective stages of wheat growth, including maturation, shifted, and the period of each growth stage was prolonged as a result of which the number of spikes, number of grains, and the weight of grain increased. High temperatures, dry-hot winds, early summer rains, and hailstones, which occur in the late stages of wheat growth, were avoided. These weather patterns can be avoided by changing the timing of the late stages of wheat growth. According to data collected from Yiyang, Yichuan, and Limbao counties, Henan Province, under PF the elongation stage would move forward 20 days, the stage when heads sprout would move four to eight days the stage when grains develop would move five to eight days forward, and the maturing stage would move three to seven days forward.

Many facts have already proved that wheat cultivation with PFT has significant potential. In northern China drought and long cold periods are very common constraints in wheat cultivation. In this area, due to lack of water and low temperatures, the sowing of wheat is always postponed, seedlings cannot grow well, and the wheat is always forced to mature in the late growth stages. Therefore, the wheat yield is not much. Cultivating wheat under PF is an effective measure of overcoming these constraints and avoiding natural disasters, but there are still some problems. Firstly, if wheat alone is cultivated, the benefits are not high because of the cost of PF. Secondly, the variation in wheat yield depends on comprehensive factors which are created by a series of agronomical measures. Therefore, if the other measures are not coordinated with the use of PF, an evident yield increase cannot be expected. Some suggestions are given below.

i) A single sheet of PF can be used for multiple purposes. Firstly, the PF can be used to cover wheat. After the wheat seedlings turn green, the PF can be removed and then re-used to cover other crops such as cotton, vegetables, rice seedlings, and cash crops. According to information collected from different places, when PF is used to cover wheat, 70 to 80 per cent of the PF remains in a good condition and can be used again. For example, the amount of PF used to cover one hectare of wheat can be used to cover one hectare of cotton and several hectares of melons and vegetables, thereby getting maximum benefit out of the cost of PF.

ii) It is better to use PF on wheat fields without irrigation facilities and if wheat has been sown too late. The common constraints are lack of adequate supplies of water, fertiliser, and heat, and therefore the seedlings grow slowly and are weak. PF overcomes these disadvantages and enhances the efficiency of water, prolongs the active period of growth, and increases the accumulated temperature. If PF is combined with enough fertiliser, the weak seedlings become strong, the growth stages are accelerated, and, finally, the yield of wheat increases.

Cultivation Methods

Preparing the Ground for Wheat Cultivation. In order to obtain high yields, an adequate amount of basic fertiliser is necessary. Besides common barnyard manure, human/animal faeces, urine, and oilcake can be used to prepare basic fertiliser. In addition, chemical fertilisers should be mixed with organic manure and applied as part of the basic fertiliser. Usually 600 to 750kg per hectare of ammonium bicarbonate and 450 to 600kg per hectare of calcium superphosphate are required for wheat cultivation. The ground should be carefully prepared and all stones, big clods of earth, and root residues removed. It should be ensured that the wheat field is very flat so that the PF is not torn or worn out.

When the wheat field is covered with PF, the size of the wheat colony enlarges and the height of plants increases, so that the wheat plants easily fall over and are damaged by diseases and insects. Therefore, low-stalked, lodging-resistant, disease-resistant, and high-yielding wheat varieties should be selected.

Because PF increases temperature and creates favourable humid conditions, if fertiliser is adequate the wheat seedling colony grows fast, and the individual plants grow vigorously and grow more tillers. The sowing rate of wheat covered with PF should be less than on open land and the seeds should be sown evenly, but not deeply. When the seedling density is excessive, seedlings should be thinned and, if the seedlings fail to sprout, over-drilling is required. In order to control the damage from pests under the soil, pesticides should be applied before the wheat seeds are sown.

How to Spread PF and When to Remove It. The PF can be spread in autumn, winter, and spring. In autumn, PF is spread when the seeds are sown, in winter it is spread when the wheat has emerged, and in spring it is spread when the seedlings turn green.

There are three methods of spreading. The first method is overall spreading in which all the wheat seedlings are covered with PF; the second method is punch-hole-spreading in which the wheat field is first covered with PF, then small round holes with a diameter of one to two centimetres are punched in the PF at the required distance, and seeds are sown in the holes (after the seeds germinate and emerge, they are removed from the holes and are grown in the open air); and the third method is micro-hole-spreading in which the first operation is the same as overall spreading, but when the PF is already spread, a certain quantity of micro-holes (each cm^2 has one hole) are made in the PF by using awls or needles, but the wheat seedlings still grow under the PF.

Generally, the time when PF is spread depends upon the status of the seedlings. If the colony of wheat is small and the seedlings are weak, then PF should be spread early. If the size of the colony is big and the seedlings are strong, the PF can be spread later. According to experience, the overall spreading method is better than the others.

During the period when PF is spread, it is necessary to inspect the wheat field in order to prevent man and animals from trampling. If there are spaces between the PF and the ground, immediately cover the spaces with earth. During winter, strong winds can lift the PF, so, to prevent this from happening, place some lumps of earth on the PF to press it down and prevent it from being worn and torn and to prevent the evaporation of heat and moisture.

PF should be removed in winter or in spring. If the PF is spread early and the seedlings are strong enough, the PF can be removed before winter (usually before December). In most cases, PF is removed in spring. When the air temperature stabilises at three degrees centigrade, it is time to remove the PF. In spring, if the seedlings are weak, the PF should be removed later on in the season, but, if they are strong, it should be removed earlier. Should the seedlings turn green and begin to develop joints, the PF has to be removed, otherwise the seedlings will be overcome by hot air and water. Four to five days before removing the PF, partially lift the edges of PF and let cool air in. This is called "hardening the seedlings", and it enables the seedlings to adapt gradually to the environment outside the PF. If the PF is suddenly removed, because of a low level of adaptability, the leaves of wheat seedlings would become yellow or withered.

Field Management before and after Spreading PF. Wheat fields that do not have enough moisture in the soil should be irrigated and then the PF should be spread before overwintering. Wheat fields in which PF is removed after winter require 75 to 150kg of urea per hectare combined with irrigation. After PF is removed, if the wheat seedlings become yellow and grow slowly, 60 to 90kg of urea per hectare should be applied. At the same time, more attention should be given to controlling weeds and pests. In some wheat fields, the seedlings are sprayed with Cycocel (plant growth retardant) in order to control the height of seedlings and some wheat fields are sprayed with rust preventer in order to control wheat rust disease.

IV. Application of PF in Horticultural Crop Cultivation

Vegetables

Tomatoes

Tomatoes are cultivated all over the world. According to experiments carried out in Heilongjiang, Liaoning, Qinghai, Xinjiang, Ningxia, Jiangsu, Shanghai, Beijing, and Tianjin, the effects of PF on tomato cultivation are remarkable, especially in the early stages when soil temperatures are not adequate for tomato cultivation.

Selection and Cultivation Methods. There is a great demand for tomatoes. Early-maturing and middle-maturing tomato varieties are suitable for cultivation under PF, but, apart from in special circumstances, the late maturing varieties are not suitable for cultivation under PF.

Many types of seedling cultivation methods can be used such as greenhouses, forcing beds, and seed beds with windbreaks. So that seedlings can adapt to various climatic conditions, certain common methods of cultivating tomato seedlings have been used, e.g., plastic bags as containers or nutrient soil square bricks to save seeds. These methods enable the growth of strong seedlings with a complete root system.

The seed-sowing date depends upon the time periods required for different varieties. The period for early-maturing varieties is about 60 to 70 days and the period for middle-maturing varieties is about 70 to 80 days. Four to five days before sowing, the seeds should be soaked in 0.1 per cent of potassium permanganate solution for 10 minutes to kill the germs on the surface of the seeds. Then the decontaminated seeds are placed in water (55°C) (the water should be stirred constantly until the temperature of the water drops to 30°C) and soaked for three to four hours. After that, the seeds should be taken out of the water and placed under temperatures of from 20° to 30°C for forced germination. When the embryonic root sprouts from the seed, the time is appropriate for sowing.

As the young seedlings attain the required size and two euphylla, they have to be transplanted into plastic bags or nutrient soil square bricks. During this stage, the seedlings should be carefully looked after because too much water and too high a temperature are harmful. Strong seedlings should have a height of no more than 20cm, the leaves should be dark green, and the root system should be fully developed.

Transplanting Seedlings and Spreading PF. There are two ways of spreading PF. The first method is to spread PF on the ridges, punch round holes in them and take soil out of the holes, and then plant the tomato seedlings into the holes. Before sealing the holes with earth, the seedlings should be given enough water for survival. Another method is to plant seedlings on the ridges and then to spread PF on the ground. After the edges of PF are pressed down by earth, make holes in the PF and take the seedlings out of the holes. Usually, the density of planting for early-maturing varieties is 60,000 to 75,000 and for middle-maturing varieties 45,000 to 60,000.

The Dalian Institute of Agricultural Sciences, Liaoning Province, developed a new method of spreading PF which was an improvement on the previous method and gave good results (see Figure 4-1). To prepare the ground, apply 75,000kg per hectare of basic fertiliser mixed with soil, make the ground flat, and then use the wild-flooding irrigation method to water the field. After the water permeates the soil, make a high ridge 70cm wide and 10 to 15cm high. On the middle of this ridge, a deep furrow should be dug, and some basic fertiliser applied again (about 15,000kg of compost, 1,125kg of calcium superphosphate, and 225kg of ammonium sulphate per hectare) on this furrow. Then the furrow should be filled with earth. On the two sides of this ridge, two other furrows with a depth of 20cm and a width of 10cm should be dug for planting. The seedlings should be transplanted into those furrows and sufficient water provided. Then the PF should be spread on the ridge and the edges of the PF should be pressed down with earth. After a period of time when the young seedlings touch the PF, a small hole should be made in the PF, just against the seedlings, for ventilation. After the period of late frost is over, widen the ventilating holes and remove the seedlings. With two years' experiments carried out in 1980 and 1981, the output value of tomatoes cultivated according to this new method increased by 3,674.7 *yuan* (68.5 US$) and 7,947.5 *yuan* (1477.8 US$) per hectare respectively in comparison to the common method of spreading PF.

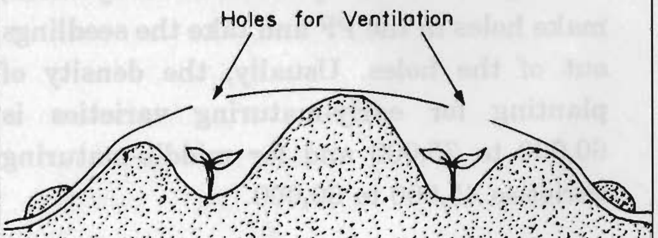

Figure 4-1: Improved Method of Spreading PF for Vegetable Cultivation

Management after Planting. When the tomato plants flower, the first flower heads should be treated with 10 to 20ppm of 2.4-D solution (2.4 dichloro-phyeroxyacetic acid) in order to increase the percentage of fertile fruit. When the other flower heads appear, they have to be treated similarly. During this period, irrigation should be stopped. When the fruit clusters reach a diameter of about two centimetres, the plant should be irrigated in combination with the application of nitrogen chemical fertiliser. From this time, the soil should be always maintained in a humid condition. If a single tomato plant is allowed to bear three to four clusters of fruit, when the second and third clusters of fruit grow to the same size as the first cluster, the tomato plants should be irrigated again and fertiliser should also be applied.

After planting, the plants need support. Usually bamboo sticks are used and the main branches are tied with string. In order to reduce the nutrient consumption and maintain the balance between the growth and development of fruit, the superfluous branches and fruits should be removed. When the fruits develop colour, they should be harvested on time.

Controlling Diseases and Pests. The pests that usually occur are aphids which spread virus diseases and cotton bollworms and tobacco worms which bore into the fruit. All these pests can be killed by spraying them with 8,000 to 10,000 units of Disis, 1,000 units of Rogor (dimethoate), or 2,000 units of 50 per cent Phoxim.

Navel-rotten, a disease that affects the fruit is caused by a physiological deficiency of calcium. According to a study conducted by Shenyang Institute of Agricultural Sciences, if the calcium available in the soil cannot meet the requirements of tomato plants, it is necessary to provide supplementary calcium to the plants. It is considered that spraying 0.5 per cent of calcium chloride during the flowering stage until the whole plant grows is an effective measure of controlling navel-rotten disease.

In very rainy areas, phytophthora blight occurs. This disease can be controlled by spraying 500 to 600 units of Daconil (chlorthalonil), 400 units of 25 per cent Ridomil-MZ (metalaxyl), or 1:1:200 of Bordeaux mixture.

When all the fruits are harvested, the tomato plants should be removed and PF so that the next crop can be planted. In some places, tomato fields covered with PF can still be used to grow other vegetables. For example, when the tomato plants are removed, the autumn cabbage seedlings or cauliflower seedlings can be planted in the holes from which the tomato plants have been removed.

Sweet Peppers

The increase in yield of sweet peppers under PF is even more than that of tomatoes. According to a study conducted by the Institute of Vegetable Research, Jiangsu Academy of Agricultural Sciences, PF not only increased the fresh weight of sweet pepper roots but also promoted the development of assimilation organs. On June 6, 1980, investigations showed that the number of leaves per plant under PF was 228.4, which was 127.6 times more than that of plants without PF, and the leaf area per plant was 1,990.8 square centimetres, which was 2.78 times more than that of the plants without PF. The plants in the PF fields started to flower seven days earlier, and the total yield and early stage yield were double those of plants without PF.

Cultivation Methods. The method for cultivating sweet pepper seedlings is similar to that used for tomatoes. Normally, the seedlings should be 110 to 120 days old and, if the soil bed is heated by electric-heating wires under the soil, the age of the seedlings should be 80 to 90 days.

The seeds require sunshine. They should be soaked in 0.1 per cent of cupric sulphate solution for 10 minutes or in 10 per cent of sodium phosphate solution for 20 to 30 minutes. Then the seeds should be washed in pure water and soaked in warm water for forced germination. After sowing and before emergence, the seed bed should be covered with temporary PF which can increase the soil temperature and promote the even emergence of seeds. The PF also protects the seeds from damage caused by mice. When the young seedlings grow two leaves, the PF should be cut with a small knife at the required distances. The temperature of the soil layer 10cm under the PF can still be increased by one to two degrees centigrade, but the temperature and humidity of the air under the PF can be reduced. This measure helps the young seedlings to grow stronger. According to a study carried out by the Zhenjiang University of Agriculture, 55 days after young seedlings were covered with PF, their height reached 12.8cm, which was 15.3 per cent taller than seedlings cultivated without PF. The fresh weight per plant reached 7.1 gramme, which was 46.9 per cent more than plants grown by the ordinary method. In addition, the dry weight of the part of the plant above ground increased by 147.7 per cent, the dry weight of the part of the plant under the ground increased by 63.4 per cent, and the leaf area increased by 46.2 per cent.

Usually, the temperature that sweet pepper seedlings require is higher by two to three degrees centigrade than that required by tomato seedlings.

Planting and Management. The appropriate time to plant young seedlings is after the period of late frost, usually later than the planting time for tomatoes.

Sweet pepper cultivation should be carried out in fields that are easily irrigated and drained and in places not previously used for them. In order to increase the yield of sweet peppers during the early stages, two young seedlings can be grown together in each hole. The density of planting depends upon the variety. For early-maturing varieties, the density should be 75,000 to 90,000 holes per hectare (150,000 to 180,000 plants) and for middle-maturing varieties, it should be 60,000 to 67,500 holes per hectare (120,000 to 135,000 plants).

For sweet pepper cultivation, high ridges, 50 to 60cm wide and 10 to 15cm high, should be made. To make the ridges, first spread the PF, then punch holes in them, and finally plant the seedlings. After planting, the holes should be sealed with earth and the whole field should be irrigated to ensure the seedlings' survival.

For sweet pepper, irrigation management is very important, e.g., the young seedlings grow slowly in the early stages, therefore, sufficient water and fertiliser are needed. When the first flower appears, the water supply should be reduced, and when the young fruits begin to expand, they should be irrigated again. During the whole period of growth, the soil should be wet. Every six to seven days, the sweet pepper fields should be irrigated. During the rainy season, attention should be given to drainage.

Under PF, in order to avoid the premature decay of plants, it is necessary to apply additional fertiliser. The principal fertiliser used should be nitrogen and it should be applied first when the first fruit is harvested. When the plants reach full-fruit stage, after every 20 days, additional fertiliser should be applied in combination with irrigation. The usual amount of additional fertiliser is 150 to 725kg of urea per hectare. During the full-fruit stage, the mixture of 0.5 per cent of potassium dihydrogen phosphate and 0.2 to 0.5 per cent of urea can be used for foliage fertilisation.

In order to increase the percentage of fertile fruit, a cotton swab should be dipped in 2.4-D - 20 to 25ppm solution, and then this solution should be applied on the flower peduncles. Seedless fruits are formed if sweet pepper flowers are treated with 2.4-D solution. The first fruit should be harvested as early as possible, otherwise plant growth is affected. When fruits reach the commercial maturing stage, they should be harvested on time.

The main pests that damage sweet pepper are aphids, cotton bollworms, and tobacco worms, and they can be controlled by using the same methods as used for tomato plants.

If the fields covered with PF are used to cultivate other crops, the sweet pepper plants should be cut off above the PF. The whole plant should not be pulled out, otherwise the PF will tear.

Egg Plants

According to experimental results from Shanghai, Jiangsu, Zhenjiang, Beijing, Tianjin, Jilin, and Helongjiang, PF can also increase the yields of egg plants; usually the yield of egg plants increases by 30 to 40 per cent and the early stage yield is double.

Cultivation Methods. The main purpose of cultivating egg plants by using PF is to increase the early stage yield as much as possible and also to increase its total yield. Thus, it is better to select the early maturing and middle-maturing varieties and to avoid the late-maturing varieties.

The method for cultivating egg plant seedlings is similar to that for sweet pepper, but there are some differences.

i) Since the seed coat of egg plants is very thick and tight, it has to be soaked for from 1.5 to 2 days. During this period, the seeds should be scrubbed twice a day until they no longer stick to each other. According to experiences at Jilin General Agricultural Extension Station, the following procedure should be carried out. When the seeds are scrubbed, adding some sodium bicarbonate (1% of the weight of the seeds) will improve the washing results. The scrubbed seeds should be washed thoroughly. The temperature for forcing germination, in the beginning, should be from 22° to 25°C, then gradually increased to from 28° to 30°C, and finally reduced to from 22° to 25°C. This measure is called warm-cold seed treatment and is very effective for forcing germination.

ii) The temperature, during cultivation, should be higher than for sweet peppers. When the seeds are sown, the temperature under the PF can be more than 30°C and the minimum should be maintained at about 15°C, thus helping emergence. When the first pair of leaves open, the seedling bed should be ventilated.

iii) When the young seedlings have three to four leaves, it is time for transplanting. Each hole should have one seedling only. Double row cultivation is not suitable for egg plants.

<u>Planting and the Management after Planting</u>. The main operations for planting egg plants are similar to those for tomatoes. The only difference is that when the high ridges are covered with PF, one should ensure that the edges of two PF at the bottom of the furrow between two ridges overlap and that the whole furrow is covered with PF. It is said that this is effective for controlling the brown spot disease. In order to irrigate, one has to punch some holes on the PF at the two edges of the ridge so as to let the water trickle into the ridges. During the rainy season, the excess water can be easily drained out through these PF-covered furrows.

Planting density depends upon the variety and on the area, e.g., in Hangzhou, 27,000 to 30,000 per hectare; in Tianjin, 34,500 to 39,000 per hectare; and in Changchun, 39,000 to 52,500 per hectare are planted. Generally, as the egg plants grow vigorously under PF, the planting density should be a little thinner than on open land.

After planting, the egg plants require a short period of silting without irrigation. When the first fruit begins to expand, they should be irrigated and, when the diameter of the fruit reaches four to five centimetres, additional fertiliser should be applied in combination with irrigation. The additional fertiliser should be ammonium nitrate (225 to 300kg per hectare), or urea (150 to 225kg per hectare), or liquid dung (30,000 to 37,000kg per hectare), any of which are sufficient for the growth of fruit. PF greatly reduces the evaporation of water from the soil, therefore the interval between two periods of irrigation can be prolonged or the amount of water can be reduced by 30 per cent of that used for open land.

Egg plants often bear flowers which have short styles. These flowers may not develop well and cannot bear normal fruit, and the blossom and fruit are shed in this case. These constraints can be overcome by using 2.4-D solution. When the first flower and second pair of flowers appear, 2.4-D solution should be applied on the sepals and peduncles. This measure can prevent the young fruit from shedding and promote the early maturation of fruit.

Controlling Diseases and Pests. The pests that frequently occur in egg plants are aphids, red mites, tea mites, and leaf hoppers. Aphids can be controlled by applying the same method used for tomatoes. Red mites and tea mites can be killed by spraying them with 800 units of teradifon. Leaf hoppers often occur in autumn and can be controlled by applying 1,000 to 12,000 units of Rogor (dimethoate).

The most serious disease that occurs in egg plants is brown spot which damages the leaves and stems. This disease can be controlled by spraying it with 1:1:160 parts of Bordeaux solution or 600 units of water-dispersible Fernasan powder (thiram), which can also control Phytophthora blight in cotton.

Verticillium wilt is another common disease which can be prevented by pouring 100 to 250 grammes of Bavistin solution (800 to 1,000 times 10 per cent Bavistin) per plant around the roots of the egg plants.

If PF is used, the egg plant fruit ripens seven to ten days earlier, so the fruit should be harvested on time. If the fruit is too big and too old, the quality will decline.

Cabbage

Cabbage is a very common vegetable which is often cultivated as an off-season vegetable in the mountainous or hilly areas. According to an experiment carried out in Dabizhuang, Tianjin, PF can increase the yield of cabbage by 31.4 per cent and the output value by 59.8 per cent. With this method, cabbage ripens 13 days earlier than on open land.

Cultivation Methods. Cabbage seedlings can be cultivated in common seed beds or in a sunlit greenhouse. Cabbage seeds should not be sown too early because the age of the seedlings will be prolonged and could decrease the yield and output value. Suitable ages for seedlings are from 90 to 100 days.

Whether in common beds or in a sunlit greenhouse, before sowing, the seed bed should be carefully prepared and sufficient basic fertiliser should be applied. The seeds should be soaked in warm water for four to five hours and then placed under temperatures of from 25° to 28°C to force germination.

Before sowing, the seed beds should be sufficiently watered. When the water is absorbed into the soil, sow the seeds and cover them with a thin layer of soil. When the young seedlings emerge from the ground, cover them with another thin layer of soil. When the cotyledons spread out and the first euphyllum appears, the seedlings should be thinned several times. When the seedlings have grown three euphylla, they should be transplanted to the seedling bed and the nutritive area for each seedling should be 10 x 10cm. After the seedlings are revived, inter-cultivation should be carried out.

Six to seven days before removing the seedlings, sufficient water should be poured on to the beds. The seedlings suitable for planting are those that have seven to eight euphylla, and if the seedlings have more than nine euphylla they are too big for planting and the yield of these seedlings will not be high.

Planting and Management. The cabbage fields covered with PF require more basic fertiliser than cabbage fields on open land. Usually, the amount of basic fertiliser should be 60,000 to 75,000kg per hectare. The best method is to spread PF first and then plant the seedlings. For early-maturing varieties, the density of planting should be 67,500 to 90,000 per hectare and about 60,000 per hectare for middle-maturing varieties.

When the seedlings are planted, they should be watered from time to time. Four to five days after planting, they should be irrigated and additional ammonium sulphate applied at the rate of 112.5 to 150kg per hectare to help the seedlings to revive and to reduce the damage from frost, as well as to accelerate the growth of seedlings and restrain early sprouting shoots.

According to an experiment carried out by the Horticultural Department of Beijing University of Agriculture, when nitrogen fertiliser was applied to cabbage fields covered with PF, the total yield increased by 23 per cent. Ten to fifteen days after planting, when the inner leaves become curly, the seedlings should be irrigated and fertiliser should be applied again. The yield and quality of cabbage directly depend on irrigation and the application of additional fertiliser. If the plants begin to sprout heads and the outer leaves are not big enough, irrigation and application of additional fertiliser will be too late and will not increase the yield of cabbage, because by this time the leaf balls are tightly wrapped and excess water and fertiliser would break the leaf balls. If water and fertiliser are applied too early, the outer leaves will overgrow and the head sprouting stage will be prolonged. Regulation of irrigation and application of additional fertiliser are key measures in increasing cabbage yields.

Controlling Pests and Timely Harvests. Cabbage aphid, cabbage worm, cabbage webworm, and cabbage moth are the most common pests. They can be controlled by spraying them with 8,000 units of Decis (deltamethrin).

For early maturing varieties, harvesting should be carried out when the leaf balls attain a weight of more than 0.5kg and do not break. Within ten days after the ball weight reaches 0.5kg, the total weight of the ball should increase by 30 to 40 grammes per day. If harvesting is carried out early, the yield will be reduced, and, if it is carried out too late, the leaf balls will break.

Cauliflower

According to data collected by the Agricultural Bureau of Beijing, when PF was spread on 71 hectares of cauliflower fields, the yield increased by 6,817.5kg per hectare. Another experiment showed that the increased rate of yield in spring cauliflowers was 87 per cent, but, in autumn, the yield did not increase.

Cultivation Methods. Cultivating strong seedlings is a key measure in cauliflower cultivation. Temperature is the most important factor for seedling beds. During the day, the temperature should be maintained at from 28°C to 30°C, and, at night, the temperature should not be less than seven to nine degrees centigrade.

According to experiments carried out during the seedling cultivation period, long periods of lower temperatures damage the root system and lack of water ages the seedlings. The ageing seedlings form flower balls too early, and these are small and yields decrease. During the seedling stage, excessive humidity should be avoided, otherwise the seedlings will be damaged by downy mildew on the crucifers.

Management. Cauliflowers require more fertilisers than cabbage. Besides applying more basic fertiliser before planting, when the transplanted seedlings are revived, they should be immediately given sufficient water and additional fertiliser. It should be ensured that the seedlings are constantly given sufficient water and additional fertiliser so that the nutritive organs of the cauliflowers grow well. Fully-grown nutritive organs (big leaves) will help in the formation of a big flower ball, otherwise the flower ball will be too small or too loose. When the flower ball attains a diameter of three centimetres, a cotton swab should be dipped into a solution of 50ppm of gibberellin and applied onto the flower ball. This will promote the growth of the flower ball. During the growth period and the expansion of the flower ball, the leaves should be bound together to shade the flower ball so as to prevent the flower ball from becoming yellow.

Onions

PF can increase onion yields because it enables the formation of a strong assimilation system and a strong root system, consequently accelerating the formation and growth of squamose bulbs. According to investigations carried out under PF in from 0 to 50cm soil layers, the total length of onion roots increased by 52.3 per cent, the fresh weight of roots increased by 85.9 per cent, and the yield of squamose bulbs increased by 28.6 per cent. PF also protects onion seedlings over the winter. Despite the tendency of PF to cause the growth of early-producing onion shoots, it does not reduce onion yield, and this has been proven in practice.

Cultivation Methods. Normally, onion seedlings can be cultivated on open land, but in mountainous or cold areas, helio-greenhouses or forcing beds are needed. In order to prevent the growth of early-producing onion shoots, it is necessary to cultivate seedlings to the proper size. These seedlings should be 20 to 25cm high, they should have three to four euphylla, the diameter of the leaf sheath should be six to seven millimetres, and the plant weight should be four to six grammes. If the size is too big, it encourages the growth of early-producing shoots, and, if the size is too small, yields will be reduced.

Scattering seeds is the common method used to cultivate onion seedlings, and the sowing rate is about 60 to 75kg per hectare. After sowing, the seed beds should be covered with fine soil and then covered with ready screen or crop stalks. It should be ensured that the material used for the screen permits sunshine to enter but prevents the escape of moisture. When the seeds emerge and the cotyledon stretches, the screen should be removed gradually. Before the onion seedlings attain a height of from 10 to 15cm, irrigation should be carried out. After that, the water supply should be properly controlled. The seedlings should not be thinned out too early. When the second euphyllum has grown, thin out the surplus seedlings as per the density of 650 to 750 plants per square metre. Application of nitrogen chemicals should be combined with irrigation.

Planting and Management. Onion fields should be deeply ploughed and basic fertiliser should be applied at the rate of about 60,000kg per hectare. Then 50 to 60cm-wide ridges should be made and water poured along the furrows between the ridges. Two ridges should then be combined to make a 10 to 15cm high and 100 to 120cm wide ridge. Spread PF, 1.4m in width, on this high ridge (the width of the ridge can be adjusted according to the width of PF available). Flat ridges are also made in practice. Before spreading PF, the flat ridges should be adequately irrigated. After the water is absorbed, weedkillers should be applied. The required amounts per hectare are 15kg of nitrofer (25%) and 2.25kg of trifluration (48%). Spread PF on the ridges and ensure that the edges of the PF are pressed down with earth.

Before planting, the seedlings should be carefully selected and those too big or too small should not be used. The selected seedlings have to be treated by cutting the fibrous roots down to from 1.5 to 2cm so that they can be easily implanted.

In order to increase onion yields, proper close planting (increasing the density of plants) should be carried out. A plant density of 450,000 to 525,000 per hectare is suitable. Before planting, holes should be punched in the PF and the seedlings implanted into the holes. They should be planted at a depth of about three centimetres which is favourable for the growth of new roots and for over-wintering.

Onion seedlings that are planted in the autumn should be irrigated before the soil freezes, and those planted in spring should be irrigated on time after the seedlings are revived. When the leaves are fully grown and the leaf sheaths begin to expand, proper wilting of plants (to stop irrigation) is required. After wilting, the squamose bulbs gradually expand and irrigation should be continued until the bulbs are nearly mature. Ten days before harvest, irrigation should cease. Application of additional fertiliser should be combined with irrigation, the amount required being from 300 to 375kg per hectare (ammonium sulphate).

<u>Controlling Pests and Diseases</u>. Root maggot is the most common pest and can be prevented by applying 2.5 per cent of Dylox powder at the rate of 22.5 to 30kg per hectare. This should be applied when the ground is prepared. Thrips can be controlled by spraying 1,000 units of Rogor emulsion or 800 units of dichlorvos continuously two or three times. The miner grub can be controlled by applying a mixed solution (40% of Rogor [0.5kg], kerosene [0.5kg], and water [250kg]). Purple blotch can be controlled by applying 10,000 units of amobam or 600 units of Daconil (chlorthalouil). As it is difficult for pesticides to adhere to the leaves, it is suggested that 0.2 per cent of washing powder should be added to the pesticide solution.

When 50 per cent of the leaves fall over on the field, the onions are ready for harvesting. It is better to harvest the squamose bulbs before rainfall, because a high water content makes storage difficult.

Kidney Beans

The use of PF in the cultivation of kidney beans is beneficial. It is estimated that yields increase by 20 per cent and income by more than 50 per cent. The main reason why kidney beans mature early and give high yields under PF is because PF greatly increases the active accumulated temperature (above 15°C) of the soil, facilitating emergence ten days earlier and making it possible to harvest the beans six days in advance. As a result, the first three batches of kidney beans yield 2.18 times more than comparative yields on open land.

Cultivation Methods. Sowing seeds directly into the field is the usual method of kidney bean cultivation. One day before sowing, the seeds should be soaked in warm water (20°C) for 10 hours. When the seed skin begins to wrinkle, the seeds should be sown. According to tests, under a temperature of 25°C, the kidney bean seeds need 3.7 to 4.3 days for emergence and, under a temperature of 12°C, they need 13.2 to 16.2 days. Apparently, if the soil temperature is not sufficiently high, sowing seeds in advance is useless. In this case, only PF can help the seeds to emerge early. If PF is spread after sowing, the field should be tended carefully and the PF should be removed on time to take the young seedlings out, otherwise they will wither. If the seeds are sown after spreading PF, seedlings should not be taken out. Usually, for dwarf varieties, the distance between rows should be 40cm and the space between holes should be 20 to 23cm; for viticula varieties, the distance between rows should be 60 to 70cm and the space between holes should be 15cm. Each hectare should have 105,000 holes and each hole should be sown with two to three seeds.

Viticula kidney beans require a frame constructed of bamboo sticks when the seedlings have grown sufficiently. During the early stages, when flowers appear, they do not need much water. When the young bean pods appear, irrigation should be carried out and additional fertiliser applied. Kidney beans need more phosphoric and potassic fertilisers, therefore it is better to apply complex fertiliser. The required amount is 150 to 225kg per hectare. It should be ensured that the viticulae of kidney beans are twined evenly around the sticks, otherwise the entangled viticulae will result in a reduction in yield.

Controlling Pests and Diseases. Aphids, red mites, and tea mites often harm kidney beans. These pests can be controlled by using the same methods that are used for egg plants. The main diseases are rust and bacterial pustules which can be controlled by spraying 500 units of Dithane.

Harvesting. When the young bean pods have grown to the required size, they should be harvested. Only those bean pods that have reached commercial maturity should be picked and the flowers and young bean pods should not be damaged. In the late harvesting stages, when most of the bean pods have been harvested, push out the viticulae, do not remove the bamboo sticks, and plant cucumber seedlings in the holes where the kidney bean plants have been removed. Thus the PF and bamboo frame can be used again.

Radishes

Cultivating radishes with PF is practised in many places in China. The extent to which yield increases depends upon the variety of radish. The margin of increase varies between 30 per cent and 46 per cent. In general, the effect of PF in autumn is not as positive as in spring, but, in mountainous areas or cold areas, application of PF in radish cultivation still yields remarkable results.

Results of Applying Various Types of PF. Radishes can be planted on high ridges or on flat ridges. The method is to sow the seeds first and then spread the PF or to wait for the seedlings to sprout, thin them, and then spread the PF. However, yield increase varies according to the type of PF that is used. According to tests carried out, transparent and black PF increase radish yield by 30 per cent and silver PF increases yield by from 72.8 to 75.8 per cent. In addition, silver PF also dispels 84.7 per cent of aphids 10 to 20 days after emergence. One report mentions that silver PF can control virus disease in radishes to an extent of 80 per cent. This figure is based on investigations that took place over a period of three years.

Sowing and Spreading PF. The key purpose of cultivating radishes by using PF is to produce strong seedlings. First, while preparing the ground, enough basic fertiliser should be applied, for example, 45,000 to 52,500kg of manure per hectare. After applying fertiliser, flat ridges should be made and sufficiently irrigated, and then PF should be spread on the ridges and the edges pressed down with earth. Based on the predetermined distance between rows and inter-plant space, make cross-shaped holes in the PF and sow five to seven seeds in each hole, then seal them with fine earth. After several days, the young seedlings will emerge and, when two cotyledons and one euphyllum appear, they should be thinned several times. Finally, one single strong seedling should be left in each hole. When the taproots of the radishes begin to expand, irrigate them and apply additional fertiliser. PF can shorten the growth period for radishes and harvesting takes places 10 days earlier than normal.

Potatoes

The potato is one of the most popular crops in the world, and it is used both as a staple food and main vegetable. The use of PF in potato cultivation has been tested by many institutions, particularly the Institute of Horticulture of the Helongjiang Academy of Agricultural Sciences. Their experiments have demonstrated that the yield increased 68 per cent. Tanggu State Farm, Tianjin, tested various varieties of potato and the increased yield was between 27.5 to 45.1 per cent depending upon the variety. Experiments carried out in different places have shown that PF can promote early maturation and increase yields.

Selecting Varieties and Forcing Germination. If the objective of potato cultivation is early sale, it is better to select early-maturing varieties, and if the objective is to increase yield, middle-maturing and late-maturing varieties should be selected.

In order to promote early emergence and prolong the period of growth, forced germination is commonly adopted. The seed tubers are cut into small pieces (according to the distribution of eyes). Then the small pieces of tuber are dried in the sun for a half to one day. Forced germination is carried out by placing the potatoes in large baskets. Spread rice straw on the bottom of the basket, followed by a three to four centimetre thick layer of wet sandy soil. Place a layer of potato tubers on the soil and cover them with three to four layers of wet sandy soil. Finally, place the basket in a room in which the temperature is below 20°C, in order to force germination. After 20 days or more, when the potato sprouts grow to two to three centimetres in length, these tubers can be sown.

Making Ridges, Spreading PF, and Sowing. To cultivate the potatoes, a compact planting method with wide ridges and double rows is used, and this is considered to be an effective measure for increasing yields. If this compact planting method is used, more basic fertiliser should be applied. Usually, one hectare requires 45,000 to 60,000kg of barnyard manure, but, if there is not sufficient barnyard manure, add urea or ammonium dihydrogen phosphate at the rate of 225 to 300kg per hectare as compensation. After preparing the ground, dig high ridges with widths of 50cm and heights of 20 to 25cm and spray nitrofen weedkiller (50% of water-dispersible powder at the rate of 30kg per hectare) over the ridges and then spread PF on the ridges. In compact planting, double holes are punched alternately in the PF at from 20 to 25cm distance and from 20 to 25cm of plant space. The sprouted potato tubers are then sown in the holes and sealed with earth. In areas which have saline-alkaline soil, the PF should be spread immediately after making the ridges. Otherwise, not only will the soil moisture escape but the salt and alkali will also gather on the surface of the ridges, thus harming the young potato sprouts. Another method is to spread the PF after sowing and, for this, it is necessary to make holes in the PF and take the young sprouts out on time, because, if the sprouts are taken out too late, they will wither.

Field Management. When all the sprouts have emerged from the PF, the potato field should be irrigated, but, during the stage between floral initiation and flowering, the plants should have withered. After the flowers wither, young potato tubers form in the earth. In order to promote the growth of the young tubers, the potato field should be irrigated again. The water level should not exceed half the height of the ridge at any time in order to keep the soil loose and wet, which is favourable for the growth of tubers. One week before harvesting, irrigation should cease. Additional fertiliser should be applied before floral initiation but application of too much fertiliser during the growth stage would promote too vigorous a growth of the plants, and this is not advantageous for tuber formation. When most of the potato plants wither and wilt, they should be harvested.

Spreading Temporary PF. In some places, e.g., in Nanjing and Shanghai, forced germination of potato tubers is carried out in the middle of January and these tubers are sown in the middle of February. Since, at that time, the soil temperature is not high enough for the emergence of potato tubers, PF is used temporarily to cover the potato field, so that, in 20 to 40 days, the sprouts will emerge. According to research, temporary use of PF can improve the quality and reduce the number of sub-standard plants, finally increasing yields.

Controlling Pests and Diseases. Pests that frequently occur are subterranean worms and aphids which can be controlled by using the same methods that are used for other vegetables. Potato blight is a very common disease that often occurs under wet environmental conditions. If plants are affected by this disease, they should be sprayed with 1:1:100 units of Bordeaux solution or 0.1 per cent of copper sulphate solution. Potato-ringed putrescence is another disease which affects potato tubers. To eradicate this disease, when the seed tubers are cut into small pieces, two knives are used alternately. First, the knives should be dipped in 0.1 to 0.2 per cent of mercury bichloride solution to decontaminate them and, when the diseased tubers are out, the used knife should be changed, otherwise the healthy tubers will be infected. Potato scab can be controlled by using Formalin (formaldehyde). There are two methods of using it. The first method is to prepare 100 units of Formalin solution with a temperature of 48° to 50°C, soak the potato tubers in this solution for two to three minutes, then remove the soaked tubers from the solution and tightly cover the tubers with wet burlap bags for one to two hours, uncover and dry the tubers, then cut them into small pieces to force germination. The second method is to prepare 240 units of Formalin solution, soak the tubers for five minutes, and then cover them tightly for 24 hours.

Fruit Trees

Apples

The apple is an important fruit and its yield and area are among the highest in China. Increase in apple yields is the basic objective of growers. Fortunately, using PF to cultivate apples has achieved satisfactory results.

Effects of PF on Apple Cultivation.

i) PF promotes the activity of the root system and enhances the use of light energy. Research carried out by the Experimental Station of Pomology, Huairen county, Shanxi, with 16 year-old apple trees covered with transparent PF, over a one-year period, has shown that in 33 cubic centimetres of earth, the roots weighed 2.51 grammes, and the roots of contrast plants weighed 2.01 grammes; the total length of the roots was 650.5cm, and the roots of contrast plants were 291.5cm; the area of leaves increased by 3.82cm^2; and the weight of 100 leaves increased by 7.08 grammes compared to the contrast plants.

ii) PF maintains soil moisture and promotes the early growth of apple trees. In northern China, spring is always characterised by little rainfall, strong winds, and rapid evaporation, therefore the orchards often suffer from drought, and sometimes young apple trees die as a result of serious drought. PF can greatly improve moisture conditions in orchard soils. It was determined that when the shaded area of apple trees was irrigated and then covered with PF, the water content in 0 to 30cm of soil was greater by 3.3. per cent after 10 days, 2.9 per cent after 20 days, and 10.7 per cent after 35 days than in soils not covered with PF. PF also promoted the growth of branches and increased the percentage of fertile fruit (see Table 4-1).

Table 4-1: Effect of PF on New Growth and Percentage of Fertile Fruit from Apple Trees (Liaoning, China)

Experimental Site	Covered with PF		Contrast		Comparison	
	Length of New Growth (cm)	Percentage of Fertile Fruit (%)	Length of New Growth (cm)	Percentage of Fertile Fruit (%)	Length of New Growth (cm)	Percentage of Fertile Fruit (%)
Wenquan, Xincheng county	69.4	11.8	65.3	10.7	+4.1	+1.1
Delishi, Gaixian county	26.0	17.9	24.0	14.9	+2.0	+3.0
Shangjin, Shuizhong county	23.7	25.8	23.4	16.3	+0.3	+9.5

Source: Chinese Association of Plastic Film Technology 1988

Reducing the Damage Caused by Pests and Diseases. In 1983, Yantai Institute of Agricultural Sciences, Shandong, carried out an experiment in which an apple orchard was covered with PF to protect it from peach fruit borers. The results showed that the first generation of grubs, which affect the fruit, was suppressed underneath the PF and could not produce a second generation. In this way the peach fruit borers were controlled and the effective rate of control was 89.2 per cent. Another experiment showed that PF could reduce the rust spots on apples. According to the investigations carried out in autumn 1980, the amount of fruit that suffered from rust spots was reduced by 90.6 per cent in an apple orchard covered with PF.

Increasing Yields and Improving the Colour of Apples. PF can increase apple yields because it increases both the percentage of fertile fruit and the weight of a single fruit. Some successful examples are given in Table 4-2.

The Agricultural Bureau of Qixia county, Shandong Province, tested the effect of PF on the colour of fruit in 1983. The results showed that the colour index on fruit covered with PF was 0.54, but without PF it was 0.36. Because PF increased the colour index, the quality of fruit also improved. The ratio of first grade and second grade fruit accounted for 90.1 per cent compared to 60.2 per cent without PF.

Table 4-2: Effect of PF on Increasing the Yield of Apple Trees (Liaoning and Shanxi Provinces, China)

Experimental Sites	Time	With PF Yield Per Tree (kg)	Without PF Yield per Tree (kg)	The Increased Yield under PF (%)
Xiongyue, Gaixian county	1981	194.8	180.0	8.2
Fruit Tree Station, Huairen county	1982	68.0	54.5	24.7
Pauzhi, Xinjin county	1983	166.0	122.0	36.0

Source: Chinese Association of Plastic Film Technology 1988

Promoting Maturity and Improving the Quality of Fruit. The Institute of Pomology of the Chinese Academy of Agricultural Sciences carried out an experiment to test the effect of silver PF on the quality of apples in Xincheng, Liaoning, in 1980-1983. The result demonstrated that silver PF could greatly improve the colour as well as the quality of fruit. According to the experiment, silver PF increased the intensity of light reflected near the ground, under the crown of the tree, from 3.3 to 6.4 times compared to the intensity on open land. This promotes the formulation of anthocyanin pigment and the accumulation of sugar. If anthocyanin pigment in the skin of the fruit increases, the red colour deepens. An increase in the sugar content of the fruit promotes maturation. As a result of using silver PF, the percentage of first grade fruit reached 74 per cent, the percentage of second grade fruit 20.3 per cent, and the percentage of third grade fruit 5.7 per cent. Without PF, the percentages were 25 per cent, 35.3 per cent, and 39.7 per cent respectively. It was learned that the effect of silver PF on apple orchards in the mountain areas was better than in the plains.

Digging Holes to Store Water and Fertiliser. This method was developed by Shandong University of Agriculture and it is especially suitable for mountain areas. According to this method, several holes are dug into the soil layer where the root system is concentrated and bundles of straw are placed in the holes to facilitate water and fertiliser storage, and then PF is spread over the holes. This method improves the growth and development of apple trees. According to research, this method can save 50 per cent of the fertiliser used, 90 per cent of water usage, and double the yield in comparision to normal methods. For example, in an orchard where there were seven to eight year-old apple trees that had never borne fruit before, one year's treatment with this method produced yields of 10,500kg per hectare, 10 times more than through normal methods. In addition, this method can help overcome the problem of alternate bearing in apple trees. This technology was used on 100,000 apple trees in Mongyang county of Shandong Province.

Cultivation Methods.

i) *Preparing the Ground and Applying Fertiliser.* PF cannot be spread properly unless the ground is prepared, therefore root turions, crop residues, and stones should be removed and the earth broken into small pieces. PF should be evenly spread over the space between two tree lines, so these spaces have to be flat and even. While spreading the PF, it should be ensured that the place near the trunk is standing higher than the surrounding area so that the rainfall will drain off. Fertiliser should be applied before spreading PF. Usually, the fertiliser is a mixture of organic matter and nitrogenous, phosphoric, and potassic chemicals. During the spring growth period, the nutrients stored in the tree are consumed so the fertiliser should be applied in autumn to help the tree over the winter and provide the tree with nutrients for consumption the following spring.

ii) *When to Spread PF.* Transparent PF should be spread early. When the soil layer below 10cm begins to thaw, PF should be spread. Spreading PF early helps to maintain moisture and to increase the temperature rapidly. Before spreading PF, the soil should be irrigated sufficiently and weedkillers sprayed on the surface of the ground (50% of Simazine of Atrazine at the rate of 3.75 to 6.0kg and 750kg water per hectare). For young apple trees in new orchards, it is better to apply 48 per cent of Trafluralin powder at the rate of three kilogrammes per hectare on the ground and to lightly till the ground after applying the weedkiller to protect the Trafluralin from sunlight. Silver PF should be spread one week before the fruits develop colour. As silver PF is spread for a duration of about five weeks, it should be removed before harvest so that it can be used again the following year.

iii) *Spreading Method.* If the orchard is in the plains, PF is spread under the area shaded by the trees. In mountainous areas, most of the apple trees are planted on terraces, and several trees are covered with a single piece of PF. In the case of young trees, they can be covered individually. Application of PF should be carried out at the same time as digging holes to store water and fertiliser. First, four to six holes with a diameter of 20 to 30cm and a depth of 40cm should be dug around each apple tree near the place where the root system is concentrated. Straw bundles are then soaked with water, or uretic water should be placed in the holes beforehand. Fill earth mixed with calcium superphosphate and urea - 50 to 100 grammes in each hole, make a small depression, and perforate the PF with small holes located above the water and fertiliser storing holes. These small holes should be used to pour in water, apply fertiliser, and let in rainfall. The PF should be pressed down with earth and stones.

iv) *Management.* The usual management methods are similar to those used in a normal orchard, but more attention should be paid to controlling pests and diseases. Trampling on the PF and tearing it while spraying pesticides should be avoided.

In mountain orchards, soil erosion frequently occurs after heavy rain and mud accumulates on the PF, so this mud should be removed. If the PF is torn, it should be covered with earth. Between the rows of trees, weeds can grow in places not covered with PF. When these weeds reach a height of about 20cm, spray 10 per cent of Roundup (glyphosato) at the rate of 3.75kg per hectare to kill the leaves and stems, but weedkillers should not be sprayed on the trunks and young leaves of the apple trees. Torn and used PF should be cleared from the orchard annually.

Citrus Fruits

Cultivation of citrus fruits is very common in the hilly areas of the Hindu Kush-Himalayan Region. PF application has proven successful in citrus orchards. Some of these success stories are given here.

Increasing the Weight of Fruit and Increasing the Yield of Citrus Trees. PF helps to increase the yield of citrus trees. From Table 4-3, it can be seen that the average yield per tree on two experimental sites was from 23.0 to 23.9 per cent. The yield increases because the weight per fruit and the percentage of fertile fruit also increase. PF does not apparently affect the quality of the fruit, but the skin of the fruit thickens slightly.

Preventing the Loss of Water and Soil. Since most of the citrus orchards are distributed throughout the subtropical hills, frequent and heavy showers cause serious soil erosion. When terraced citrus orchards are covered with PF, the raindrops cannot directly scour the soil, so the nutrients are maintained in the soil.

Quozhou Institute of Agricultural Sciences, Zhejiang Province, carried out an experiment to test the capacity of PF to maintain nutrients. In this experiment, compound fertiliser was applied to four tangerine trees (at the rate of 0.5kg per tree) and covered with PF. After one month, the soil samples collected from various layers of soil were analysed. The results for from a 0 to 60cm layer of soil showed that PF could greatly reduce the loss of soil nutrients. For example, compared to the normal method of cultivation, 36.6 per cent of total nitrogen, 113.4 per cent of total phosphorous, 120.7 per cent of alkali-hydrolysed nitrogen, 103.2 per cent of rapidly available phosphorous, and 97.2 per cent of rapidly available potassium were saved.

Table 4-3: Effect of PF on Fruit and Yield of Citrus Trees

Experimental Sites	Treatment	Weight Per Single Fruit (g)	Thickness of Skin (mm)	Soluble Solid Substances (%)	Average Yield Per Tree (kg)
Zhejiang University of Agriculture (Wenzhou Orange)	Covered with PF	112.1	3.52	10.18	75.7
	Without PF	96.1	2.96	10.39	58.3
	PF Increased (%)	16.6	18.9	-2.0	23.0
Quzhou Institute of Agricultural Sciences (Pong Tangerine)	Covered with PF	129.3	2.60	12.50	28.9
	Without PF	111.1	2.60	12.90	22.0
	PF Increased (%)	16.4	0	-3.1	23.9

Source: Chinese Association of Plastic Film Technology 1988

Protecting Citrus Trees from Freezing Over the Winter. Citrus trees often suffer from cold or freezing, especially in the northern marginal areas of the citrus-growing zone of China. Usually, citrus orchards are protected by digging soil, covering with straw, and spreading rice chaff.

According to an experiment carried out from 1981 to 1982 by the Bureau of Agriculture and Forestry of Wuxi city of Jiangsu Province, PF can stably increase soil temperatures. For example, during the cold winter of 1981, the minimum temperature of the soil surface under PF was higher than on open land by two degrees centigrade, and the temperatures at 5, 10, 15, and 20 centimetres were higher than on open land by more than four degrees centigrade. PF not only increased the temperature quickly but also prolonged the increase. Spreading rice chaff only increased the temperature of the shallow soil layers, but the surface temperature was lower than on open land, which is disadvantageous for the collar of citrus trees in the winter. In addition, the effects of rice chaff only lasted for 10 days after spreading and gradually disappeared.

Spreading PF. The operative technology for spreading PF in citrus orchards is similar to that used in apple orchards, but there are some differences, and these are given below.

Generally, the area shaded by the tree should be covered, but this should be in line with local conditions. For trees that are planted along contour lines, a long strip of PF should be spread on the ground along the trunks of the trees and spread wide accross the width of the PF. For large trees, PF should be spread individually and the joints should be tightly sealed with earth. The ratio at which PF should be spread in citrus orchards depends on the size of the trees. For new orchards, the ratio is about 40 per cent and, for old orchards, it is about 60 per cent.

Appropriate Time for Spreading. Since the air temperature during spring in southern China is quite unstable, and citrus trees often suffer from damage caused by freezing or cold, spreading PF early protects the citrus trees and increases yields.

According to an experiment carried out by Quzhou Institute of Agricultural Sciences in

1982, an orchard covered with PF on January 15 increased its yield by 23.9 per cent, but an orchard which was covered with PF on 10 July increased its yield by only 9.9 per cent compared to orchards without PF. The range of yield increase in orchards covered earlier was higher than that of orchards that were covered later by a factor of 14 per cent.

Applying Fertiliser. As citrus trees sprout several times a year, except during the dormant stage, the trees continue to grow during the other stages. Citrus trees bear more fruit and the fruits remain on the trees for a long time, so these trees need more fertiliser and more applications of fertiliser. If the trees are covered with PF, it is difficult to apply fertiliser several times. The first application of fertiliser should be carried out before spreading PF, and it should be combined with irrigation. Each big tree needs 2.5kg of cake fertiliser, 0.5kg of complex fertiliser, and 25kg of human excrement. The second application of fertiliser should be carried out when the fruit expands, and additional fertilisers, such as urea and boric acid, should be applied. The third application should be carried out after the harvest. To prevent the leaves from falling during winter, promote the emergence of flower buds, and enhance the accumulation of nutrients for the new sprouts in the following year, this fertiliser application is the most important. The amount of fertiliser should be half the amount of the total applied throughout the whole year. The method used is to dig ring-shaped furrows or radial furrows around the tree after removing the PF and then to apply fertiliser in the furrows. Application of fertiliser should be combined with irrigation.

Controlling Pests and Diseases. Many pests and diseases damage citrus trees and fruit. Mites are the most common pests and they can be killed by applying Baume, 1.5 degrees of lime sulphur mixture, or 600 units of Tedion (tetradifon). Coccids can be controlled by applying 500 units of 50 per cent Malathion or 1,000 units of Rogor. Collum rot disease can be controlled by scraping off the diseased spots and applying 10 units of copper sulphate solution on the scraped spots. Canker of citrus is a dangerous disease but can be controlled by applying 1,000 units of 50 per cent of Kasumin-Bordeaux (Kathugamycin) in March and April to protect new sprouts. Every two weeks, the citrus orchard should be sprayed thoroughly, but care should be taken not to trample the PF while spraying.

Grapes

PF has been successfully applied in the cultivation of grape saplings; in establishing new orchards by direct planting and cutting; and in rejuvenating old grape orchards, yielding remarkable economic benefits.

Effects of PF on Grape Cultivation. PF promotes the growth of grape saplings. Grape buds sprout under an air temperature of 10°C and new roots develop under a soil temperature of 20°C. If grape saplings are cultivated on open land, because the temperature of the ground surface in spring rises again slowly, the wind is strong, and there is an intensive evaporation of moisture from the soil, the cuttings and young sprouts will wither or die because the growth of new roots is slow and the young sprouts lose water quickly. PF can solve this problem.

According to an experiment carried out in a grape nursery in Tianjin in 1981, the sprouting and survival rates of cut saplings covered with PF were higher than in grapes cultivated through normal methods by from 10 to 17 per cent and from 82.6 to 84.0 per cent respectively. PF can increase survival rates, because the growth rate of roots increases. According to the experiment, the cuttings began to grow roots 30 days after they were covered with PF; 25 to 30 days earlier than with normal methods. The growth rate of the roots was 60 to 80 per cent higher than normal.

PF can also improve the quality of saplings. In Shihezhi Farm, Xinjiang, the percentage of first grade saplings, when covered with PF, was 59.1, but without PF it was 27.2. On three demonstration plots in Huhe Haute, Inner Mongolia, the percentage of first grade saplings, when covered with PF, was 89.1, and without PF it was 50.

PF increases the yield of grape orchards. In some saline-alkaline soil areas, for example, the total salt content reaches 0.2 per cent and the pH of the soil is more than eight, so establishing new grape orchards by directly planting cuttings was unsuccessful. However, PF can be successful in this case too. For example, Tianjin Grape Farm established a grape orchard by directly planting cuttings and covering them with PF in 1982. The following year, the yield of the orchard reached 4,702.5kg per hectare and the orchard began to bear fruit one year earlier than orchards planted with one-year old saplings, but without PF.

PF can increase the yield of old grape orchards. According to an experiment carried out by the Bureau of State Farms, Tianjin, the yield of an old grape orchard covered with PF was 54.4 per cent higher than one without PF (see Table 4-4).

Table 4-4: Effect of PF on the Yield of Grape Orchards

Items / Treatment	Fertile Fruit Rate (%)	Average Weight Per Cluster (gramme)	Weight Per 100 Grapes (gramme)	Yield (kg/hectare)
Covered with PF	46.4	365.5	385	22,500
Without PF	41.2	330.0	395	14,574

Source: Chinese Association of Plastic Film Technology 1988

Cultivation Methods.

i) *Forced Growth of Roots.* Root growth has to be forced in order to increase survival rate and produce strong saplings. Root growth can be forced in a heated seedling bed or by covering the seedling bed with PF. The indicator that the seedlings are ready for forcing is when the grape cuttings have grown calli on the pruning wounds but do not take root. These cuttings are ready to be forced and can be used both to cultivate saplings and to plant directly in the orchard.

ii) *Cultivation.* Preparing the ground, applying basic fertiliser, and irrigating the field should be carried out in the previous year and ridges should be made the following spring after the soil thaws. The size of the ridge should be about 8 to 10cm high, 100 to 120cm wide, and three to five centimetres long. The surface of the ridge should be level and without big lumps of earth. Before spreading PF, the ridges should be sprayed with a weedkiller, such as Atrazine (ametryn), at the rate of three kilogrammes per hectare. After spraying the weedkiller, spread the PF immediately and press down the edges of the PF with earth. Usually the grape cuttings are planted on the ridges at the beginning of April. The distance between the rows should be 30cm and the distance between cuttings should be from 10 to 15cm. A hole should be made in the PF with a small wooden club, and then the cuttings should be placed in the hole. It must be ensured that the top bud of the cutting is located in the place where the PF is and that the top bud is pointing upwards. It should then be covered with two to three centimetres of earth. When the temperature rises to 10°C, the young sprouts will emerge from the soil.

iii) *Management.* When the new shoots emerge, temporary or permanent trellises should be built to support the saplings. The lateral shoots should be removed in the latter stages of growth. After the harvest, when the leaves fall, the fallen leaves and the diseased branches should be burned in the grape orchard to control the spread of black rot and powdery mildew. White rot is another dangerous disease and can be controlled by applying 1,000 units of Thiram, once every two weeks, three or four times. According to a report received from Jixi Extension Station of Agricultural Sciences, Helongjiang, PF can prevent damage by downy mildew to grapes. The incidence of disease in PF-covered grape orchards was lower than in normal orchards by 60 per cent. The percentage of dead saplings in PF-covered orchards was one per cent and, in orchards without PF, it was 42 per cent.

Strawberries

The strawberry is an early-maturing fruit and is very easy to cultivate. It is usually planted between fruit tree rows as an intercrop. Sometimes it is also grown in vegetable gardens near towns or cities because of their closeness to the market.

Effects of PF on Strawberry Cultivation.

i) *Protecting Strawberry Plants during Winter.* In northern China, strawberries need to be protected from the cold and from freezing. Usually, the stalks of crops are used for mulch in a strawberry garden. For example, in Mancheng county, Hebei Province, wheat straw was used to cover strawuberries, but the percentage of dead plants was 1.4 to 2.3 per cent, the green plant rate was 48.7 to 57.1 per cent, and only 20 per cent of the green leaf area remained. When PF was introduced in strawberry cultivation, the green plant rate and the survival rate was 100 per cent; the remaining green leaf area after winter was from 70.0 to 82.8 per cent, compared to strawberries covered with wheat straw in which the green leaf area was only 18.1 to 20.6 per cent. In addition, PF brought about flowering seven days earlier and harvesting three days earlier, prolonging the harvest by four days.

ii) *Increasing Strawberry Yield and Output Value.* According to an experiment carried out by Hebei University of Agriculture in 1982-1983, the yield from strawberry plants covered with PF was higher by 15 to 19 per cent than from those covered with wheat straw. A report from the Institute of Horticulture, Jiangsu Academy of Agricultural Sciences, showed that PF could increase yields by 66.8 per cent over normal methods. The Institute of Pomology of the Chinese Academy of Agricultural Sciences tested the effect of various types of PF, and the results are given in Table 4-5.

Variance analysis of yields with the use of different types of PF showed that, in comparison to the normal method, transparent PF has a higher yield level than green and black PF. Transparent PF had an evident level of difference compared to other methods of cultivation, whereas the green and black PF have no significant difference.

From Table 4-5, it can be seen that the increase in output value is much higher than the yield increase of strawberries, because the early-maturing fruit could be sold for high prices in the market. For example, in Xuzhou Orchard in 1988, the output value of strawberries in the early period accounted for 21.5 per cent of the total output value, but that of contrast plants only accounted for 8.4 per cent. In some places, the output value of early-maturing fruit accounted for 40 per cent of the total output value.

Table 4-5: Effects of Various Types of PF on Strawberry Yields in Xuzhou Orchard, Jiangsu Province

Treatment	Early Yield (7-15 May)		Middle Period (16-20 May)		Late Period (22-27 May)		Total Yield	Yield Per hectare	Comparison of Yield
	Yield (kg)	(%)	Yield (kg)	(%)	Yield (kg)	(%)	(kg)	(kg)	(%)
Transparent PF	4.61	16.98	11.27	41.47	11.29	41.55	27.2	17,137.5	124.8
Green PF	2.87	12.00	10.03	42.00	11.00	46.00	23.9	15,060.0	109.6
Black PF	2.78	11.73	8.74	42.00	13.68	51.40	23.7	14,923.5	108.7
Contrast	1.11	5.10	8.00	36.87	12.67	58.20	21.8	13,732.5	100.0

Source: Chinese Association of Plastic Film Technology 1988

iii) *Improving the Quality of Strawberries.* According to tests carried out in Xuzhou Orchard by the Institute of Pomology of the Chinese Academy of Agricultural Sciences, various types of PF can improve the quality of strawberries in the early period. For example, the content of sugar and solid substances, the weight of a single fruit, and the size of fruit were higher with the use of PF; the content of organic acids was lower than in fruit without PF; and transparent PF yielded better results than other types of PF.

Cultivation Methods.

i) *Preparing the Ground.* In northern China, flat ridges are often used because strawberries have to be protected from freezing, but, in southern China, high ridges are used because strawberry fields need drainage. As strawberries consume more fertiliser and water, and as it is a renascent herb, the planting field should be ploughed deeply and sufficient organic manure should be applied. Since the width of PF is fixed, the width of the ridge has to fit the width of the PF. Before spreading the PF, 48 per cent of trifluralin at the rate of 22.5kg per hectare should be sprayed on the field to control weeds.

According to a study carried out by the Institute of Pomology of the Chinese Academy of Agricultural Sciences, trifluralin does not harm strawberries and can effectively control weeds until the beginning of May.

ii) *The Time to Spread PF.* Usually PF is spread in early spring, but, in northern China, PF is spread in combination with measures carried out to prevent freezing. For example, in Mancheng county, Hebei Province, before the soil freezes (late November), the field is first irrigated with sufficient water, then covered with PF, and finally wheat straw is spread on to the PF. In the middle of February in the following year, the wheat straw should be removed so as to enable the temperature of the soil to increase. In the middle of March, when the strawberries begin to sprout, the plants should be removed along with the PF, and the collum parts of the plants should be sealed with earth.

iii) *Management.* During the growth period, strawberry plants should be given additional fertiliser, especially in the flowering stage. The plants should be sprayed with 0.2 per cent of potassium dihydrogen phosphate or urea water solution. In addition, the soil in the strawberry field should always be maintained in a wet condition. When the strawberry field is covered with PF, the fruit will no longer be spoiled, and so the quality and grade of fruit will improve. However, in order to weed and irrigate, the PF should be removed when the temperature of the soil rises to 15°C. The best method is to carry out drop irrigation combined with PF application. This not only saves water but also enhances the effect of PF. After the fruit is harvested, as the stoles of the strawberries begin to grow young roots and the young seedlings require fertiliser, the PF should be removed.

Other measures include picking off small flower buds on the inflorescence to improve the quality of fruit and eliminating surplus stoles and leaves so as to save nutrients and increase the quantity of flower buds for the next year. Grey mould is the most dangerous disease and can be controlled by applying 1,000 units of thiophantate solution. Red mites can be controlled by spraying chrorfensulphide.

Pineapple

Effects of PF on Pineapple Cultivation. It has been proven in a number of countries that spreading PF on pineapple fields is an effective measure for increasing the yield.

Before the advent of PF use, it was very common to use asphalt paper as mulch on pineapple fields. Now black PF is being used in Italy, Thailand, and Taiwan. Use of black PF makes the soil wet and loose, prevents erosion, and controls weeds so as to promote the growth of pineapples and improve the quality of the fruit. The effect of using PF in arid areas is quite remarkable. For example, in Guinea, when black PF was used, the yields from pineapples growing in sandy soil increased by 20 per cent. The Agricultural Bureau of Puni County, Guangdong Province, carried out experiments over a period of three years on the use of PF in pineapple fields, and good results were achieved (see Table 4-6).

From Table 4-6, it can be seen that PF increased pineapple yields by 54.5 per cent. In addition, PF increased the temperature of the soil by four to five degrees centigrade and the moisture in the soil by 30 per cent. It also promoted the early maturation of fruit and shortened the period of production, increasing economic benefits. As the pineapple is a shallow-rooted crop, ground weeding can easily damage the root system. PF can control weeds and tilling does not have to be carried out.

Table 4-6: Effects of PF on Pineapple Cultivation

Treatment	New Leaves Per Plant (pieces)	Average Length of Leaves (cm)	Average Width of Leaves (cm)	Average Height of Plants (cm)	Yield (kg/ha)	Yield Comparison (%)
Covered with PF	33	22	48	29	63,750	154.5
Without PF	5	12	20	11	41,250	100.0

Source: Chinese Association of Plastic Film Technology 1988

Cultivation Methods. Pineapples should be planted on gently sloping hills where soil layers are deep, fertile, and loose. In newly established plantations, the fields should be deeply ploughed, at least down to more than 35cm, and sufficient organic fertiliser should be applied. All perennial weeds and their residuary roots and stones should be removed. Flat ridges are normally used for pineapple plantation. The width of each ridge should be about 100 to 150cm and the width of the furrows between the ridges should be about 30 to 40cm. The depth of the furrow should be more than 25cm to facilitate drainage. It is recommended that the density of planting should be 75,000 to 90,000 plants per hectare. Proper close planting has some advantages; e.g., the leaves of the pineapples shade the ground, thus reducing the evaporation of moisture from the soil and increasing the relative humidity near the ground, and the dense leaves decrease the temperature of the soil surface in summer and increase the temperature in winter.

When PF is spread on the ridges, it must be ensured that it is flat and close to the ground. According to the planned distance, holes should be punched in the PF and the young pineapple seedlings should be planted in these holes. During the growth period, foliage fertilisation is often used in pineapple plantations. Other measures, such as digging, eliminating crown buds, spraying growth regulator on the plants, controlling diseases and pests, and preventing the effects of frost, should be carried out as normal.

V. Application of PFT in Cash Crop Cultivation

Sugarcane

Application of PF in sugarcane cultivation in China started very late, but its development took place rapidly. The first experiment was carried out in Guangdong Province in 1980, and, up to 1982, the area of sugarcane cultivated under PF was only 200 hectares throughout the whole county. Since then, this technology has become popular in Guangdong, Guangxi, Hunan, Zhejiang, Sichuan, and Yunnan, and the total area cultivated with PF had reached 8,660 hectares in 1984. As cultivating sugarcane under PF yielded better results than open land cultivation, farmers considered it to be an effective measure of increasing yields. In 1985, the area of sugarcane cultivated by using PF reached 8,000 hectares in Guangdong Province.

Effects of PF on Sugarcane Cultivation

Prolonging the Growth Period of Sugarcane. Usually, the sprouts of sugarcane emerge at 13°C and the leaves grow at 15°C. But, in some areas of cultivation, for example, in Guangdong, the air temperature in winter is always below from 13°C to 15°C, and the weather is also very dry. Under these conditions, the sprouts emerge very slowly, the period of sprouting is very long, and the percentage of sprouting is very low. Since PF increases the soil temperature and retains moisture, the sprouting and growth of sugarcane are greatly improved.

According to research carried out in Yiwu county, Zhejiang Province, as the temperature of the air under the PF increases by six to seven degrees centigrade, the sprouts emerge 20 days earlier than normal, the rate of sprouting increases by 20 to 30 per cent, the rate of stooling increases by 100 to 200 per cent, and thus the yield of sugarcane increases by 28 to 42 per cent over sugarcane cultivated by normal methods. In Hunan Province, it was discovered that PF is very useful for overcoming the problems of low temperatures and of overcast rainy weather which cause late sprouting, low sprouting rates, and non-emergence, of plants. PF can also help decrease the damage caused by early frost in the late period of growth. As a result of prolongation in the period of growth, sugarcane can absorb the abundant heat and sunshine in June, July, August, and September, thus increasing the yield of sugarcane. The longer the period of growth, the higher the yield.

Increasing the Yield of Stubble Sugarcane. When stubble sugarcane is cultivated on open land, a number of the buds on the stools of the sugarcane die during the winter. According to research carried out by Guangxi Agricultural College, after stubble sugarcane was covered with PF, the rate of dead buds decreased from 42 per cent to 19 per cent. These buds neither die nor sprout before reaching the stage when sprouts appear. In this case, the total number of buds that sprout would be doubled if PF was used. As the buds sprout early, quickly, and evenly, the available stems (or canes) increase and the weight of a single stem (or cane) would also increase.

The Agricultural School of Dongguan County, Guangdong Province, carried out experiments over a period of two years on the use of PF to cultivate stubble sugarcane. The results showed that the yields of sugarcane covered with PF reached

105,442.5kg per hectare, compared to yields from sugarcane cultivated on a field without PF (37,055.0kg per hectare); PF increased the yield by 36.8 per cent. In addition, the content of sugar in the canes covered with PF reached 15.15 per cent and that in those cultivated without PF reached 13.57 per cent. This means that PF increased the content of sugar by 1.58 per cent.

Cultivating Sugarcane with PF

Operative Technology for Newly-planted Sugarcane Fields. PF is suitable for sugarcane planted in late autumn, after the rice harvest, and in winter and early spring.

i) *Decontamination and Forced Sprouting.* Because of the high humidity caused by PF, diseases are easily spread. Before layering the seed canes, they should be soaked in two per cent of lime solution for 24 hours in order to decontaminate the canes and promote water absorption. Then the decontaminated cane sections should be piled from 33 to 66cm high on the wet rice straw, sufficient water should be poured on the cane sections, and the cane sections should be covered with earth. Finally spread PF on the piles. After 10 to 15 days, the sprouts emerge. Under the PF, due to high temperature and high humidity, the rate of sprouting increases so that the layering quantity of cane sections decrease by 10 to 20 per cent compared to the layering quantity on open sugarcane fields.

ii) *Application of Sufficient Basic Fertiliser.* As it is difficult to apply additional fertiliser after spreading PF, it is necessary to apply sufficient basic fertiliser. Since the temperature of the soil is high under the PF, the organic matter decomposes quickly, and it is better to apply more manure. Each hectare requires 22,500 to 37,500kg of miscellaneous manure; 375 to 750kg of calcium superphosphate; 187.5 to 450kg of potassium chloride; and 187.5 to 450kg of urea.

iii) *Sufficient Irrigation.* Before layering the cane sections, the furrows should be irrigated, the mud stirred, and the cane sections should be inserted into the mud (about half of the length of the cane section). After that, the furrows should be irrigated again. This irrigation ensures that the cane sections absorb enough water after sprouting. After the water has been absorbed into the soil, spread a thin layer of soil on the cane sections, and then cover them with PF. In those areas where there are no irrigation facilities, the rush-planting (quick planting) after rainfall is adopted. In this case, preparing the ground, applying basic fertiliser, and making furrows should be carried out in advance. When the field is saturated with rain, rush-plant the cane sections immediately and cover them with PF. This measure can satisfy the minimum water requirements of sugarcane when they are in the seedling stage. When monsoon begins, water supply is no longer a problem.

iv) *Controlling the Weeds.* Under the PF, high temperature and high humidity promote the growth of weeds so application of weedkillers is necessary. In Guangdong Province, in sugarcane fields without intercropping, 2.63kg per hectare of simazine or ametryn is sprayed; in fields with intercrops, such as peanuts and beans, if the dominant weeds are monocotyledons, three kilogrammes per hectare is sprayed; if the dominant weeds are both monocotyledons and dicotyledons, a solution of 100 grammes of Machete (butachlor) plus 50 to 60kg of water, or a solution of 100 grammes Lasso (alachlor) plus 150 grammes of Roundup (glyphosate) and 50 to 60kg water is sprayed. In Hunan Province, usually a solution of 100 grammes of MCPA-sodium, 250 grammes of Nitrofen, and 30 to 35kg of water, or 400 grammes of Diuron and 30 to 35kg of water is sprayed.

v) *Spreading PF*. When the cane sections are planted in one row, the width of PF should be from 45 to 50cm and the required amount is from 45 to 52.5kg per hectare. As PF is relatively narrow, it should be carefully spread so that light can permeate the pervious area and so that the effect of temperature increase is enhanced. This method can save the amount of PF and reduce the cost of spreading. When the cane sections are planted in double rows, the width of PF should be from 160 to 180cm. This method permits light to permeate the pervious area, effectively increases temperature, and maintains moisture. In fact, the rate of sprouting, the amount of stooling, and the leaf area index under wide PF are higher than under narrow PF, but, under wide PF, when the sprouts emerge, young leaves will scorch, because of high temperatures and strong light. It is necessary to remove them from the PF on time. When the sprouted cane sections account for more than 80 per cent of the total cane sections, the PF should be removed. This PF can then be used for other crops or re-used the following year.

vi) *Intercropping*. Since there is more space between the rows of newly established sugarcane fields, proper intercropping can fully utilise land and increase income. For example, in Yiwu county, Zhejiang Province, several crops were interplanted in a sugarcane field covered with PF and harvests were 870 to 1,125kg of good soyabeans per hectare, 90,000 to 10,500kg of potatoes per hectare, 17,295kg of sweet potato vines per hectare, 71,430kg of cucumbers per hectare, and 34,500kg of kidney beans per hectare. According to research carried out, intercrops did not influence the yield of sugarcane and, in some places, the yield of sugarcane still reached 75 to 135 tonnes per hectare. It is recommended that cash crops be planted as intercrops, e.g., water melon, sweet peppers, tomatoes, egg plant, and garlic.

vii) *Removing PF and Management after Removal*. If the temperature under PF reaches 40°C, the PF should be removed, otherwise the young sprouts will be scorched. But if the PF is removed too early, it will affect the growth of sprouts and reduce the rate of stooling. Timely thinning of sprouts is an important measure, because the number of sprouts evidently influences the sugarcane yield.

According to experiments carried out in Yiwu county, Zhejiang Province, when each hectare contained 165,000 sprouts and 210,000 sprouts, the yield was 130.5 tonnes and 100.5 tonnes respectively. But when each hectare contained all the sprouts produced without thinning, the yield was only 60 tonnes. For varieties with big stems, the suitable density is from 5,000 to 6,000 sprouts per hectare.

Operative Technology Suitable for Canes.

i) *Reserving Stubble Canes.* When the stubble cane field is selected, the sugarcane should be cut down using a very sharp knife, and the sprouts that emerge in autumn and winter also should be cut off. All cut sections should be flat in order to avoid tearing the PF or making holes in them. In areas where the air temperature is high, when the sugarcane is cut down the stubble cane should be immediately covered with PF to not only prevent the cut section from diseases and germs but also to control water evaporation from the stubble cane field. In areas where the air temperature is lower, treating the stubble cane and covering them with PF should be carried out late, for example, it can be carried out from the beginning of February to the beginning of March.

ii) *Digging Furrows and Loosening Soil.* During the whole season of growth, soil piles up on the ridges that are subjected to the sun and rain, therefore the soil becomes very hard. The underground buds are pressed by the thick, hard soil, so it is very difficult for them to emerge. In practice, the later the buds sprout, the higher their mortality rate. That is why digging furrows between ridges and loosening the soil between sugarcanes are very important measures. Usually, the furrows should be dug more than 10 to 13cm deep and the old soil, piled up the previous year, should also be dug over. The soil between sugarcanes should be loosened and turned over and the old cane should be revealed. If digging furrows and loosening soil are not carried out thoroughly, the rate of sprouting will evidently be reduced.

iii) *Applying Fertiliser.* As the period of sugarcane growth is very long, it is difficult to apply fertiliser after spreading PF. The sugarcane field needs application of more basic fertiliser to meet the requirements for the whole period of growth. It is recommended that miscellaneous, indigenous manure, at the rate of 15,000 to 45,000kg per hectare; calcium superphosphate, at the rate of 375 to 750kg per hectare; and potassium chloride, at the rate of 150 to 225kg per hectare, should be applied. In sugarcane fields that are located on hill slopes, application of fertiliser should be combined with irrigation because the soil lacks water. It is recommended that semi-liquid manure, at the rate of 45,000 to 60,000kg per hectare, be applied to sugarcane fields in hilly areas.

iv) *Controlling Pests and Diseases.* Sugarcane borers and grubs are the most common pests. They can be controlled by spraying a solution of Phoxim (6-9kg Phoxim plus 15,000kg water) before covering the field with PF. In order to protect the cut section of the stubble cane from disease and germ infection, 0.2 to 0.5 per cent of Bavistin or Thiophanate should be sprayed on the cut sections immediately after harvesting the sugarcane.

v) *Spreading PF.* Since the size of the stubble cane is bigger than that of newly-planted cane, the PF should be wider. To cover one row of stubble cane, the width of PF should be 60 to 80cm and the required amount of PF should be 60 to 75kg per hectare; to cover double rows, the width of PF should be 160 to 180cm and the required amount of PF should be 105 to 120kg per hectare. When the PF is spread, it should be ensured that the edges are sealed tightly. According to research carried out, if the PF is not sealed properly, the rate of sprouting will be reduced by 30 per cent.

vi) *Removing the PF*: The duration of cover depends upon whether conditions are favourable for sprouting. If the weather is fine, the air temperature high, and the soil fertile, the duration of PF cover will be short. Usually, when the sprouts reach 60,000 to 75,000 per hectare, each sprout has three to five leaves, and the air temperature has stably increased to 20°C, it is time to remove the PF. After removing the PF, application of fertiliser and irrigation can promote the growth and strength of young sprouts. At the same time, after the sprouts have reached the expected number, the surplus sprouts should be thinned. After thinning, the sugarcane ridges should be dug out so as to restrain the unproductive stools from emerging.

Cultivation of Sugarcane Seedlings.

i) *Cultivating Sugarcane Seedlings by Using PF has Some Advantages.* First, the seedlings are concentrated in a small area so that they can easily be kept under favourable conditions, e.g., favourable temperature and humidity. They can be provided with enough water and fertiliser so that the seed canes can be saved to the extent of 1,500 to 3,750kg per hectare, and the seedlings are stronger than those emerging directly from the field. Second, since these seedlings are very strong and, even when they are transplanted into the fields, they grow quickly, 10 to 20 per cent more stems are available than those directly emerging from the field. The yield of sugarcane can increase by 7.5 to 30 tonnes per hectare and the saccharine in them can increase by 0.5 per cent. Third, sugarcane seedlings can be cultivated with PF in the slack season, and thus save labour, pesticides, and fertiliser.

ii) *Cultivating Sugarcane Seedlings with PF in Soil.* This method has been widely-adopted in sugarcane cultivation areas. The operative technology is as follows. The seed canes are soaked in two per cent of lime solution for 24 hours, and then they are removed and soaked in 0.2 per cent of Bavistin or Thiophanate for three to five minutes. This measure prevents diseases. Before layering the seed canes, sufficient water should be poured on to the seed bed and the seed canes should be laid on the bed one by one. After that, the seed canes should be covered with mixed manure and water poured on them again. Finally the PF is spread. When the sprouts emerge and two to three young leaves appear, these seedlings are ready to be transplanted. According to experience, the quantity of seedlings from one hectare of nursery beds could meet the requirements for 180 to 300 hectares of sugarcane field.

To cultivate big seedlings, the bed should be framed with a bamboo canopy and covered with PF. In this bed, when the sprouts emerge and two young leaves appear, they should be given water and fertiliser, and when five leaves have grown the seed canes should be transplanted into the sugarcane field. When the air temperature reaches 20°C, it is time to transplant. In order to ensure the survival of seedlings, the leaves should be cut down to one-third and, after the seedlings are planted, they should be irrigated several times so that all the seedlings survive.

iii) *Cultivating Sugarcane Seedlings with PF without Soil.* This is a new improved method of cultivating sugarcane seedlings, and, compared with the old method, it can save land, labour, PF, fertiliser, and pesticides. It is also easy for farmers to learn. This method can be used not only in the field but also indoors. According to experience, the quantity of seedlings from one hectare of nursery can meet the requirements of 600 to 750 hectares of sugarcane field. The quality of seedlings cultivated by this method is very good, and the yield usually increases by 7.5 to 30 tonnes per hectare. The operative technology is as follows. In a corner of the field, a bed that is 10m long and 1.5m wide should be prepared. A layer of rice straw with a thickness of 6 to 10cm should be laid over the bed. Enough water should be poured on the bed and Dipteryx solution (one unit of Dipteryx plus 600 units of water) should be sprayed on the bed to protect the seed canes from rice borers and sugarcane borers. At one edge of the bed, a small mound should be made with rice straw and covered with pig dung, then the seed canes should be laid on the mourrd at 70° oblique angles, one by one. (All these seed canes should be soaked in two per cent lime solution for 24 hours before laying them out.) Then, the four edges of the bed should be mounded with rice straw and pig dung. Liquid pig dung should be poured on these seed canes on the bed and 0.2 per cent of Bavistin or Thiophanate should be sprayed to protect the sections of the seed canes from diseases. Finally, PF should be spread on the bed and the four edges of the PF should be sealed properly. Although the seed canes touch the soil, they easily suffer from lack of water, so every three to five days the PF should be removed and water poured over the seed bed. After 10 fine days (in winter) or 7 to 10 fine days (in spring), the sprouts emerge and the seedlings are ready for transplantation. If big seedlings are required, the bed should also be framed with a bamboo canopy and covered with PF. Under this PF canopy, the seedlings grow vigorously. After more than 20 fine days (in winter), or more than 10 fine days (in spring), the seedlings grow five to six leaves and are ready for transplantation.

Peanuts

Peanut cultivation by using PF started in China in 1979, and it rapidly became popular in most areas. In 1985, the area of peanut cultivation under PF reached 233,333 hectares. According to statistics, through PF, the yield of common peanut fields reaches 3,750 to 4,500kg per hectare, the yield of better peanut fields reaches 5,250 to 6,000kg per hectare, and the yield of the best peanut fields reaches 7,500kg per hectare. Generally, the adoption of PFT can increase the yield by 1,500kg per hectare.

Effects Of PF Use on Peanut Cultivation

Expanding the Area of Peanut Cultivation. PF increases the temperature of the cultivated soil layer and the effective accumulated temperature, so peanuts can be cultivated in areas where the frost-free period is short and the natural heat is not enough. PF can meet the heat required in the early stages of growth and thus prolong the whole period of growth, shorten the stage of maturation, and ensure that the normal yield is obtained.

Potential Increase in Yields of Various Varieties. In Lianoning Province, as the heat is insufficient, only early-maturing and middle-sized (nut) varieties can be cultivated but the yields of these varieties are not high. The middle-maturing and large-sized (nut) varieties can be cultivated in very narrow regions, and the yield is low, usually from about 2,250 to 3,000kg per hectare. From 1979-1985, the PF technology was popularised throughout the province. Some middle-maturing and big-sized (nut) varieties were cultivated in big areas and the yield of peanuts reached from 5,250 to 6,000kg per hectare, and, in some areas, it reached 7,500kg per hectare. In the Loess Plateau of Shaanxi Province, before 1980, the peanut yield was less than 1,500kg per hectare. From 1981, PF was introduced in these areas and the middle-maturing and large-sized (nut) varieties were cultivated at the same time. The peanut yield reached 4,500 to 5,250kg per hectare and the highest peanut yield was 9,480kg per hectare.

Increasing the Yield of Peanuts and Improving Their Quality. According to research, PF can accelerate the stages of growth, for example, emergence can be eight to 12 days earlier, flowering eight to 12 days earlier, pod setting four to nine days earlier, and maturation eight to 10 days earlier. The harvesting stage under PF in the Loess Plateau would be one month earlier than without PF. As the period of growth accelerates, the peanut yield also increases. As the plant size increases, the branches of the plant as well as the fruit increase, and the increase in yield is the inevitable outcome.

According to research carried out by the Shandong Institute of Peanut Research, when the peanut field is covered with PF, the number of fruit branches increased (1.7 to 2.9 per plant), the number of fruits increased (18 to 48 per kilogramme), the peanut pod yields increased by 20.6 to 48.7 per cent, and the peanut seed yields increased by 31.7 to 63.2 per cent. According to an analysis carried out by the Jinzhou Institute of Agricultural Sciences, Liaoning Province, PF can increase the content of the total amino acids (including 17 amino acids) by 7.22 to 18.10 per cent.

Cultivating Peanuts with PF

Preparing the Ground and Applying Fertiliser. The cultivation method is similar to non-tilling. The root system of peanuts is very strong, the taproot penetrates deeply into the soil and the lateral roots extend widely, therefore the peanut field should be deeply ploughed in order to increase the thickness of the arable layer. Deep ploughing should be carried out before winter, or in early spring, and the depth of ploughing should be more than 20cm.

Deep ploughing should be combined with the application of fertiliser, otherwise the fertility of soil does not improve. According to estimates in northern China, if the expected yield of peanuts is 5,250kg per hectare, pig dung and miscellaneous manure should be applied at the rate of more than 60,000kg per hectare, calcium superphosphate at the rate of from 300 to 450kg, plant ash at the rate of from 1,175 to 1,500kg, and ammonium sulphate at the rate of from 225 to 375kg per hectare; in southern China, cattle dung at the rate of from 6,000 to 7,500kg per hectare, plant ash at the rate of 7,500kg per hectare, calcium superphosphate at the rate of 375kg per hectare, and urea at the rate of 150kg per hectare are applied as basic fertilisers.

During the middle and late stages of growth, the pods develop very quickly and the dry materials are quickly accumulated in the pods, therefore, additional fertiliser should be applied so that complementary nutrients are provided.

Application of additional fertiliser can be carried out in two ways; one method is to make a small hole, with a depth of five centimetres, on the ridge and at a distance of five centimetres from the peanut plant, and then apply ammonium sulphate at the rate of from 150 to 225kg per hectare, or urea at the rate of from 75 to 105kg per hectare, into the small holes. The other method is to spray liquid fertiliser on to the leaves. Suitable fertilisers are potassium dihydrogen phosphate, sodium bisulphate, and microelement fertilisers such as boric, molybdic, zinc, and iron.

It has been proved that this can promote nodule formation and increase the quantity of nodules in the root system. This measure can increase the yield of peanuts by 5.9 to 15.0 per cent and increase the rate of plump-eared seeds by 4.4 per cent.

Spreading PF. The time when PF should be spread depends on the temperature and the moisture of the soil. In hilly areas, the soil temperature rises quickly so PF should be spread early, but soil moisture should be taken into consideration. If there are no irrigation facilities in the peanut cultivation area, it is necessary to use the natural moisture of the soil, which means that PF should be spread immediately after plough-ing land, preparing the ground, applying fertiliser, and making ridges. If the water content of a five centimetres' layer of soil is less than 15 per cent, irrigation should be carried out or natural rainfall taken advantage of.

The standard ridge for peanut cultivation under PF is shown in Figure 5-1. This ridge can guarantee that the pod needles prick the PF stably. The PF should not be removed until the peanuts are harvested. According to data collected from northern China, if the PF is taken away in the middle or late stages of growing, the peanut yield decreases by 10.7 to 17.2 per cent. Nevertheless if there is too much rainfall in the growth season and there is too much water under the PF, the PF should be removed, otherwise the peanut pods will be damaged.

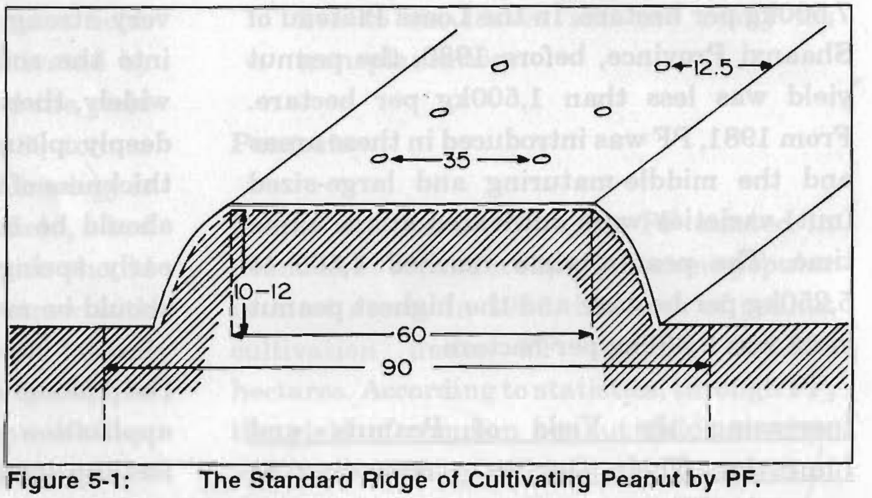

Figure 5-1: The Standard Ridge of Cultivating Peanut by PF. (Unit: cm)

Applying Weedkillers. After spreading PF, the peanut field cannot be cultivated and weeded, therefore it is necessary to spray weedkillers before spreading the PF. The commonly used weedkillers are Lasso (alachlor) and Nitrofen. Lasso is a selective weedkiller and the required amount is from three to 3.75kg of 48 per cent Lasso and from 750 to 1,125kg of water. According to a test carried out by the Institute of Plant Protection, Liaoning Academy of Agricultural Sciences, if the required amount of Lasso exceeds 4.5kg per hectare, the nodule bacteria will be affected, the quantity of nodules will decrease, and the nodules will be small.

Sowing Seeds. When to sow depends upon three factors: the date when the local frost ends, the number of days from sowing to emergence, and the minimum temperature required for the emergence of peanut seeds. The early-maturing and middle-sized varieties should be sown when the temperature of soil at five centimetres' depth stabilises at 12°C, and the middle-maturing and large varieties should be sown when the temperature of soil at a depth of five centimetres stabilises at 15°C and the soil moisture is adequate. If seeds are sown too early, they emerge slowly because of low temperatures and are damaged. If seeds are sown too late, the economic benefit of PF cannot be realised.

High-quality seeds should be selected to obtain full stands and sound seedlings. Selection of seeds is an important task which must be carried out before sowing. It is necessary to select first and second grade seeds which are big and plump, with strong germinating potential and a high germinating percentage. In addition, it is necessary to force emergence and treat seeds with nodule bacteria before sowing. Proper sowing practices are also important, and it is recommended that punching holes, pouring in water, sowing seeds, and covering them with earth should be combined and carried out continuously. The size and depth of the holes should be as follows: diameter - 4.2cm and depth - 3.5cm. Two seeds should be sown in each hole and immediately covered with earth after sowing.

Spraying Plant Growth Regulator. At the end of the blooming stage, if the plants grow too vigorously and become leggy seedlings, it is suggested that the plant growth regulator - B9 - should be sprayed to slow down the growth of stems and leaves, make the pods plump, and increase the yield of peanuts by 10 per cent. The recommended concentration of B9 is 1,000 to 1,500ppm. Another plant growth regulator - Fosamine has been tested and found to be effective. During the later stage of pod setting, 500 to 1,000 PPF of Fosamine should be sprayed on to the leaves to control the growth of stems and leaves, reduce the nutrient consumption of non-bearing flowers in the later stage, and promote the transference of photosynthates from the leaves to the pods so as to greatly increase the yield. Experiments show that the pods can be increased by 6.7 to 20.1 per cent and the seeds can be increased by 10.0 to 23.5 per cent.

Controlling Pests and Diseases. Grubs, cutworms, and wireworms are the underground pests that damage peanuts when they are in the seedling stage, and chafers, snoutbeetles, and thrips are the pests above ground that damage peanut seedlings, especially in the dry season. To control underground pests, it is suggested that a mixture of earth and Phorate (30-37.5kg of Phorate plus 225kg of fine earth per hectare) be applied in combination with constructing ridges or sowing seeds. Another method of control is to dress seeds with Phoxim. First, a solution mixed with 100 grammes of 50 per cent Phoxim and 1.5 to 2kg of water should be prepared, then 50kg of seeds should be dressed evenly with this solution and the seeds placed in a plastic bag for three to four hours. Finally, take the seeds out and dry them in the air before sowing. For the pests above ground, it is suggested that Dipteryx solution (one unit of 90% Dipteryx plus 800 units of water) should be poured into the root area. Another method of control is to prepare some branches of elm tree or poplar tree which are soaked with Dipteryx solution (one unit of 90% Dipteryx plus 500 units of water) and then they should be inserted into the soil; the pests die while eating them. Aphids not only damage the leaves and flowers but also spread viruses, but can be controlled by spraying 1.5 per cent of Rogor powder at the rate of from 30 to 37.5kg per hectare, or Rogor solution (one unit of 40% Rogor plus 1,500 units of water). Cotton bollworm often damages the peanut leaves in the latter growth stages, but it can be controlled by spraying 0.01 per cent of Pyrethrin powder at the rate of from 22.5 to 30kg per hectare.

Peanut leaf spot, nest blotch, stem rot, and rust disease are very common in the area under peanut cultivation in China. According to the data collected from different areas, these diseases should be controlled in the early stages of occurrence (the central, diseased plants appear in the field). Peanut leaf spot can be controlled by spraying the water-dispersible powder Bavistin (one unit of 50% Bavistin and 1,000 units of water) or the water-dispersible powder Thiophanate (one unit of 50% Thiophanate and 1,500 units of water). These fungicides should be sprayed three to four times, every 10 to 12 days. Peanut stem rot can be controlled by treating seeds with the water-dispersible powder Bavistin. The weight of Bavistin accounts for 0.3 per cent of the weight of peanut seeds. Peanut rust disease can be controlled by spraying Chlorthalonil (one unit of 75% Chlorthalonil and 700 units of water) or Amobam (one unit of 45% Amobam plus 500 units of water). These fungicides should be sprayed alternately three to four times every eight to 10 days. Spraying these two fungicides alternatively would be more effective.

Tobacco

The objective of tobacco cultivation is to provide leaves of good quality. When the yield of tobacco leaves is not so high, it leaves room for improvement in the quality of leaves and increase in its yield. But when the yield reaches a certain level, the increase in yield of tobacco leaves goes into rapid decline. In the various ecological regions and under different cultivation conditions, the optimum yield, in which the quality of leaves is the best, is quite different. The proper yield scope of tobacco leaves is considered to be from about 2,250 to 2,625kg per hectare. The key measure in tobacco cultivation is to control the yield of tobacco leaves according to the optimum scope and to improve the quality of the leaves.

Effects of PF on Tobacco Cultivation

Maintaining Moisture in the Soil. The effects of PF on moisture conditions depend on the water content of the area of soil in which the root system is concentrated. During the early and middle stages of tobacco growth, if there is too much rainfall and if the soil is too wet, when the tobacco ridges are covered with PF, the water content in the area where the roots are concentrated is less than that of open land. PF is favourable for tobacco cultivation during the early and middle stages of tobacco growth. If the rainfall is inadequate and the water content in the soil is insufficient, PF cultivation is disadvantageous for tobacco. During the maturation stage, if the rainfall is too much and the soil is fertile, the tobacco plants will absorb too much nitrogen, prolonging the maturation period for tobacco and reducing the quality of the leaves. In this case, PF can restrain the rainfall entering the area where the roots are concentrated so as to ensure the maturation of tobacco leaves.

Increasing the Light Intensity Near the Ground. The quality of the leaves growing on the lower part of the tobacco plant is the poorest. Besides the physiological features, inadequate light is one of the important reasons why this is so. Since PF can reflect light, by the use of PF more light is received by the space near the ground.

According to tests carried out in tobacco fields, in the case of vigorously growing broad-leaved varieties, after tip pruning and closing of tobacco plants, the amount of natural sunshine above the tobacco plants totalled 120,000 luxes. The intensity of reflex light on the backs of the leaves 20 to 30cm above the open ground was 200 to 300 luxes, and this is lower than the compensation point of light; that above the PF covered ground was 600 to 800 luxes, which is equal or higher than the compensation point of light. This means that PF can improve the intensity of light received by the back of the leaves on the lower parts of the tobacco plants. It also darkens the colour on the back of the leaves after curing, and this colour is usually very light when tobacco is grown on open land. PF can improve the quality of the leaves by increasing the intensity of the light reflected.

Controlling Pests, Diseases, and Weeds. Transparent PF and silver-gray PF can reflect light which would disperse aphids, so the number of aphids on tobacco leaves grown under PF is much less than on open land. Since cucumber mosaic virus is the main disease that affects tobacco, and since it is spread by aphids, PF can greatly reduce its occurrence. According to research carried out in the region where the cucumber mosaic virus prevails, during the early stages of tobacco growth, the incidence of the disease in the field covered with PF was only one to two per cent, but incidence in the open field was 51 per cent. As most varieties of tobacco cannot resist this virus, application of PF greatly increases the yield and improves the quality of tobacco leaves.

Under PF, soil temperature and soil moisture are higher than in open fields, and this creates favourable conditions for the propagation and activity of pathogenetic organisms; e.g., some diseases which spread through the soil such as root rot, black shank, and fusarium wilt (these would worsen); and other diseases which usually occur in the rainy season when the temperature and moisture are high would occur more rapidly if PF is used. This shortcoming can be avoided through alternate cultivation. In areas where diseases spread through the soil frequently occur, these diseases should be controlled by spraying fungicides before spreading PF.

Leaf diseases spread through the soil would spread quickly in open fields during the rainy season, because the raindrops spatter and transfer germs on to the tobacco leaves. If the tobacco ridges are covered with PF, the incidence of disease is greatly reduced and the air humidity near the ground is also reduced. Thus, PF can obviously alleviate the damage caused by leaf diseases.

Under the PF, weeds also grow very quickly and vigorously, and it is very difficult to pull them out. It is necessary to spray weedkillers before spreading PF. In those tobacco fields seriously affected by weeds, black PF should be used because it is very effective for controlling weeds.

Feasibility of PF Use in Cultivating Tobacco in Various Ecological Zones

In Regions with High Latitudes and High Altitudes. In these regions, although the days in which the average daily temperature is more than 20°C can meet the requirements for tobacco growth and maturation, the temperature of soil in spring rises very slowly. When the tobacco seedlings are transplanted, they grow slowly. Besides this delay in growth, maturation takes place when the temperature is low and this adversely affects the maturation of tobacco leaves. Sometimes they suffer from damage caused by cold. PF can facilitate the transplantion of tobacco seedlings at an earlier date than normal. It can also facilitate rapid growth so that most of the leaves mature in the season when the temperature is high, which not only increases the yield but also improves the quality of the tobacco leaves. Using PF to cultivate tobacco in these regions is of significant economic benefit.

In Regions with More Rainfall during the Growing Season . Because of heavy rainfall in the early stages of tobacco growth, there are heavy soil and fertiliser losses, therefore additional basic fertiliser has to be applied. Several applications of additional fertiliser cost more money and labour. In addition, heavy rainfall makes the soil wet and brings about a decrease in the temperature of soil, consequently, the root system does not grow properly, the plants become thin and weak, and the yield and quality of tobacco leaves decline. Application of PF on the tobacco field can reduce the loss of soil and fertiliser and prevent soil from becoming too wet. Due to the increase in the soil temperature, the root system grows properly and the plants become strong. Finally, the yield of tobacco is greatly increased.

In Regions with High Temperatures and Little Rainfall during the Transplantation Stage. In these regions, the rainfall is not sufficient and is uneven during the early and middle stages of growth, but there is too much rainfall in the maturation stage. The survival rate of the transplanted seedlings is usually low and they grow very slowly. Even if there is rainfall, the seedlings still do not grow properly. The tobacco yields are not high as a result. In this region, the ability of PF to maintain moisture can be fully used. Before transplanting seedlings, the tobacco field should be irrigated or immediately covered with PF after rainfall. This measure can retain moisture under the PF and help the seedlings to tide over the dry period when temperatures are high. It must be ensured that the seedlings are not transplanted too early, because during the dry period when high temperatures prevail, moisture under the PF would be exhausted by the tobacco plants and they would be damaged or would die before rainfall.

In Regions with Low Temperatures during the Early and Middle Stages of Tobacco Growth. In the tobacco production area of the Sichuan Basin, the weather is characterised by low air temperature and more rainfall always occurs in May. Under these weather conditions, the growth of tobacco seedlings is often stagnant and they easily suffer from diseases. This leads to a reduction in both the yield and quality of tobacco leaves. But by using PF, since the soil temperature is higher than on open land, the seedlings can be transplanted early and they can grow quickly and attain the required size before the period of low temperatures and before the rainy season. These large, strong seedlings can resist the damage caused by diseases and ensure the expected yield. According to experiments carried out in recent years, under normal weather conditions, the yield of tobacco covered with PF increases by from 375 to 450kg per hectare, and, under unfavourable weather conditions, the tobacco yields increase by more than 750kg per hectare.

In Regions where Tobacco and After Crops Compete for Time. In the Sichuan and Fujian provinces, after the tobacco harvest, rice is the after crop. If tobacco matures too late, the rice seedlings cannot be transplanted in time. The gap would be prominent, especially if the temperature was low. As PF can increase the soil temperature, it enables the early transplantation of tobacco seedlings and they grow quickly, the period of maturation can be preponed by 10 days. So rice can be transplanted 10 days earlier.

Tobacco Cultivation with PF

Spreading. In regions with high latitudes and high altitudes, when the soil thaws, there is more water in the soil, and the soil temperature rises very slowly. Sometimes the air temperature reaches the required point for transplantion, but the soil temperature is insufficient for transplantation. Even if the seedlings were to be transplanted, they would grow very slowly and bloom early, which greatly reduces the yield. In such cases, the tobacco field should be prepared in advance and spread with PF 10 to 20 days before transplantation. PF can increase the soil temperature and maintain the moisture content to provide the seedlings with favourable conditions for fast growth. In northern China, in spring, the soil moisture is not always sufficient and rainfall is always scarce. If there are no irrigation facilities, the tobacco field should be prepared in advance. PF should be spread on the tobacco ridges as soon as it rains but not when the soil moisture is insufficient after transplanting, because sufficient rainfall does not enter the area where the root system of tobacco is concentrated as the PF obstructs it. In this case, the moisture content under PF is lower than on open land. In addition, due to the fact that tobacco plants grow quickly and consume more water under PF, if the weather is dry the moisture content under the PF will be worse than that on open land. So PF should be spread when the moisture content in the soil is sufficient.

Duration of PF Use. In the hilly areas, PF should be removed when the tips of the tobacco are pruned to enable the root system to receive more rainfall. In the plains, if the tobacco plants are cultivated on big, high ridges, the PF should be replaced and retained until harvest after the tips are pruned. Generally, the duration of cover depends upon the moisture content; only sufficient moisture content in the soil can guarantee adequate yield and good quality tobacco leaves.

Planting Depth. Under PF, the taproot of tobacco is not as deep as it is on open land and the area where the roots are concentrated will be higher. When the tobacco plants flower, they can fall over in strong wind and rain, so the planting depth under PF should be one to two centimetres deeper than on open land. Often, when the seedlings are transplanted, the average daily air temperature will have reached more than 15°C, therefore the seedlings under the PF do not grow properly. This is due to the fact that the temperature in 10cm of soil is too high, and this restrains the growth of tobacco. In this case, the depth at which seedlings are planted should be increased to attain normal growth.

Application of Nitrogenous Fertiliser. Proper application of nitrogenous fertiliser is necessary to obtain the expected yield and good quality, but it is difficult to control the required amount. The exact amount of nitrogen required in different tobacco fields and in different years with varied rainfall is not known. The required amount of nitrogen fertiliser under PF should be decided according to experiment. In Japan, the amount of nitrogen fertiliser required decreases by 10 to 15 per cent if PF is used. In China, according to tests in fields which contain more organic matter and more rapidly available nitrogen fertiliser, the amount of nitrogen fertiliser is reduced. In fields which contain less than 30ppm of rapidly available nitrogen, the amount of nitrogen fertiliser should not be reduced and in fields which have low soil fertility, especially in the hill areas, the amount of nitrogen fertiliser should be increased in order to achieve the expected yield and desired quality.

Transplanting Time. If the tobacco field is covered with PF, transplanting can be carried out well in advance, and the seedlings will grow fast and mature early. In this case, however, the maturation stage of tobacco leaves will shift from the optimum season to the non-optimum season, which would mean a reduction in the quality of tobacco. So the time for seedling transplantion should depend upon the local optimum maturing season, i.e., the maturing stage of the best leaves should coincide with the season that is most favourable for the quality of tobacco.

Jute

Effects of PF on Jute Cultivation

Since 1981, some experiments with PF in jute cultivation have been carried out in the Zhejiang and Jiangsu provinces of China. The results showed that PF can promote the early maturation, improve the quality, and also increase the yield of jute (see Table 5-1).

Table 5-1: Areas of Jute Cultivation with PF and Their Yields in Zhejiang Province, China

Time	The Area Covered with PF (ha)	Average Yield (kg/ha)	Increased Yield (kg/ha)	Compared with Contrast (%)
1981	0.13	5442.5	1279.1	30.00
1982	4.8	7832.9	1250.6	18.96
1983	47.8	7906.8	1153.2	18.44
1984	562.6	7127.7	1112.3	18.49

Source: Chinese Association of Plastic Film Technology 1988

According to experiments conducted by the Xiaoshan Institute of Jute and Cotton Research, Zhejiang Province, PF can increase the yield of jute by from 1,875 to 3775kg/per ha and the increased rate is about 70 to 90 per cent. In addition, other features also improved, for example, the height of jute covered with PF was higher than that of jute without PF by from 7.4 to 13.9 per cent; the stem diameter was bigger by from 7.3 to 17.3 per cent; the length of the fibre was longer by 22.9cm; the strength of the fibre increased by 4.6kg per gramme; and the number of fibre layers, the total number of vascular bundles, and the number of fibrocytes were evidently more than that of jute without PF.

If PF is used, jute seeds can be sown about 10 days earlier. Accordingly, the harvest date will shift and the yield of jute will not decrease. After the jute is harvested, the rest of the growing season can be used for planting other vegetables, e.g., radishes.

PF not only increases temperature, retains moisture, maintains the soil in a loose condition, and increases the efficiency of fertiliser, but it also restrains the root nematode disease which affects jute. According to research, the incidence of disease decreased by 30 per cent and the index of disease decreased by 46.5 per cent when PF was used. In the case of jute culture without rotation, PF increased the yield of jute remarkably.

Use of PF in Jute Culture

Ridge Construction. The width of ridges will depend upon the width of PF. If the proper width is selected, the benefits of PF can be fully realised, i.e., the effect of PF on temperature increase. If two lines of jute are planted on the ridges, the width of the ridge should be 45 to 50cm and the width of the PF should be 70 to 80cm; when the lines of jute are planted, the width of the ridge should be 80 to 90cm and the width of PF should be 120cm. During interplanting, the fore-crop should have short stalks and should be of the early-maturing variety, so that light is received and the effect of PF on increasing the temperature of soil is enhanced.

Sowing . When PF is used in jute cultivation, seeds can be sown seven to 10 days earlier than normal which prolongs the growing period and prevents the young seedlings from withering under the PF, as happens when seeds are sown late and the temperature is high.

According to practice, the sowing rate is about 18.75kg per hectare. If the sowing rate is lower than this, there would be no seedlings in some places in the fields' sowing furrows. If the sowing rate is higher than this, the cost would increase as well as the labour required for thinning. The moisture content of the soil is very important. If the soil is too dry, it will be difficult for seeds to germinate. If the soil is too wet, the young seedlings will be damaged by disease. In the latter case, the seeds can be sown first and, when the soil has dried, the PF can be spread.

Timely Removal of Seedlings. If the seedlings are removed too early, they grow very slowly. If they are removed too late, they will wither under the PF. According to practice, when 70 per cent of the seedlings emerge from the soil, it is time to remove the seedlings, and this should be carried out several times to remove all the seedlings. When all the seedlings are removed, the holes in the PF should be sealed tightly with earth to maintain the required temperature and moisture and to prevent weeds.

Application of Fertiliser. Once the jute field is covered with PF, it is difficult to apply additional fertiliser until the end of June. As the fertiliser in the soil under the PF is not easily washed away, adequate basic fertiliser should be applied before spreading PF. Usually, organic manure is applied while ploughing. Cake fertiliser and chemical fertiliser are applied by making furrows on the ridges. The depth of the furrows should not be less than eight centimetres and, after the fertilisers have been applied to the furrows, they should be immediately covered with earth. The seeds can be sown just in the furrows of the ridges. In order to prevent the premature decay of jute, application of fertiliser is necessary after the PF is removed.

Controlling Pests, Diseases, and Weeds

In some jute fields, underground pests heavily damage the young seedlings. These pests can be controlled by using poison bait before sowing and spreading PF. Rhizoctonia disease occurs often in jute fields, and it can be controlled by pouring Bavistin solution into the soil around the roots of jute or by covering the roots of jute with earth soaked in Bavistin solution. Once the jute field is covered with PF, it is impossible to till and weed it. It is necessary to spray weedkiller before spreading PF. Rasso is considered to be an effective, low-cost weedkiller for jute fields, and it is suggested that 1.5kg/ha is the maximum amount. If the amount of Rasso exceeds this, the jute seedlings will wilt.

Mulberry

PF Application in Young Mulberry Plantations

PF has been successfully applied in young mulberry plantations. A study carried out by the Institute of Sericulture of the Chinese Academy of Agricultural Sciences demonstrated that the sprouting date of mulberries covered with PF was five to six days earlier, the growth of branches accelerated, and the maximum rate of growth was earlier by eight to 12 days than normal. Compared to normal methods, the total number of branches on each plant, the average length of the branch, the diameter of the trunk, the number of leaves on each plant, the number of leaves on each branch, and the number of leaves per metre evidently increased. Under the PF, the root system was widely and deeply distributed throughout the soil, and the total amount of roots was more than without PF. For example, the root system of a two-year old sapling under PF penetrated up to a depth of 70cm into the soil and that of plants without PF were only 50cm; the horizontal root system expanded 70 to 80cm, that of plants without PF were only from 35 to 40cm. In the case of most mulberry varieties, PF can increase their yields, but this can only be observed at certain times. Twenty days after spreading PF, there are no differences between the plants under PF and those cultivated by the normal method but, after two months, the effects of PF on mulberry plants are very remarkable.

Mulberry cultivation methods with PF are similar to those of other crops. In new mulberry plantations, PF should be spread first and then the saplings should be transplanted. Once the saplings are planted, the holes in the PF should be sealed tightly with earth in order to prevent the moisture from escaping and to prevent the growth of weeds. PF can be used throughout the whole period of growth without it being removed.

Applying PF in the Cultivation of Mulberry Saplings by Cuttings

The survival rate for mulberry cuttings is not high in many areas where there are no irrigation facilities in spring, or which have saline-alkaline soil, or low spring temperatures and cold weather. Applying PF in the cultivation of mulberry cuttings can greatly change the content of water, heat, and air in the soil so as to increase the survival rate of saplings and improve their quality.

Experiments carried out in Luopu County, Xinjiang Province, demonstrated that the survival rate of mulberry cuttings under PF reached 72 per cent, 18 per cent greater than those without PF. In addition, PF can promote early sprouts in cuttings and increase the height of saplings. For example, in June and July, the heights of saplings under PF and without PF were 8.5cm and 14.5cm respectively.

PF can help to enhance the growth rate of mature saplings by 20 per cent, i.e., there is an increase of 15,000 saplings on each hectare of nursery and the quality of the saplings is improved, so the saplings are accordingly upgraded by one grade.

The method for cultivating mulberry saplings under PF is described below.

Usually, mulberry cuttings are cultivated in middle or late April, depending upon the local weather conditions. For example, when the period of local late frost is over, cutting can be carried out. First, the nursery should be carefully prepared and enough basic fertiliser applied. Long ridges with widths of from 60 to 70cm and heights of 10cm should be built and the PF spread on these ridges. When the nursery is ready, one-year old branches should be pruned from the mother plants and cut into 25cm long sections. These cuttings should be soaked in 0.1 per cent of potash permanganate solution or two per cent of sucrose solution for 24 hours. After that, the cuttings will be ready. Each ridge can hold two rows of cuttings. The distance between rows should be 50cm and the space between cuttings should be from 15 to 20cm. By using this method, each hectare of nursery can produce 105,000 to 125,000 saplings. When the cuttings are inserted in the ridges, it must be ensured that each cutting has one winter bud left above the PF. One month after cutting, the end of the cutting will have grown calli and, after three months, the sprouts will have grown from 20 to 30cm. Five months later, the saplings will be 60cm high.

VI. Retrieval and Reprocessing of Used PF

The Importance of Retrieving Used PF

Along with the application of PF in agriculture, the amount of used PF which remains in the fields is also increasing year by year. According to calculations, during the seven years from 1980 to 1986, if half the amount of PF applied in the field were retrieved and the other half remained in the field, i.e., from 0.2 to 0.25 million tonnes of used PF would remain in the whole of China. Used PF cannot dissolve into the soil and causes tilling and field management problems as well as negatively affecting the growth and development of crops. In addition, if animals accidentally eat the used PF, they will suffer from intestinal diseases. In order to prevent the pollution of cultivated land as a result of using PF, and to clear the agricultural environment, it is necessary to retrieve the used PF so that it can be recycled for further use.

Practice has proven that retrieving and reprocessing used PF are possible. In regions where PF is used extensively, retrieving and reprocessing the used PF not only prevents the pollution of cultivated land and protects the environment but also saves plastic resources and increases the incomes of farmers.

Retrieval of Used PF

Plastic Film Technology is growing in popularity, so it is necessary to disseminate information regarding the damage caused by used PF if it remains in the fields. It is necessary to inform farmers that PF can increase the yield of crops and has various benefits, but that it also pollutes the agricultural environment. This way farmers can be mobilised to retrieve the used PF. It is a good idea to establish a convenient network for farmers, so that they can sell the used PF and collect it easily for reprocessing. In addition, a reasonable purchasing price should be fixed to encourage the farmers to collect and sell the used PF.

Reprocessing the Used PF

Previously, in some places the used PF was retrieved and was either burned or buried. Burning and burying does not eliminate the pollution caused by used PF in the agricultural environment but rather wastes the plastic resources and the labour expended in collecting the used PF.

At present, some reprocessing factories have been established in the region where PF is extensively used. According to estimates made, if there are more than 1,500 to 2,000 hectares of cultivated land under PF in a country, a reprocessing factory should be established to recycle the used PF. The size of the reprocessing factory depends upon how much of the used PF can be retrieved. For example, to establish a reprocessing factory which has the capacity to produce a 100 tonnes of granular materials, a 100 square metres for the workshop, a 100 square metres for the storehouse, 300 square metres for the air-drying yard, a 100 square metres for the dumping ground, and necessary equipment, such as two material-washing machines, three extruding machines, and one granule-cutting machine, are required. In China, this type of factory requires a sum of from 18,000 to 20,000 *yuan* (3,333-3,703 US$). Generally, if 100 tonnes of reprocessed granules are produced, a profit of from about 20,000 to 30,000 *yuan* (3,703-5,556 US$) can be realised.

The reprocessing method is very simple. The used PF can be reprocessed to produce granular materials or recycled products for the market.

Production of Granular Materials

The production method can be divided into three steps.

1) Washing the Used PF. The retrieved PF has to be washed manually or by machine. The quality of the reprocessed granules and products depends upon the degree of cleanliness. The Agricultural Technology Extension Centre in Suizhong County, Liaoning, has a machine which is 12 times more efficient than manual washing and the machine not only increases efficiency but also guarantees cleanliness.
2) Melting and Extruding. The cleaned PF is placed in the extruding machine whee it is melted into rough, low density material. The materials are then placed in the second extruding machine and, through continual heating, a dense sticky paste is extruded. This material is then placed into the third extruding machine where it is heated once more to produce a brightly coloured density strip material 0.3 to 0.4cm in diameter. In this procedure, the key point is temperature control. Accurate and appropriate temperatures guarantee that the reprocessed material is of high quality.
3) Cutting. The reprocessed strip material is placed in the cutting machine and cut into granular material of from 0.5 to 0.6cm in diameter. When the reprocessed slips are cut and packed, it must be ensured that miscellaneous objects are not mixed with the granules in order to guarantee the quality of the reprocessed product.

Manufacture of Reprocessed Products

Granular materials can be processed into various products of daily use such as bicycle handle sleeves, decorative household items, shoe heels, plastic pipes, washboards, and bottle caps. The manufacturing process depends upon the shape of the products. For example, products with simple shapes can be manufactured as described below.

Put the hot and sticky paste material from the second extruding machine into the mould which is designed according to the required shape. Through extruding and pressing, the reprocessed product is directly manufactured. This production method shortens the working procedure, reduces costs, and enhances benefits. To manufacture products that are heavy and which need to be continually processed, for example, plastic pipes, the granular materials are melted again and then the melted materials are placed in special machines and special moulds and, through extruding and shaping, the plastic pipes are manufactured. Since the special machines and moulds are very expensive, establishing this type of factory requires more investment, and it is necessary to study the feasibility and construction plan before establishing the factory. According to Chinese experience, a reprocessing factory should be set up in regions where there are more than 20,000 hectares under PF.

Retrieval and reprocessing of the used PF have certain economic benefits. Generally, production of one tonne of granular material can yield an income of 200 to 300 *yuan* (37-55.5 US$); if the granular material is processed into one tonne of reprocessed products, it will yield an income of 300 to 600 *yuan* (55.5-111.1 US$). If the factory is managed properly, the quality of products from the recycled material will be good and so will the economic benefits.

Annexes

Annex 1

A.1. The Area Per Unit Weight and the Weight Per Unit Area in Different Thicknesses of Polythene Film (LDPE)

Thickness (mm)	m^2/kg	$gramme/m^2$
0.010	108	9.3
0.011	98	10.2
0.012	90	11.1
0.013	83	12.0
0.014	77	13.0
0.015	72	13.9
0.016	67	14.9
0.017	63	15.9
0.018	60	16.7
0.019	57	17.5
0.020	54	18.5

Low Density Polythene

A.2. The Area Per Unit Weight and the Weight Per Unit Area in Different Thicknesses of Polythene Film (HDPE)

Thickness (mm)	m^2/kg	$gramme/m^2$
0.005	209	4.8
0.006	175	5.7
0.007	150	6.7
0.008	131	7.6
o.009	116	8.6
0.010	105	9.5

High Density Polythene

A.3 The Area Per Unit Weight and the Weight Per Unit Area in Different Thicknesses of Polythene Film (L-LDPE)

Thickness (mm)	m^2/kg	gramme/m^2
0.006	173	5.8
0.007	148	6.8
0.008	130	7.7
0.009	115	8.7
0.010	104	9.6
0.011	94	10.6
0.012	86	11.6

Line - Low Density Polythene

A.4. Quantities of PF Per Unit Area Consumed under Different Covering Rates

	Covering Rate of PG (%)			
	100	90	80	70
m^2/kg	kg Consumed per *mu*			
200	3.3	3.0	2.6	2.3
190	3.5	3.2	2.8	2.5
180	3.7	3.3	3.0	2.6
170	3.9	3.5	3.1	2.7
160	4.2	3.8	3.4	2.9
150	4.4	4.0	3.5	3.1
140	4.8	4.3	3.8	3.4
130	5.1	4.6	4.1	3.6
120	5.6	5.0	4.5	3.9
110	6.1	5.5	4.9	4.3
100	6.7	6.0	5.4	4.7
90	7.4	6.7	5.9	5.2
80	8.3	7.5	6.6	5.8
70	9.5	8.6	7.6	7.6
6	11.1	10.0	8.9	7.8
50	13.2	12.0	10.4	7.2

Note: One *mu* equals 1/15 hectare

A.5. The Area Per Kilogramme and the Length under Different Widths of PF

Length (m) m²/kg	Width of PF (mm)		
	900	800	700
	Length (m)		
50	55	63	71
60	67	75	86
70	78	88	110
80	89	100	114
90	100	113	129
100	111	125	143
110	122	138	157
120	133	150	171
130	144	163	186
140	155	175	200
150	167	188	214
160	78	200	229
170	189	213	243
180	200	225	257
190	211	238	271
200	222	250	286

Annex 2: Some Examples of Cultivation with PF

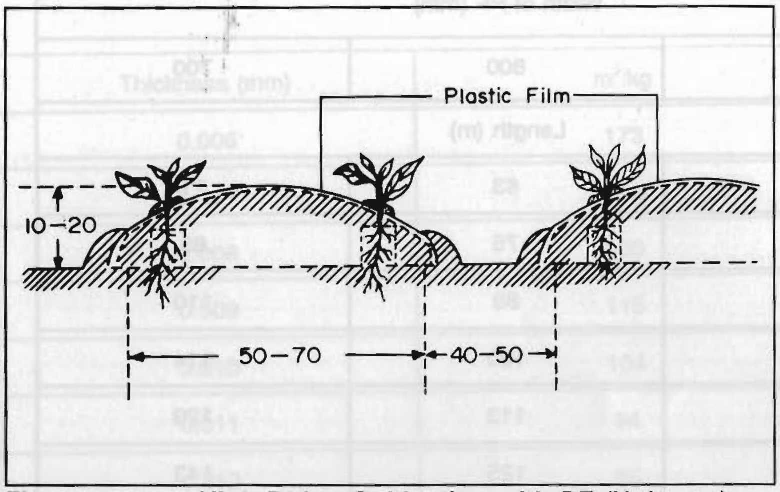

Figure 1: High Ridge Cultivation with PF (Unit: cm)

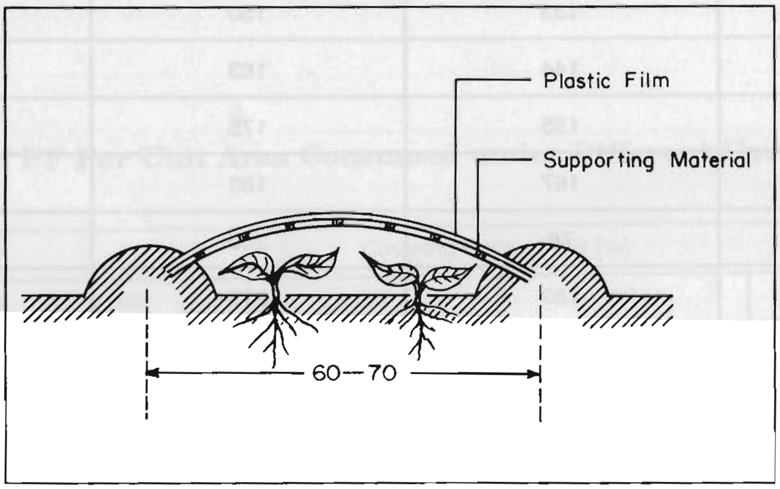

Figure 2: Flat Ridge Cultivation with PF and Supporting Materials for Short Duration (Unit: cm)

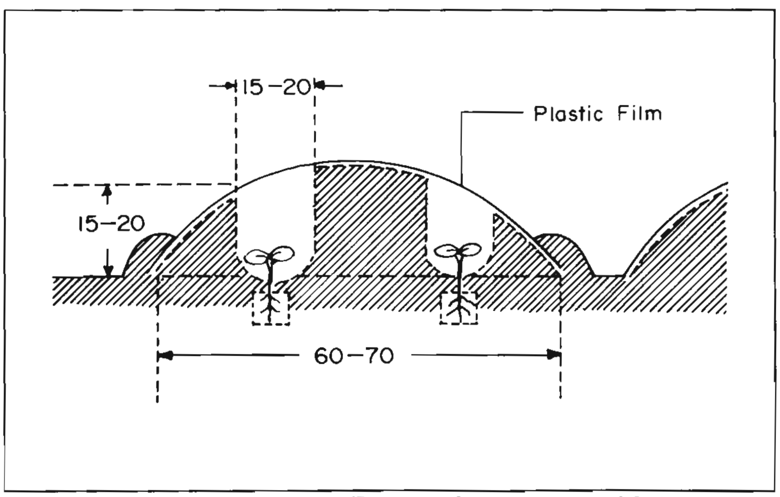

Figure 3: High Ridge Furrow Cultivation with PF (Unit: cm)

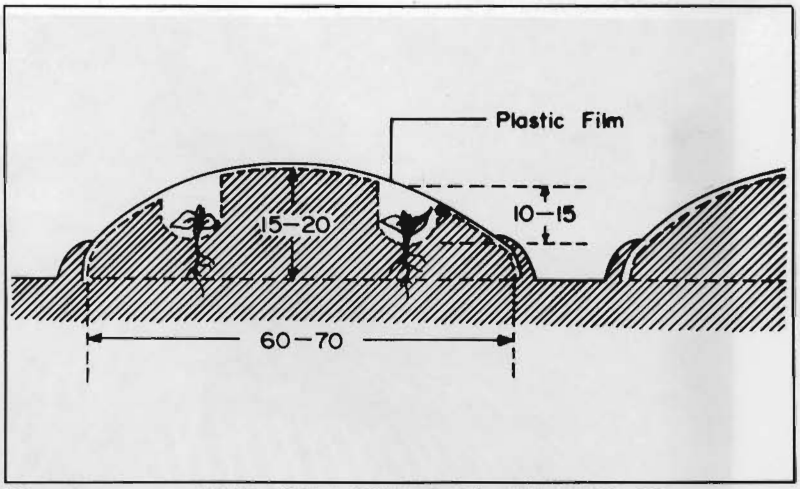

Figure 4: High Ridge, Hole Cultivation with PF (Unit: cm)

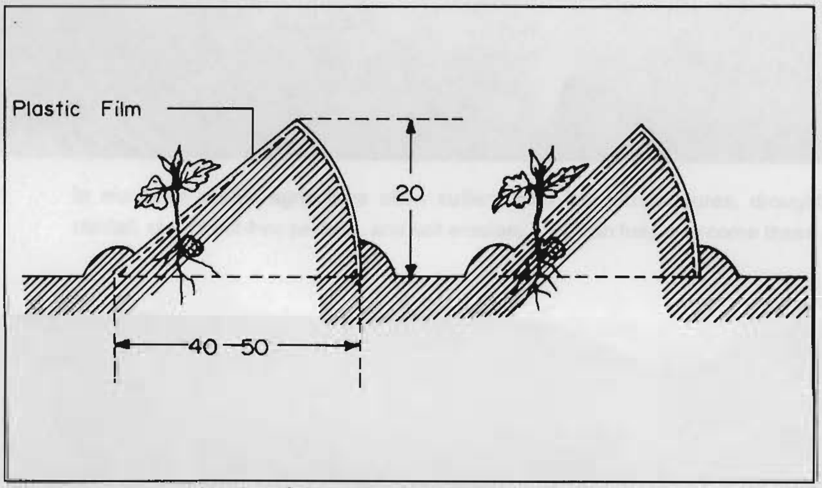

Figure 5: High Ridge, Facing Sunshine Cultivation with PF (Unit: cm)

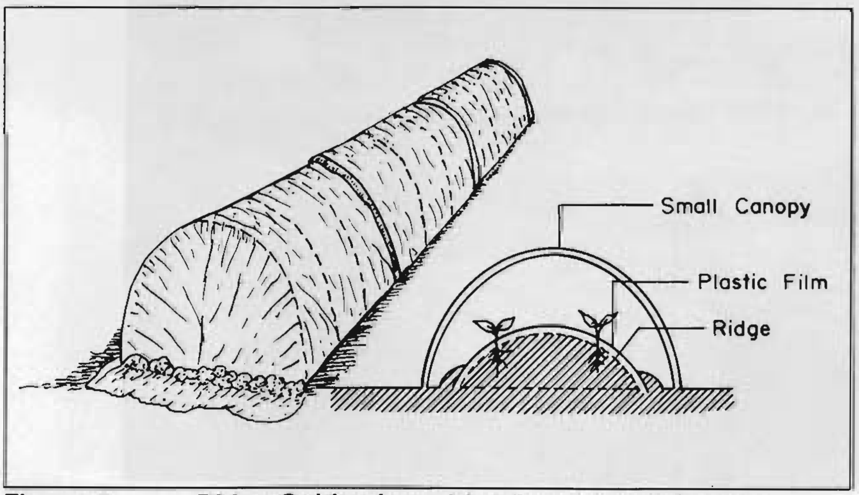

Figure 6: Ridge Cultivation with PF and Small Canopy (Unit: cm)

Plates

Plate 1 In mountain areas, agriculture often suffers from low temperatures, drought, too much rainfall, short frost-free periods, and soil erosion. PFT can help overcome these constraints.

Plate 2 Through 15 years of efforts, farmers have accepted PFT as an important agronomic measure that increases production. Officers and scientists have recognised that PFT can accelerate the merging of traditional agriculture with modern agriculture.

Plate 3 Maize is a worldwide staple grain. Chinese farmers' experiences show that maize yields can be increased by 30-50 per cent, sometimes even doubled, by proper use of PFT.

Plate 4 Cultivating good rice seedlings is a key measure in and the basis of high yields in rice production. PF can guarantee early sowing, early transplantation, early maturation, and high yields.

Plate 5 The use of PF in wheat cultivation can greatly increase yield; the average increased yield per hectare was 255 to 3,120kg and the increased rate was from five to 53.5 per cent. An evident difference between cultivation with PF and without PF can be seen in this photo.

Plate 6 When a cotton field is covered with PF, a stable and suitable environment is created, changing the ecological characteristics of cotton and promoting increases in yield. For example, in the PF-covered cotton field, without irrigation the increase rate was from 225 to 375kg per hectare and, with irrigation, the increase rate was from 300 to 450kg per hectare.

Plate 7 Vegetables receive more benefit from PFT. Since PFT can promote early maturation (by 8 to 10 days) farmers' incomes are increased.

Plate 8 Plastic Film combined with small canopies gives more benefits, especially in areas where spring air temperatures are low. This combination increases temperatures, both in soil and air, so that the yields of vegetables will be greatly increased.

Plate 9 Due to the light reflected by PF, crops receive more light enabling close plantation. In the case of cucumber, PF plus bamboo-supporting frames can enable an increase in the plant numbers per unit area and increases yields.

Plate 10 Using PF, the yield of kidney beans increases by 20 per cent and the income by more than 50 per cent, because PF greatly increases the active accumulated temperature (above 15°C) of the soil and promotes accelerated emergence (ten days early). The beans can be harvested six days in advance. As a result, the first three batches of kidney beans yield 2.18 times more than comparative yields on open land.

Plate 11 Cultivating peanuts by using PF, some farmers in northern China achieved a world record in the yield per unit area (more than 7,500kg per hectare). PF not only increases the yield, but also improves the quality of peanuts. For example, the ratio of oleic acid and linoleic acid increased from 1.49 to 1.69; the 8 amino acids needed by human beings increased by 27.9 per cent and 17 amino acids, including glutamic acid, increased by 24.5 per cent.

Plate 12 Watermelon cultivation suffers from three constraints: drought in spring; too much rainfall in summer; and inadequacy of accumulated temperature at high altitudes. PFT is one option that can help to overcome these problems. Now watermelon cultivation has been moving to the northern and high altitude areas and almost all the watermelon cultivation areas in China have adopted PFT.

Plate 13 Since most citrus orchards are distributed throughout the subtropical hills, frequent and heavy showers cause serious soil erosion. When terraced citrus orchards are covered with PF, raindrops cannot directly scour the soil, so the nutrients are maintained in the soil.

Plate 14 In apple orchards, PF not only maintains soil moisture and enhances soil temperature, promoting increased yields of apples, but also protects the fruit. Apples suffer from peach fruit borers. It was found that PF can increase the intensity of reflex light near the ground under the crown of the tree and the reflex light can greatly improve the colour of the fruit skin as well as the quality of fruit.

Plate 15 Sunburn and pecking by birds are common types of damage when grapefruit is maturing. Plastic film is used to overcome these problems.

Plate 16 Ginseng is a precious medicinal plant which is very sensitive to sunlight and moisture. Shading and covering with PF can provide favourable conditions for ginseng cultivation. Experiments have shown that PF can increase the yield by 16.1 per cent. The use of PF upgraded ginseng roots and the value of output increased by 18 per cent.

Plate 17 Horticulture is the most promising farming activity for cash income in mountain areas. Hailstones are frequent hazards in mountain areas. It has been proven that a plastic network can effectively protect apples from damage by hailstones.

Plate 18 PF can be spread by machine. A PF-spreading machine, drawn by a four-wheeled tractor, can increase efficiency by 15-25 times compared to manpower. Some complex machines can prepare the land, spread plastic film, sow seeds, apply fertiliser, and spray weedkillers. This greatly increases working efficiency.

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Founding of ICIMOD

ICIMOD is the first and, so far, only international centre devoted to integrated mountain development. ICIMOD was founded out of widespread recognition of the alarming environmental degradation of mountain habitats and consequent increasing impoverishment of mountain communities in the Hindu Kush-Himalayan (HKH) Region.

This vast mountain region covers all or part of eight countries, i.e., Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan. It extends over 3,500 kilometres from east to west and contains a population of more than 120 million people in mountain farming communities. In addition, its ecological management affects the much larger population in the plains and river basins below. The Region is characterised by great variations in altitude, aspect, soil conditions, climate, water resources, and access, all inducing an immense variability upon agricultural technology and farming systems. A coordinated and systematic effort, on an international scale, was therefore deemed essential to design and implement more effective development responses to promote the sustained well-being of the fragile mountain environment and its inhabitants.

The establishment of ICIMOD was based upon an agreement between His Majesty's Government of Nepal and the United Nations Educational Scientific and Cultural Organisation (UNESCO) signed in 1981. ICIMOD was inaugurated in December, 1983, and began operating in September 1984. Nepal, the Federal Republic of Germany, Switzerland, and UNESCO were the founding sponsors.

Participating Countries of the Hindu Kush-Himalayan Region

- **Afghanistan**
- **Bangladesh**
- **Bhutan**
- **China**
- **India**
- **Myanmar**
- **Nepal**
- **Pakistan**

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