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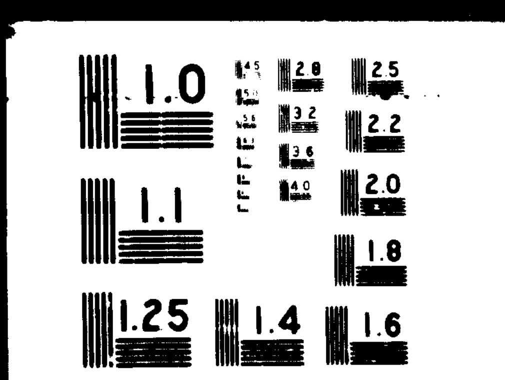
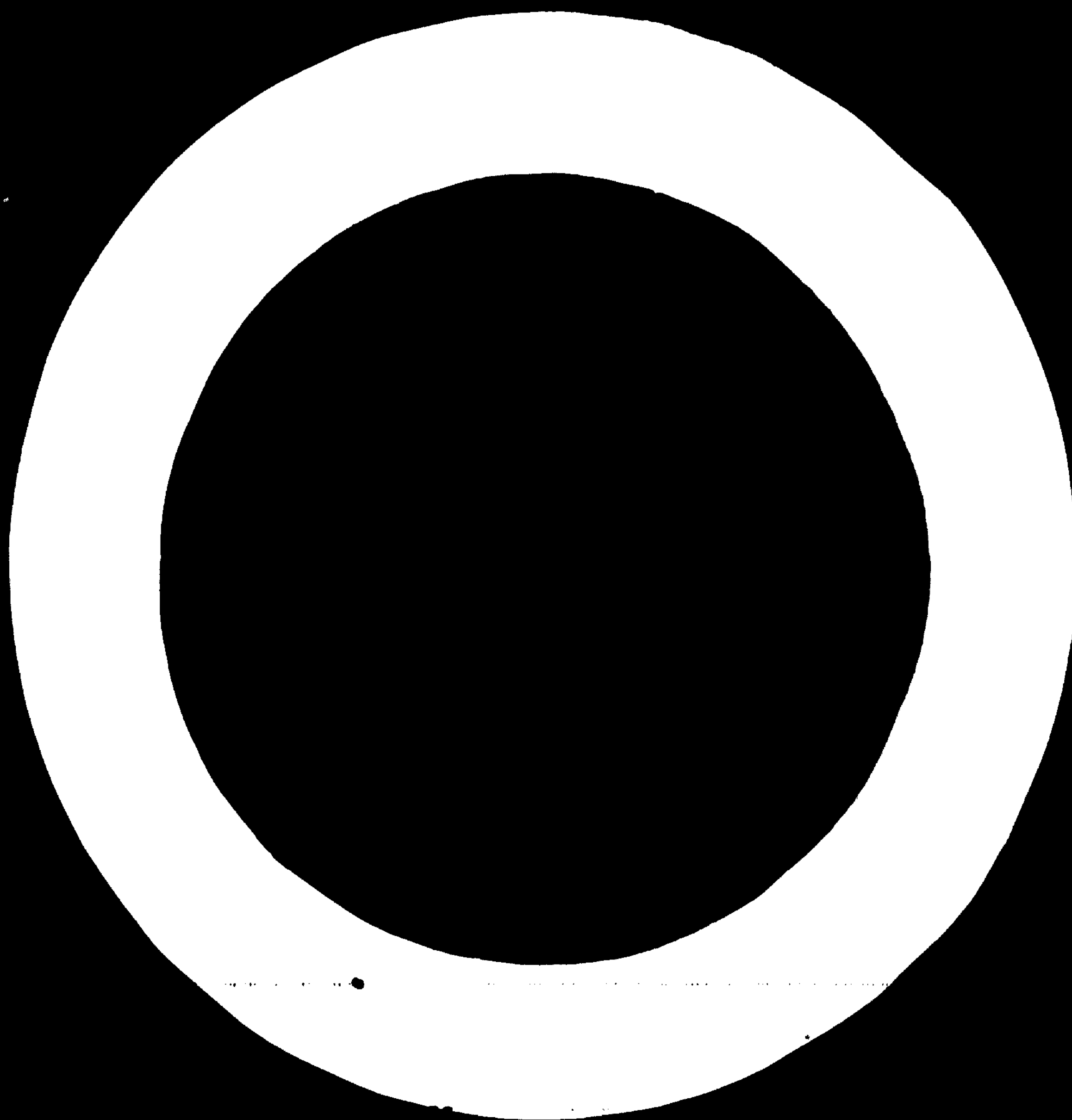




Of the many problems afflicting mankind, one of the most difficult has to do with the constantly increasing demand for fresh water, due both to the expanding population and the development of a great many human activities which require water as a primary necessity.

The concern of the student of this problem cannot be limited, therefore, merely to a search for new sources of supply, but must extend to the question of how the systems for managing the water now available can be improved and made more official by reducing waste so that this precious resource can be more carefully husbanded. It is clear that the economizing of water must not be merely the concern of scientists, but a matter of vital importance to everyone who uses it.

In the area of agriculture, and especially horticulture, one method of economizing water by limiting its use to strictly necessary amounts is through the use of mulching coupled with the kind of irrigation which enables the water supply to be adjusted to the plants' needs and thus avoids wastage.

A plant draws the water it needs to sustain life almost entirely from the soil. The water must therefore be available in the soil, and particularly in the area in which the roots develop, in quantities optimal for the plant, and must not re-escape into the atmosphere except by transpiration through its leaves. This means that, as far as possible, losses caused by evaporation and seepage into the deepest layers of the ground must be avoided.

Water, it will be recalled, can be found in the ground in three different forms:

(1) Hygroscopic water - up to the limit set by the hygroscopic coefficient, as an integral part of the cells of the soil's different components and thus available to plant life.

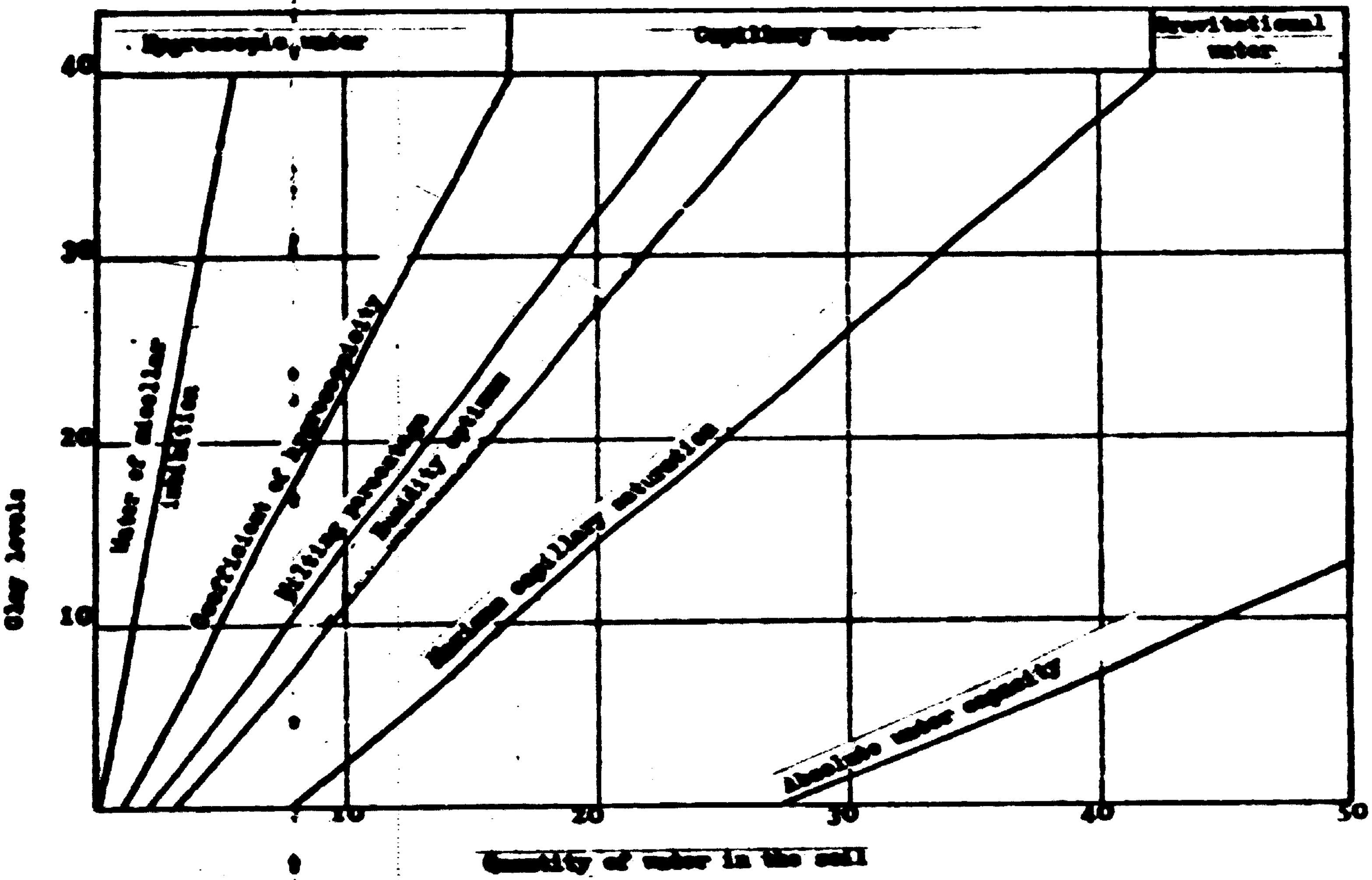
(2) Capillary water - beyond the hygroscopic coefficient up to maximum capillary saturation.

Over a certain range, up to the wilting percentage, capillary water is tied to the soil and not available to meet the requirements of the plants, which in that case will show signs of decline. Beyond the wilting percentage and up to maximum capillary saturation the water is available to plant life and is not subject to seepage, but will evaporate.

(3) Gravitational water - from maximum capillary saturation up to the absolute water capacity; it is available to plant life, but is subject to seepage.

The dividing line between one form of water and another shifts according to the nature of the soil and, especially, its clay content. In Protolongo's diagram (fig. 1) the distribution of the different forms of water in the soil is shown according to the clay levels, assuming, as is usually done, a constant silt content of about 10 per cent.

FIG.1 - DIAGRAM SHOWING THE DISTRIBUTION OF THE FORMS OF WATER IN THE SOIL



(after [illegible])

The optimal soil humidity, ensuring the best plant performance, is found near the point of <u>total capillary saturation</u>.

The water at this stage is able to circulate in the soil, carrying with it the nutrient elements, while at the same time leaving sufficient space for good aeration, which is an essential condition if the plant is to properly absorb the nutrient solution.

This then is the balance in which the soil's water content must be maintained, since, as already noted, at this point the problem of losses through seepage does not yet arise.

If losses do occur, they are precisely of the kind that can be eliminated, or at least reduced, by mulching.

MULCHING

The following are the factors most affected by plastic mulching:

(1) The temperature, humidity and specific structure of the soil;

(2) The soil's nitrogen and carbon-dioxide content, and the resultant chemical, biochemical and microbiological activity;

(3) The development of roots and their location in the soil;

(4) Weed control.

The effect of mulching on soil temperature

Ideally, the effect of mulching on soil temperature should be to reduce substantially the variations in heat - that is, the purpose of mulching is to raise the temperature of the soil during periods and in pedoclimatic environments which are cold, and to reduce it when prolonged exposure to the sun raises the heat of the soil to levels harmful to the normal development of plant life; in other words, in both cases to reduce the temperature range.

It is obvious, of course, that no one type of plastic material can produce all these effects. It becomes necessary, therefore, to select the best suited plastic film to the specific conditions in each individual case.

Accordingly, let us examine the behaviour of the different types of film most commonly used for mulching in relation to temperature:

(1) Black polyethylene (PE) film;

(2) Transparent PE film;

(3) Transparent polyvinyl chloride (PVC) film;

(4) White film;

(5) Smoked grey film.

Naturally, if mulching is to have a noticeable effect on soil temperature, the mulched area must be large enough. Ideally, the entire soil surface should be mulched; as a minimum, the strip mulched should be at least one metre in width.

1. Black PE film

This film absorbs all the light and heat rays of the sun, transmitting (by conduction and convection) only a small portion of the latter to the soil layer in direct contact with it. This layer is heated to a greater or lesser degree, depending on its structure and humidity. During the night-time hours the heat loss from soil mulched with black film is slower than in the case of mulching with transparent PE film or bare soil. Thus, when black film is used, the average day-time temperature is lower than with transparent film (PE or, still more so, PVC), but higher than in the case of bare soil, although a lower temperature than for bare soil alone can be expected during the hours of brightest sunshine. This last fact is probably due to the greater reflection of sunlight by the black film.

During the night, the temperature is higher than in the case of transparent PE film, but equal to or lower than with transparent PVC (depending on the colour and humidity of the soil, since a darker and damper soil absorbs more heat).

Thus, black film gives an average temperature which is lower than with the other films, but higher than with uncovered soil. There is also less fluctuation in temperature than with the other varieties, and this is generally an advantageous factor for plant life and productivity.

On the basis of these characteristics and their effect on soil temperature, black polyethylene film would be preferable in very hot locations exposed to strong sunlight, if it did not have other drawbacks linked specifically to its black colour. It must be remembered that if it gets too hot the film may burn the vegetation in direct contact with the rim of the hole and that excessive irradiation is harmful to small, young plants. Accordingly, this film should be used only with certain precautionary measures (for example, surrounding the small plants with tiny pellets of expanded polystyrene) when transplanting during periods of heat and strong sunlight.

When plants are transplanted during more temperate periods and when it can be expected that by the time the weather grows warmer they will already have enough leaves to give the film adequate shade, the danger of burning and overheating can be avoided.

2. Transparent PE film

This film passes the short infrared rays, which are then absorbed by the soil. Even the infrared radiation emitted by the soil itself passes through film of this type, although to a lesser degree since it is partially reflected by the many tiny droplets of water which generally cover the inside surface of the film. The result is a pronounced heating of the soil during sunny hours and a very rapid cooling off during the night or on sunless days. Thus the temperature range is fairly wide, which may be harmful to productivity, despite the fact that the larger quantity of heat stored generally produces earlier crops than the black film and, to an even greater degree, uncovered soil. In any case, this is a type of mulching which, provided weed control is possible, can be used to advantage with almost all crops in regions without too much sun when the vegetation is not thick enough to provide shade for the plastic coming into contact with the plant.

Since film of this kind absorbs only a minor portion of the heat, there is no risk that the aerial part of the plant will be burned by contact with the film or overheated by radiation.

3. Transparent PVC film

This film behaves in more or less the same way as transparent PE film with respect to the transmission of the short infrared part of the solar spectrum. It differs, however, with respect to the loss of heat during sunless hours because polyvinyl chloride retains a higher percentage of the long-wave infrared radiation. The temperature range is thus smaller than for transparent polyethylene film while the average temperature is distinctly higher.

In practical terms, earlier crops can be achieved than with transparent polyethylene, still more so black polyethylene, at the same time that, because of its more limited temperature range, which is comparable to that of black polyethylene, there is no drop in productivity provided this film is not used in particularly hot or sunny regions.

As in the case of transparent polyethylene, there is no risk of damage because of burning or overheating of the aerial parts of the plants.

4. White film

White film transmits and absorbs only a small fraction of the sun's rays, whether in the light or heat portion of the spectrum, but reflects some 80 per cent of this radiation. F~ this reason, the soil beneath the film becomes less heated than with any other film - and still less than in the case of bare soil - which delays the crop. Nevertheless, its reflectivity increases photosynthetic activity in the leaves nearest to the soil, whether in the greenhouse or in the open field. Consequently, this film is to be recommended whenever lack of light is a limiting factor.

5. Smoked grey film

According to the percentage of carbon black added to the natural polyethylene, this film may be closer to black or to transparent film. It ought to be free of the drawbacks of both types while retaining their advantages. In reality, however, this is not always so because of the difficulty of weed control, and for this reason it would appear advisable to use black or transparent film as the situation requires.

Effect of mulching on soil humidity

A number of writers agree that the quantity of water under a plastic mulch is almost always greater than in bare soil, except immediately after rainfall.

What is certain is that, for any type of film, a possible cause of water loss is seepage following excessive irrigation or abundant rainfall. Since evaporation is almost totally ruled out (there being only minor losses through the openings made in the films to permit transplanting), the water in the soil remains available to the plant for the supply of nutrients and transpiration. As in the case of temperature, soil humidity is affected only if a sufficiently large area around the plant is mulched.

When the entire soil surface is mulched - a good practice for virtually all horticultural crops - evaporation is reduced to a minimum since even the free space between the planting rows is now eliminated.

When irrigation is by means of small perforated tubes below the mulch, the disadvantages sometimes encountered in furrow or sprinkling irrigation systems are eliminated. With other types of irrigation the buried portion of the film hinders the passage of the water; the pathways get trodden down and compacted, particularly in the case of soil, with a lot of clay in them, which blocks imbibition; the mulch prevents sprinkled water from getting through, etc.

The beneficial effect of mulching on the hydrological condition of the soil is not merely the result of the greater quantity of water trapped under the cover, but also of its distribution throughout the soil. What happens is that capillary attraction causes the water to rise and accumulate particularly in the uppermost layers where the soil is richest in nutrients and the roots can develop better without having to reach down in search of a damper environment.

By applying the irrigation water in the right amounts and taking the best possible advantage of the way the mulch affects soil humidity, it is possible to maintain a virtually constant and near optimal water regime - that is, one which will be close to maximum capillary saturation - so as to ensure good circulation of the nutrient solution at all times and completely against the risk of root drowning what is present in other irrigation systems based on soil imbibition up to the point of maximum water capacity.

being made to avoid as far as possible the kind of clumps of hard earth which present a serious obstacle even to the capillary movement of the water as it rises towards the mulch during the warmer hours and redescends, albeit in smaller quantities, during the cooler period of the day.

It is precisely this movement of the water which can somewhat improve the soil structure.

In any event, provided the mulched soil is not trodden down too much, it remains porous enough to permit more extensive root development, better oxygen circulation, greater production of carbon dioxide and more vigorous movement of the gas to the planting holes, through which it can rise into the air around the leaves and thus play its role in the life of the plant.

Effect of mulching on the soil's nitrogen and carbon dioxide content and on chemical, biochemical and microbiological activity

The problem of the nitrification of ammonia nitrogen and its use in mulched as opposed to bare soil has produced the greatest discrepancies in the findings of different writers. Over against the very favourable results cited by some of these authors one finds the negative, or at least doubtful, results of others. Thanks to the findings of Professors Malquori and Cecconi, as communicated to the Third National Conference on the Use of Plastics in Agriculture held at Palermo, this problem has now been clearly resolved.

Apart from the physical and chemical composition of the soil itself, its temperature and humidity and their interrelation, by influencing the activity of the microbial flora and the chemical and biochemical reactions in the soil, have a decided effect, for better or worse, on nitrification.

Since the temperature can be influenced by the selection of the mulching film, and since the humidity can be easily manipulated and maintained almost constantly at optimal levels by installing a permanent irrigation system, the soil can be better conditioned for good nitrification.

With respect to temperature, it seems that the maximum value, at which nitrification stops, lies between 45 and 52°C, and that the ideal varying according to the soil - from the most sandy to the most argillaceous - is between 25 and 45°C. Moreover, while bare soil requires a high level of water saturation (between 60 and 80 per cent) to produce the best nitrification, a lower level of saturation (between 50 and 60 per cent) is sufficient for mulched soil.

In any event, the nitrate nitrogen supplied by fertilizers or produced by nitrification remains largely available to the plant since, through the use of mulching and by controlling the flow or irrigation water (which is possible by placing pipes underneath the mulch), podzolization, which causes severe nitrate losses, is reduced to a minimum.

The soil's microflora activity is determined by its physical condition, humidity and temperature. As we have seen, all these factors are favourably affected by mulching. It may be easily reasoned, therefore, that mulching also promotes microflora activity. According to Professors Favilli and Benvenuti, "Mulching has a positive effect not only on the size of the microbe community and of each of its constituent biological groups, but also on the distribution of these groups in depth and their particular activities."

It has been reported by Ferretti (1931), working with soil mulched by roofing felt, that at a depth of 5 cm four times more micro-organisms were present in mulched soil than in unmulched. As a result, the mulched soil had a higher capacity for ammoniation, nitrification and nitrogen fixing.

Microbe activity, particularly during the transformation of organic matter, promotes the production of carbon dioxide to such a degree that, as established by Sheldrake (1963), the amount present under polyethylene films is four times greater than in uncovered soil. This is the same ratio found by Ferretti for micro-organisms.

Escaping through the planting holes and filtering (although only very slightly) through the film itself, the carbon dioxide bathes the plants and provides them with a genuine carbon fertilization, ultimately resulting in higher productivity and better quality.

Effect of mulching on the development of roots and their distribution in the soil

As a result of the total effect of mulching on the temperature, humidity and structure of the soil, far larger root systems tend to develop than in uncovered soil.

Agulhon, in 1970, observed a 50 per cent increase in the weight of mulched vineroots over unmulched. Appreciable increases had already been reported by Waggoner, Miller and De Roo (1960) for tobacco, Zocca (1963) for strawberries, Gambogi and Verona (1966) for broad beans, Benvenuti (1969) for French beans and maize, and by Milella and Deidda (1970) for nursery-grown citrus trees.

All these writers and others, such as Scaramuzzi, Payan, Fortney, Clarkson and Chisci, have noted that under mulching the root systems, whether of trees or plants, develop more extensively near the surface, with a considerable increase in the number and activity of the root hairs. As another of these writers has pointed out, this takes place without prejudicing the development of the roots in depth. Naturally, more vigorous root activity can only result in improved productivity.

Effect of mulching on soil structure

Mulching keeps the structure of the soil in the same condition as at the time the plastic was applied. Only in certain specific cases are improvements noted. For this reason, the soil should be prepared with great care before mulching, efforts

Effect of mulching on weeds

The most noteworthy effect of mulching with black plastic film is the virtually complete elimination of weeds. The fact is that there are only a few varieties of Cyperus (e.g., Cyperus Rotundus L.), occurring naturally in Central and Southern Italy, which with the silicious and sharp tip of their bracts are able to pierce through the black film so that the entire plant emerges in a normal development.

The herbicidal effect of black film (due mainly to its impermeability to light, which blocks the principal physiological activities of weeds) is excellent even against those weeds which are most difficult to combat through the use of conventional selective herbicides, such as Sorhum Halepense Pers., Cynodon Dactylon Pers., Digitaria Sanguinalis Scop., Setariae gen., Agrotis gen., Cirsium gen., Phalaris gen., and others. Moreover, in weed control film mulching is free of the drawbacks frequently associated with the use of conventional herbicides which show up in the form of accumulation effects when a succession of crops are treated and in the more luxurious growth of those weeds which are not vulnerable to the particular herbicides employed.

When transparent film is used, weeds develop more or less abundantly, depending on the species; often, one has the impression that they are being force-grown, so thick a carpet do they present. This happens whenever there is the possibility of air entering through the planting holes, or around the edges of film which has been poorly anchored in the ground, since such air lowers the high temperature attained under the film during the hours of sun. In order to prevent this and combat weeds even when using transparent film, as soon as the nursling plant is set out, the planting hole should be sealed with a spadeful of earth or some other heavy material to anchor the film well to the ground and prevent even the slightest circulation of air. In this way, [because of] the high temperature and humidity, the weeds which do germinate [perish] in their earliest stages before they grow sufficiently to raise the film as they seek the air they require1/. In any event, transparent film will produce its beneficial effects on soil and crops far more effectively if the potential density of the weeds is lower at the time of mulching.

Smoked grey film should be made dark enough to check the development of weeds decisively. If this cannot be done or if in order to control the weeds the same measures have to be taken as with transparent film, it is advisable to use either that film or the black.

1/ Translator's Note: This sentence is incomplete in the original and the bracketed words represent only an attempt to reconstruct its probable meaning.

A solution which could eliminate the shortcomings of both the black and the transparent film, while improving their performance, might be afforded by a reddish-brown PVC photoselective film, which, when used as a mulch, though permitting the passage of the short infrared heat rays and completely blocking the long ones, would be impenetrable to radiation in the visible portion of the spectrum.

This would result in an increase in the average temperature, which is a characteristic of the transparent film, along with the weed-control properties and reduced temperature range typical of the black film.

This photoselective film, which was tested and described by Benvenuti and Glatti as early as 1969, with later reports by Benvenuti in 1970 and 1971 followed by other writers thereafter, has not yet reached the stage of commercial marketing, although one would wish that it might soon be made available to growers because of its very promising possibilities.

FERTILIZING IRRIGATION

If water is to be supplied with sufficient accuracy not to cause seepage losses while constantly maintaining the soil at optimal hygrometric conditions for the plants, the soil's physical and chemical structure must be precisely known and these data must then be matched against all the atmospheric characteristics (air temperature and humidity, light intensity, wind, etc.) capable of affecting the plant's transpiration.

If this is difficult to achieve even at a research institute, given the difficulty of selecting from among the various procedures proposed by the different authorities writing on the subject, it is quite impossible for the average farmer, who has no alternative in the matter but to rely on his knowledge of the soil, the vegetative development of his crops and, above all, his common sense in order to provide the amounts of water he considers proper.

By using a mulch to eliminate almost completely water wastage due to evaporation, seepage losses can be reduced by means of a fixed irrigation system underneath the mulch consisting of perforated plastic tubes. Such a permanent system provides an easy means of irrigating the plants for brief periods with the required frequency, in order to restore to the soil the water which it is constantly losing through plant transpiration.

The system consists of suitably perforated polyethylene or polyvinyl-chloride tubes installed along the future rows before mulching (in the case of total or manual mulching) or at the same time (in the case of mechanical mulching using a spreader).

To carry the water from the pump to the irrigation area, pipes 80 to 120 mm in diameter are used, made of steel, rigid plastic or, best of all, flexible PVC. Depending on the surface to be irrigated, they are equipped with steel or plastic branch connexions of a diameter suitable for attachment to the irrigation tubes. When flexible polyvinyl chloride is used, the walls will be 1 to 1.2 mm thick.

The irrigation tubes, which are 30 to 40 mm in diameter and are perforated every 30-40 cm with opposing holes 1 to 1.5 mm in diameter, may be made from polyethylene or polyvinyl chloride, of different thickness depending on the working pressure required. Usually, the PE tubes are fairly thin, for use during only a single planting; for this reason, they have a limited pressure tolerance and can be used only for rather short irrigation lines.

PVC tubes are thicker. They are recovered at the end of the growing season to be used again. Since they are able to withstand greater pressures, they can be employed for longer lines, provided they ensure a sufficient flow rate.

Our preference is for a system of the following type.

1. PVC feed pipes, 1 mm thick and 120 mm in diameter, with two opposing branches of rigid PVC every 1.30 m, to which the irrigation tubes are fitted. Unused opposing branches should be closed off or, better still, interconnected by a by-pass of unperforated tube.

   The feed pipes are laid along the centre-line of the plot to be irrigated so that the watering tubes are of approximately the same length.

2. PE irrigation tubes, 25 to 30 mm in diameter, for use during a single planting. We prefer to use non-recoverable tubes because experience has shown that, following a crop, even with the thickest - and therefore least flexible - PVC tubes, the holes become clogged more easily, especially if the water is hard.

   The tubes may be as long as 50 to 60 m, but not more; this length is well suited to our fields, which are usually just about 100 m long. For longer plots it will be necessary to install a feed pipe with the appropriate irrigation tubes every 100 m or at fractions of that distance.

3. We prefer opposing holes 1.5 mm in diameter because they are less likely to become clogged than those of 1 mm, although the latter make possible longer branch lines. The spacing between the pairs of holes is then about 30 cm.

4. The colour selected for the irrigation tubes should be as opaque as possible to the rays ... 2/ algae which could block the holes. For this reason, black is recommended over any other colour.

2/ Translator's note: Sentence garbled in the original.

5. The irrigation tubes are laid along each row of plants, unless the space between two adjacent rows is less than 50-60 cm, in which case a single tube midway between them is enough to irrigate both rows.

6. The tube is knotted at the end to prevent the water from running out.

With a system of this kind a pump can be connected and irrigation started very quickly. It is safe to say that a water saving of approximately 80 per cent can be realized over traditional irrigation methods. This is because the duration of irrigation is reduced to about 1/12, with approximately twice the frequency. In other words: if irrigation by traditional methods would require a period of two hours once a week, with this system one would irrigate for ten minutes twice a week, and that would be enough to ensure sufficient water for the crops.

By attaching a mixing-batching device for fertilizing irrigation to the pump, it is a very simple matter to supply soluble fertilizer to the plants when they need it.

This mixing device consists of a hopper (capacity: 200 litres) connected, by means of two flexible pipes, before and after the pump. One pipe, which carries the water to the hopper, runs from the compression stage of the irrigation system. When the pressurized water inlet valve is opened, a whirlpool effect is created in the hopper, dissolving the soluble fertilizer with which it has been loaded in the amount required to fertilize the irrigation area. The second flexible pipe running from the hopper is attached to the pump intake tube which draws the water from a ditch, pool or artesian well. When the fertilizer has been thoroughly dissolved in the hopper, the outlet valve for the pump intake connexion is opened, causing an agitation of the fertilizing solution, which then runs into the irrigation system, getting diluted as it goes. Irrigation continues for five or six minutes after the hopper has been emptied to ensure that all the fertilizing solution has been used. The system is then shut down.

This technique offers a means of circumventing one of the drawbacks of mulching - the difficulty, because of the obstacle created by the plastic film, of applying supplementary fertilization to covered crops.

In fact, since mulching draws the root hairs up into the layer nearest the soil surface, the water can carry even the least mobile nutrient substances to them. In this way, even such nutrients as phosphos pentoxide, potassium oxide and the micro-elements which otherwise must be added to the soil before planting can be made available to the plants at the time they most need them.

In addition, the cost of distributing the fertilizer is virtually eliminated with this method.

MULCHING AND FERTILIZING IRRIGATION FOR MAJOR HORTICULTURAL CROPS

Strawberries

This is the crop for which mulching is most frequently used. In addition to all the usual beneficial effects found with other crops, for strawberries mulching and fertilizing irrigation bring the following extra advantages:

1. By isolating the fruit from the soil, mulching prevents the fruit from becoming dirty. The result is a more attractive product which complies with the sanitary standards governing the sale of goods.

2. Mulching, particularly when it covers the entire growing area, hinders the evaporation of water from the soil and keeps the fruit from coming into contact with the ground. Irrigation under a plastic film keeps the aerial portion of the plant dry; if the plant is shielded from the rain by means of a protective covering well enough ventilated to prevent the condensation of transpiration humidity, even the risk of attacks of Botrytis Cinerea can be avoided. In any event, even when used alone, mulching greatly reduces the severity of this disease.

3. While maintaining the structure of the soil and the shape of the ridges as they originally were, with mulching it is possible to plant 20-40 cm above the level of the pathways, thereby making picking easier and increasing the hourly yield by 10-15 per cent.

4. Fertilizing irrigation permits the application of the proper amount of fertilizer at the right time to achieve excellent differentiation of the buds, a good set and larger fruit even after the first crop.

For strawberries, most writers favour mulching by transparent film, provided weeds can be controlled. If planting is preceded by fumigation (a technique which has other remarkable advantages, but is very expensive) and the use of weed-killers (which do not always yield results), transparent film is certainly to be preferred.

Potatoes

Mulching of patato crops offers the possibility of growing the plants on the surface, between the soil and the plastic, thereby considerably reducing harvesting costs in addition to saving on the digging and mounding work involved in conventional cultivation. In addition above-ground cultivation under plastic results in qualitative and quantitative improvements in production by increasing the size of the tubers and reducing waste. Black film obviously has to be used in the case of potatoes to prevent them from turning green. To avoid burning of the shoots because of overheated film, the tubers must be slightly buried whenever planting is carried out during periods of strong sunlight or if there is reason to expect that such periods will occur before the leaves are developed enough to shade the black film.

Combining mulching with protection by small perforated tunnels will yield excellent results, including earlier ripening.

Even in potato-growing it is very important that one should be able to apply irrigation and fertilization as required. For this purpose, it is necessary to install a tubing system under the mulch.

Melons

Transparent film is generally used. It must be well anchored to the ground so that, by preventing the circulation of air between the film and the soil, weeds can be controlled until the aerial part of the plant itself has time to cover the surface and prevent the weeds from developing.

Transparent film makes the fruit ripen considerably earlier than black film, which compensates for the lower productivity sometimes noted.

Good results have been obtained by combining the black film with the transparent variety. By impeding the reflection of heat rays and the radiation of heat from the black film, while ensuring a narrower temperature range than with transparent film alone, this method seems to provide an early ripening lead equal to or greater than that which results from the use of transparent film, without the productivity being any lower than with the black film alone.

Asparagus

Asparagus can be mulched by covering the crop with a transparent film, which raises the soil temperature, so that the turions ripen considerably earlier. To make it possible to observe the turions as they emerge, an anti-fog transparent film is used which, by preventing condensation on the inside surface, ensures visibility.

At the Experimental Centre for the Use of Plastics in Agriculture at Mantua, however, the preferred method is to grow asparagus above the soil (with the rootlets planted in the uppermost layer of the soil) using a transparent forcing tunnel to get green asparagus, or a dark red photo-selective tunnel for a white crop. In this way, picking is easier and can begin some two weeks earlier than with mulching alone.

Tomatoes

The many research workers who have studied tomato mulching have reached widely conflicting conclusions. For those who achieved very favourable results, there are others whose findings did not differ from those obtained with control plots, either with respect to early ripening or productivity.

The present writers, who employed total mulching, setting out the plants at a relatively early date (generally during the first two weeks of March) when their first set of buds was already visible, and carefully controlling irrigation and fertilization so that there was never too much humidity under the mulch, consistently achieved far greater productivity (from 15 to 40 per cent higher) through the use of black film.

With transparent mulching, still earlier crops (by one to two weeks depending on the year) and a further rise in productivity were achieved in comparison to the control plot. However, the results were not satisfactory when weeds were not kept well under control.

It would therefore appear, in our opinion, that good results with tomatoes are only easy to achieve if the humidity under the mulch is checked carefully and if additional fertilizing irrigation is supplied after the first harvests. We consistently follow this practice.

Pimento and eggplant

The different writers have almost always reported positive results. Productivity increases, over bare soil, of 40 to 60 per cent for pimento and as much as 200-300 per cent for eggplant have been noted.

Our own findings are in line with those for tomatoes (productivity increases of 30-60 per cent for pimento and 40-70 per cent for eggplant), provided soil humidity is precisely monitored. This kind of monitoring is decisive in the case of pimento, for which amounts of water even slightly above the soil's retention capacity produce negative results by making the roots susceptible to cryptogamic diseases.

Lettuce and chicory

According to a number of writers, excellent results can be obtained by combining mulching with fertilizing irrigation.

Black film has always been used for the mulch. The results are as follows:

Productivity increases of 20 to 70 per cent;
Fewer losses due to botrytis and other diseases;
A more uniform and attractive final product.

Pimpini, in tests with the Castelfranco variety of chicory, achieved productivity increases of 51 per cent over the commercial product. In our own tests with chicory of the Rosolina variety the combination of mulching with fertilizing irrigation resulted in a productivity increase of 62 per cent, due mainly to the greater development of the hearts.

Controlled growing of chrysanthemums

For three years now, at the Experimental Centre for the Use of Plastics in Agriculture, chrysanthemums have been grown under controlled conditions, with black film mulching and fertilizing irrigation.

The results have been truly encouraging. In addition to the total elimination of weeds, the following successes have been achieved: a considerable reduction in the danger of attacks of Septoriae gen.; larger stems resulting in a more resistant flower even after picking, during the packaging and transport stages; great ease in feeding of the flowers once a week with the nutrients they require. Transplanting has been quite simple despite the fact that the flowers were planted close together (12 x 15 cm): all that was necessary was to make a small opening, large enough to introduce the rooted slip. Rooting has always been satisfactory.

It would take too long to describe in detail the results achieved with mulching on different varieties of plants and trees, as noted by a large number of writers. Suffice it to say that there are reports on cucumber, watermelon, marrow, celery, garlic, onion, green beans, peas, etc., among the garden vegetables; gladiolus, zinnia, dahlia, tulip, lilium gen., gardenia, camellia, etc., among the flowers; pineapple, grape, peach, pear and apple, among the fruit trees, as well as nursery-grown ornamental and fruit-bearing plants, and extensive crops such as maize, tobacco, cotton and others.

In every instance, provided the mulching was properly performed, the results were favourable. The writers lay particular stress on the combination of mulching with irrigation underneath the film in view of the possibility of fertilising irrigation which this system offers.

In our view, whatever negative results have been reported, where they were not caused by the wrong choice of film, were due to improper water management under the mulch.

These poor results could have been avoided if the right amounts of water had been supplied at the right time, avoiding too much as well as too little.

In our opinion, the combination of mulching and fertilizing irrigation produces a synergistic action which heightens the beneficial effect of the two methods taken individually. For this reason it cannot but contribute to better growing.

In addition, the combination of mulching and fertilizing irrigation results in such a saving of water that successful growing is possible even in places where, because of the scarcity of water, cultivation by traditional methods would otherwise be impossible or at the mercy of dry spells.

SUMMARY

A scarcity of water is often a limiting factor in growing many vegetables and flowers. On the other hand, the traditional systems of cultivation and irrigation are accompanied by severe losses of water either because of evaporation -- an ever present phenomenon - or because of seepage, which, following every irrigation (which, with conventional systems, is inevitably excessive) drains off the water into the lowest layers of the soil beyond the reach of the roots.

By means of mulching, i.e., covering the soil with a plastic film which prevents evaporation, and by a system of irrigation (using perforated tubes of flexible plastic under the mulch) which permits control of the water supply to avoid any excess and prevent seepage, it is possible to economize water by some 80 per cent and thus grow horticultural crops in areas where the shortage of water was previously a limiting factor.

With the same system, using the irrigation water as a vehicle, crops can be simultaneously fertilized and irrigated at the right time - that is, when the plants require it.

Different types of mulches and their use with a number of horticultural crops are analysed.

BIBLIOGRAPHY

ACQUIER G. 1966 - Le paillage du Melon et de la Tomate dans le Sud-Ouest (IXe Colloque des Plastiques en Agriculture - Montpellier).

ADAMS J.E. 1965 - Effect of mulches on soil temperature and grain sorghum development (Agr. Jour. 57-5).

AGULHON R. 1970 - Le paillage de la vigne (Atti del IV° Colloque International des plastiques en agriculture - Paris).

BASSOCCHI R., CHLOTTI C., CARACCHI I. - 1969 - Effetti del film plastico di diverso colore nella pacciamatura della fragola (L'Informatore Agrario 27).

BENVENUTI A. 1969 - Prove di pacciamatura su colture di pieno campo (Atti del IV° Convegno Nazionale sulle Applicazioni delle Materie Plastiche in Agricoltura - Mantova)

BENVENUTI A. 1970 - Primi risultati di una prova di pacciamatura con film fotoselettivi su colture di pieno campo (IV° Colloque International des Plastiques en Agriculture - Paris).

BENVENUTI A. 1971 - Ulteriori risultati di prove di pacciamatura su colture ortive di pieno campo con l'impiego di film fotoselettivi (Atti del V° Convegno Nazionale sulle Applicazioni delle Materie Plastiche in Agricoltura - Montecatini Terme).

BENVENUTI A., GIATTI F. - 1969 - Primi rilievi su un nuovo film fotoselettivo da pacciamatura (Atti del IV° Convegno Nazionale sulle Applicazioni delle Materie Plastiche in Agricoltura - Mantova).

BLACK A.L., GREB B.W. - 1962 - Nitrate accumulation in soils covered with plastic mulch (Agronomy Journal 54-4).

BONFIGLIOLI O. 1966 - La pacciamatura con film plastici nei vivai. (Conferenza Nazionale per l'Ortoflorofrutticoltura libro II - tomo I - Verona).

BONFIGLIOLI O. 1967 - La pacciamatura con film di materia plastica nell'orticoltura e floricoltura (Conferenza Nazionale per l'Ortoflorofrutticoltura - libro II - tomo 3° - Napoli).

BONFIGLIOLI O. 1970 - Ottimi risultati nell'ortoflorofrutticoltura con la pacciamatura a mezzo di film plastici (Informatore di Ortoflorofrutticoltura 8).

BRANZANTI E., CELOTTI C.V. - 1967 - Influenza del foglio di plastica di diverso colore sul microclima di parcelle pacciamate (L'Informatore Agrario 50).

BRUN R. 1968 - Bilan de six années d'étude et d'emploi du paillage plastique en France (Actes III° Congreso Int. sobre las applicaciones de los materiales plasticos en Agricoltura - Barcellona).

BRUN R., VERONIAUD P., GINOUX G. - 1965 - Le paillage du Melon (VIII° Colloque Nation. des Plastiques en Agriculture - Paris).

BUCKOLZ C. 1965 - Il controllo delle erbe infestanti sotto la pacciamatura di plastica trasparente (Proc. VIth Nat.Agr. Plastics Conference - Ithaca-NY).

BUCLON F. 1971 - Bilan de 10 années de recherche et d'applications de paillage plastique en France et dans le monde (Plasticulture n.10-11).

BUCLON F. 1972 - Aperçu sur le développement de la plasticulture dans le monde (Plasticulture n°14).

BUGALHO SEMEDO C.M. - 1972 - L'application des matières plastiques dans l'horticulture tropicale - Cas de Iles de "Capo Verde" (Atti del V° Colloquio Applicazioni Materie Plastiche in Agricoltura - Budapest).

CANNEL G.H., VOTH V., BRINGHURST R.S., PROEBSTING E.L. - 1961 - The influence of irrigation levels and application methods polyethylene mulch and nitrogen fertilisation on strawberry production in Southern California (Proc.Am.Soc.Hort.Sci.78).

CANUSO P. 1967 - Risultati di esperienze di pacciamatura in orticoltura e floricoltura (Atti del III° Congresso Nazionale sulle Applicazioni delle Materie Plastiche in Agricoltura - Palermo).

CHISCI P. 1966 - L'impiego di film plastici nella pacciamatura di piante ornamentali in vivaio (Atti del II° Congresso Internazionale Applicazioni Materie Plastiche in Agricoltura - Pisa).

CLARKSON V.A. 1960 - Effects of black polyethylene mulch on soil and microclimate temperature and nitrate level (Agronomy Journal, 52-3).

CRESCINI F. 1959 - Agronòmia Generale 127-141 - Reda Roma -

CULTRERA R. 1968 - Chimica Agraria vol.III° - 295-318 - CEDAM Padova.

DE DONATO M. e GARIBALDI ACCATI E. - 1963 - Influenza della pacciamatura del terreno con film plastico sulla produzione del cetriolo (Atti del III° Convegno Nazionale Applicazioni Materie Plastiche in Agricoltura - Palermo).

DE DONATO M. e GARIBALDI ACCATI E. - 1971 - Esperienza poliennale sulla pacciamatura e la non lavorazione del terreno in orticoltura (Rivista di Ortoflorofrutticoltura Italiana 6).

DIAMANTI V. 1970 - Guida alle Materie Plastiche (Ed.Etas Kompass Milano).

EDMOND J.B., SENN T.L., ANDREWS F.S. - 1957 - Fundamentals of Horticulture (Mc Graw - Hill Inc. - New York).

ELIA P. 1963 - Risultati dell'impiego di fogli di polietilene, in funzione pacciamante, nella coltura del Pomodoro (Atti del I° Convegno sulle Applicazioni delle Materie Plastiche in Agricoltura - Bologna).

ELIA P., ACCATI E. - 1964 - L'impiego dei fogli di polietilene nero in funzione pacciamante nella coltura del gladiolo: effetti sulla umidità del terreno e sull'esito della coltura (Frutticoltura 3).

FAVILLI R., BENVENUTI A. - 1963 - La pacciamatura del terreno (Progresso Agricolo n.7).

FEKETE J. 1972 - Plastics in water economy (Vth International Colloquium Plastics in agr. - Budapest).

FREGONI M. 1967 - Il Polietilene nella pacciamatura del terreno del vivaio e delle piante madri di vite. (Atti del III° Convegno Nazionale Applicazioni Materie Plastiche in Agricoltura - Palermo).

GAMBOGI P., VERONA P.L. - 1966 - Effetti della pacciamatura del terreno con laminati in plastica sulla coltura di Vicia Faba Major Mars (Agricoltura Italiana 3).

GARCIA LOZANO F. 1972 - Exposicion de ensayos con riegos de goteo y pulverizacion (Atti Vth International Colloqium Pla stic in agr. - Budapest).

GIDDENS J. 1964 - Some effects of various mulching materials on soil temperature, soil moisture and soil nitrogen (Proc. Fifth Annual National Agricultural Plastics Conference Athens Georgia).

GUARIENTO M. 1965 - Esperienze con film plastici nella coltura del le fragole (Atti del II° Convegno Nazionale sulle Ap plicazioni delle Materie Plastiche in Agricoltura - La tina).

GUARIENTO M. 1966 - L'applicazione dei film plastici alla coltura delle fragole (Atti del II° Congresso Internazionale sulle Materie Plastiche in Agricoltura - Pisa).

GUARIENTO M. 1968 - Un quadriennio di ricerche sulle Applicazioni delle Materie Plastiche alla coltura della fragola (Atti del III° Congresso Internazionale sulle Appli cazioni delle Materie Plastiche in Agricoltura - Bar cellona).

GUARIENTO M. 1969 - Applicazioni delle Materie Plastiche in Agricol tura nel particolare ambiente della Valle Padana (Atti del IV° Convegno Nazionale sulle Applicazioni delle Ma terie Plastiche in Agricoltura - Mantova).

GUARIENTO M. 1970 - La coltura protetta della Fragola (L'Informato re Agrario 23).

GUARIENTO M. 1972 - Pacciamatura e Fertirrigazione (Atti del VI° Co nvegno Nazionale sulle Applicazioni delle Materie Plastiche in Agricoltura - Foggia).

GUARIENTO M., MICHELINI R. - 1969 - La coltura della Patata con applica- zioni di film plastici (Atti del IV° Convegno Nazio- nale sulle Applicazioni della Materie Plastiche in Agricoltura - Mantova).

HAJDU M. 1972 - Application of plastic film in early potato pro duction (Atti del Vth International Colloquium Plastic in agric. - Budapest).

HANRAS R. 1970 - Amélioration dans la qualité des films de poly- éthylène (IVe Colloque International des plastiques en agriculture - Paris).

HANNON S.A., MORLEY R. - 1964 - Effects of plastic mulch sheeting on Can- taloupe production in South Georgia (Proc. Vth Annual Nat.Agr. Plastics Conference - Athens, Georgia).

HONMA S. and Others - 1959 - Soil and air temperatures as affected by polyethylene film mulches (Quart. Bull.Mich.Agric. Exp.Stat.41).

HORANSZKY Z.S., KISS A.S. - 1972 - Subsurface irrigation and nutrient re placement with gap-valve PVC-pipes in vineyards on sandy soil (Vth International Colloquium Plastics in Agriculture - Budapest).

KISS A.S. 1972 - Heat economy of plastic greenhouses and mulching (Atti Vth International Colloquium Plastics in Agric.- Budapest).

KRAMER P.J. - 1959 - Transpiration and the water Economy of Plants - Plant Physiology by F.C. Steward - vol.II° 607-730 Academic Press - New York.

LAFON R. 1964 - Premiers résultats de lutte contre la pourritu re blanche de l'ail à l'aide du paillage avec film de polyéthylène. (Atti del I° Congresso Internazionale sulle Applicazioni delle materie Plastiche in agricol tura - Avignone).

MALQUORI A., CECCONI C.A. - 1966 - Nitrificazione in terreno sotto mulch plastico (II° Congresso Internazionale sulle Applica- zioni delle Materie Plastiche in Agricoltura - Pisa).

MICHANELLES N. 1970 - Prove di pacciamatura sul Pomodoro (L'Informa- tore Agrario 21).

MICHELINI R. 1970 - La coltura forzata della patata (Informatore di Ortoflorofrutticoltura 7).

MILELLA A., DEIDDA P. - 1970 - Osservazioni sulla pacciamatura e sul diserbo chimico in semenzali di arancio amaro (L'Informatore Agrario 37).

MONELLI C. 1967 - Risultati di prove di pacciamatura con film di Polietilene nero su alcune varietà di gladiolo (Atti del III° Convegno Nazionale sulle applicazioni delle Materie Plastiche in Agricoltura - Palermo).

MONELLI C. 1969 - Prove biennali di pacciamatura su talee di pioppo (Atti del IV° Convegno Nazionale sulle applicazioni delle Materie Plastiche in Agricoltura - Mantova).

MONJARDINO R. 1970 - Contribution pour l'étude du paillage dans l'arboriculture fruitière (IV° Colloque International des Plastiques en Agriculture - Paris).

MONJARDINO R. 1971 - Le paillage plastique dans l'arboriculture fruitière (P.N.K. 118).

MONJARDINO R. 1972 - L'application du plastique dans la culture du bananier (V^th International Colloquium Plastics in Agriculture - Budapest).

PANTANELLI E. 1953 - Agronomia Generale - 47-57 - Edagricole Bologna.

PAPANICOLAOU C.D., CRISTOPOULOS G. - 1972 - Report on the "multi-valve" drip irrigation experiment (V^th International Colloquium Plastics in Agriculture - Budapest).

PIMPINI F. 1972 - Impiego di film plastici e influenza della concimazione azotata e fosfatica sulle caratteristiche produttive e qualitative del radicchio "Variegato di Castelfranco" (Cichorium intybus L.).- (Rivista di Agronomia 2).

PIMPINI F. 1973 - Impiego di diversi film plastici per la pacciamatura delle zucchine Cucurbita pepo L. (Colture Protette 1).

PLESSER J. 1972 - Mulching as a method of research (Atti V^th International Colloquium Plastics in Agriculture - Budapest).

PODRAY E. 1972 - Subsurface (subsoil) irrigation with plastic pipes (Atti V^th International Colloquium Plastics in Agriculture - Budapest).

PRATOLONGO U. 1952 - Chimica vegetale ed agraria - REDA Roma -

PRINCIPI P. 1953 - Geopedologia - 181-208 - REDA Roma.

PUSZTAI A. 1972 - Effect of Mulching on soil and plant (Atti Vth Internationa Colloquium Plastics in Agriculture - Budapest).

QUAGLIOTTI L. 1963 - Esperienze biennale sull'impiego dei fogli di plastica in funzione pacciamante nella coltura del Sedano (Atti del I° Convegno Nazionale sulle Applicazioni delle Materie Plastiche in Agricoltura - Bologna).

QUAGLIOTTI L. 1969 - Effetti della pacciamatura con foglie di plastica sulla produzione del cetriolo (Atti del IV° Convegno Nazionale sulle Applicazioni delle Materie Plastiche in Agricoltura - Mantova).

RAVELLI V. 1970 - Pacciamatura e semiforzatura della patata per mezzo di film plastici (Atti del IV° Colloquio Internazionale sulla Plastica in Agricoltura - Parig).

ROBINSON J.B.D. - 1961 - The influence of mulch on natural and fertiliser levels of nitrate and ammonia in the top-soil (J.Agric.Sci. 56-49).

SABOYA Y. 1966 - Essais de paillage plastique sur tabac (Atti del II° Congresso Internazionale sulle applicazioni delle Materie Plastiche in Agricoltura - Pisa).

SANNO R. 1966 - Esperienze di pacciamatura con materie plastiche applicate a colture di pieno campo (Atti II° Congresso Internazionale sulle applicazioni delle Materie Plastiche in Agricoltura - Pisa).

SANNO R. 1967 - Ricerche poliennali sulla pacciamatura del cotone (Atti del III° Convegno Nazionale sulle applicazioni delle Materie Plastiche in Agricoltura - Palermo).

SCHALES F.D. 1963 - A study some phisical and biological effects of various mulching materials when used with several vegetables (Cornell University).

SHELDRAKE R.jr. 1963 - Carbon oxide level in the microclimate as influenced by the permeability of mulches (Proc.Nat.Agr. Plastic Conf.4).

SZITO' J. 1972 - Actual questions of the development of the surface irrigation hose equipment (Atti VIth International Colloquium Plastic in Agriculture - Budapest).

TESI R. 1970 - Risultati di una prova di pacciamatura con film plastici sul carciofo (Rivista di Ortoflorofrutticoltura Italiana 5).

TOSI T. 1970 - La pacciamatura integrale del fragoleto (L'Informatore Agrario 29).

TOURNON G. 1966 - Sperimentazione di nuove modalità di subirrigazione dei terreni (I° Convegno Nazionale dell'Associazione Italiana di Ingegneria Agraria - Portici).

TOURNON G. 1968 - Irrigazione sotterranea con tubi di plastica (Congresso Internazionale delle Materie Plastiche ed Elastomeriche - Milano).

TOURNON G. 1971 - Sperimentazione pluriennale di un procedimento di irrigazione sotterranea realizzata a mezzo di tubi di plastica (Atti del V° Convegno Nazionale sulle Applicazioni delle Materie Plastiche in Agricoltura - Montecatini Terme).

TOMBESI L. 1966 - Elementi di Scienza del Suolo - 31-72 - Edagricole Bologna.

TONZIG S., MARRE' E. - 1968 - Elementi di Botanica - vol. I° - parte I° - Casa Editrice Ambrosiana Milano).

VOTH V., BRINGHURST R.S. - 1961 - Priming and polyethylene mulching of summer planted strawberry in Southern California (Proc.Am. Soc. Hort. Sci.78).

WAGGONER P.E., MILLER P.M., DE ROO H.C. - 1960 - Plastic mulching: principles and benefits (Bull.Conn.Agric.Exp.Sta.634).

BOCCA A. 1963 - Indagini sulla fragola - Effetti della pacciamatura con polietilene nero sull'attività del sistema radicale (Rivista di Ortoflorofrutticoltura 3).

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