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.

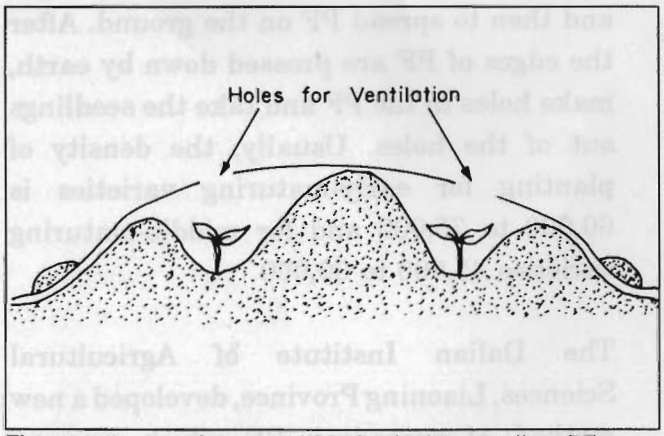

Figure 4-1: Improved Method of Spreading PF for Vegetable Cultivation

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.

Planting and the Management after Planting. 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).

Controlling Pests and Diseases. 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.