



Ginegar Plastic Products Ltd.
Kibbutz Ginegar, 38580, Israel
Tel: 972-4-6544220
Fax: 972-4-6547947
Email: GPP@ginegar.co.il

גניגר מפעלי פלסטיקה בע"מ
קיבוץ גניגור, 38580
טל: 04-6544201/9
פקס: 04-6441849
http://www.ginegar.co.il



Benefits To The Grower From The Use Of Modern "Sophisticated" Plastic Greenhouse Covers

Yehudah Ashkenazi –Eng.
Product Development
Ginegar Plastic Products-Ltd.
Israel

In the past 40 years tremendous progress has been made both in popularizing and improving greenhouse technology from what it was a half century ago when its use was principally in public botanical gardens and experimental stations. The impact that this technology has had on the fight against hunger in a world with a burgeoning population cannot be overemphasized.

One of the key elements in this revolutionary transition has been the development of (inexpensive and light-weight) plastic greenhouse covers which have virtually replaced what was traditionally considered "the" natural cover, namely quartz glass.

The choice of glass, as far back as circa pre-revolutionary France, in the Versaille gardens, was a wise and opportune one since glass has four built in traits which make it naturally suitable for this role, namely:

- its virtual indestructibility except through the use of violent physical means
- its natural retention (absorption) of heat waves "trying" to escape the greenhouse at night.
- its excellent transparency to visible radiation (light)
- its ability to support a heavy snowfall, providing that the structure is built to support the weight of the glass and the snow together

If plastic films had not largely replaced glass as the cover material for greenhouses, access tunnels and low tunnels in agriculture, it is doubtful that we would be witnessing today the use of these technologies (greenhouses etc.) on a surface area approaching two million hectares world-wide with all the implications which this statistic implies for the availability of horticultural products for the planet's inhabitants.

This switch-over to plastic has required a coordinated effort on the part of the companies which specialize in the production of chemical additives for plastic films, together with the companies known as "Masterbatchers" who produce the concentrates of these additives, and last, but not least, the product development technicians in the plants which produce the actual films.

Essential Properties In A Plastic Greenhouse Film Cover

Although polymers such as polypropylene and P V C (polyvinyl chloride) are in use in many parts of the world as supple greenhouse covers, the overwhelming bulk of the material in use is the polymer named polyethylene. Our discussion today pertains to this last, ubiquitous, material.

Two shortcomings of the polyethylene as opposed to the glass covers faced the product developers as major challenges from day one and these were:

- as opposed to glass, shreds of which we find today in many parts of the world almost intact after three thousand years of exposure to the elements, polyethylene film will totally break down to brittle crumbs or even to its ultimate gaseous products after a year's exposure to the sun's rays in certain climates.



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---A polyethylene sheet, untreated, in its "natural" state, is a very poor thermal absorber, compelling us to take certain specific steps during processing in order to bring the film up to the standard required for it to serve as a thermal greenhouse cover.

In retrospect, the shortcomings of the polyethylene with respect to glass, might have been a "blessing in disguise" which forced the developers to search for, and eventually find (or synthesize) a series of chemical additives and technologies which have made possible the production of today's SOPHISTICATED GREENHOUSE POLYETHYLENE COVERS which surpass in their properties anything we could have dreamed about making from quartz glass as a prime raw material.

If we review the properties available in these afore-mentioned sophisticated covers, we can arbitrarily divide them into 1) Essential properties and
2) Optional properties.

Essential Properties

A greenhouse cover must have resistance to breakdown for at least the length of time which the producer guarantees that the film will serve the grower in the field. This property is called, in the technical jargon "**film stabilization**".

A greenhouse cover must block or impede the nocturnal escape of accumulated heat sufficiently to call the structure a "**heat trap**". Otherwise the structure is a "shelter" and not a "greenhouse".

A greenhouse cover must be essentially transparent to the radiation in the range of what we call the **P A R** (photosynthetically active range).

A greenhouse cover must be endowed with **physical resistance** to tear if subjected to reasonable external forces and to impact of falling objects such as hail pellets.

All the other properties which we will subsequently mention, although they may be very beneficial and feasible from an economic point of view, are not ESSENTIAL and a grower may decide to elect to include them in his greenhouse film cover or to do without them and purchase a simpler, less expensive product.

Additional (Optional) Properties

---**Diffused light**. The incoming photosynthetic radiation can be compelled to change the direction of its entry into the greenhouse, providing the plant with light from all sides

---**Anti Drip**. This property is actually the prevention of the formation of LARGE drops of water on the inner surface of the film cover and substituting them with tiny, almost indistinguishable drops which look to the naked eye like a continuous, very fine, layer of moisture on the film surface.

---**Blocking the entry of ultra violet radiation** into the greenhouse. This property has significant ramifications in the field of Integrated Pest Management as well as film stabilization.

---**Permitting a large amount of ultra violet radiation** to enter the greenhouse. For certain crops this property can raise the value of the horticultural product which we are growing. Among these products one finds bi-colored roses, nectarines and peaches grown in greenhouses.



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---**Preventing the formation of mist** (fog) in the greenhouse. Films with a new and strong anti drip additive have a tendency to bring about the formation of mist in the greenhouse, when temperatures decline in the early morning hours and the relative humidity reaches the saturation point. Today a technology, replete with exotic additives which allow us to benefit from the anti drip while avoiding the damage caused by fog, is available to the grower.

---**Reducing the accumulation of dust** on the covers. A week out in the field in certain areas can be enough time during which accumulated dust reduces the transparency of a greenhouse cover by 40%!

---**Transmuting impinging wave lengths** of radiation into other (longer) wave lengths. These are the fluorescent additives which (usually) absorb U V radiation and transmute it into (photosynthetically active) blue or red radiation. The "jury is out" on whether this technology will bring about a breakthrough in greenhouse cultivation or not.

---**Blocking out (reflecting or absorbing) the N I R radiation** which contributes only heat to the greenhouse, without affecting the incoming visible (P A R) radiation. This has been a much-desired goal, an aspiration, which has not as yet been demonstrated in the field. Were it to be achieved, we would be able to present the plants with solar radiation exclusively necessary for the plants and nothing extraneous which might contribute excess heat or radiation which could bring about damage.

Stabilization of Polyethylene Greenhouse Film Covers Against Photo oxydational Degradation:

The packages of stabilizers available to the industry today are highly satisfactory for preventing breakdown of normal film covers of 150-200 microns in thickness for as long as 5-7 years if properly placed on the greenhouse and separated physically from the metal or wooden framework of the structure. But that holds true for "ordinary" or "normal" conditions.

The truth is that the real challenge has not been solved and this challenge is how to stabilize films which are exposed to **pesticides, fungicides or herbicides containing sulphur and/or halogens**. These substances react with the main stabilizers, taking them out of service and leaving the film without sufficient protection. Soon afterwards the film will deteriorate and will have to be replaced.

None of the stabilizers or combinations of stabilizer elements is totally immune or resistant to this chemical attack. Using tricks of the trade and an expensive combination of stabilizer elements, we are able to guarantee a film, in conditions of daily sublimation of sulphur, for 3-4 years of service in the field.

The photooxidational degradation is catalyzed by U V radiation of certain specific wave lengths which excite bond electrons in the polymer chain, subjecting the atoms to instantaneous oxidation and a chain reaction which leads to free radical formation and further breakdown.

The search is on for an element or a mixture of substances which could permanently defend the plastic against the U V radiation, enhancing stabilization and providing a U V free atmosphere in the greenhouse. The current U V absorbers in use are organic materials, and they are destroyed by the very same rays which they are designed to absorb. Conventional wisdom should lead us to search for a solution to this problem in the direction of an inorganic U V absorber or reflector which would not be destroyed by the U V radiation and could continue to offer protection throughout the life of the film.

This logic has led to work with certain metal oxides. However, these substances, in addition to blocking U V radiation must be transparent to the visible (P A R) radiation. This has been an elusive goal to date. The search



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is now in the direction of nano particles of these oxides, particles minute enough so as not to pose a threat to the transparency of the film.

Thermicity In A Film Cover- The Effect On Plant Temperature

At first glance we assume that the main benefit from the use of thermal films is the effect on the air temperature of the greenhouse, which is the criterion most frequently measured in order to determine whether the film is doing its job.

The truth lies elsewhere, without underestimating the importance of nocturnal greenhouse air temperature. Of prime importance is the maintenance of optimal temperatures of the plants we are growing in the greenhouse. If the air is warm at night it will impart some of its energy to the plants which it envelopes. But air, by its very nature, carries relatively little energy because its mass is so small. So there are limits to how much the air in the greenhouse can warm up plants rapidly losing energy (heat) through radiation and convection.

However, the plants are losing energy (heat) chiefly through radiation to the atmosphere and this radiation activity is strongly influenced by the type of greenhouse cover they "see" above them. The equation describing the heat flux out of the plants includes the plant temperature to the fourth power and the "sky" temperature to the fourth power. The equation is:

$$Q = \epsilon A \delta (T_a^{4th} - T_b^{4th})$$

where ϵ = emissivity (0.9)
A = leaf area and
 δ = Boltzman Constant,
Q = radiation heat flux 3.3×10^{-22nd} cal/deg.K

In other words, plants in a greenhouse covered with a thermal film which is absorbing heat radiation and is relatively warm will (theoretically, at least) be warmer than they would be were they exposed to the sky above with no plastic (or glass) cover or with a non-thermal cover.

The warming should be beneficial to the plants not only by virtue of the positive effects of the optimal temperatures on their growth and development. Another important, perhaps the most important, benefit is the fact that condensation of moisture in the greenhouse will occur on the plant surface only as a "last resort" after the moisture has condensed on other, colder surfaces

Certain Metals Threaten The Field Performance Duration of Polyethylene Greenhouse Covers

There is an entire "family" of metals which pose a threat to the life span of polyethylene greenhouse covers even when they are stabilized with the best additives. These metals appear in the Periodic Table Of The Elements as the "transition metals" in which the next to the outermost "shell" is not filled to its natural complement of electrons when the element is in its rest state. In the plastic industry professional "jargon" they are called **PRO DEGRADANTS**.

Among the more commonly occurring members of the series which threaten and often cause the early breakdown of polyethylene sheets are **Iron (Fe), Copper (Cu), Nickel (Ni), Zinc (Zn) and Titanium (Ti)**. There are various opinions as to whether these metals must be in their "zero valence" state in order to pose a threat to a film's integrity or not. However, we recommend to view these metal pro-degradants as dangerous to the plastic even if they occur as oxides. As a "rule of thumb", **400 parts per million** of (elemental) iron in a plastic film should be a "red light" to a film producer.



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How do the metal pro-degradants get into the film? There are essentially two pathways for this to occur. One is the inclusion of these metals in various additives as contaminants. A common example is the (mineral) **thermal additive** called the "I R additive". Another every-day instance of the invasion of metal pro-degradants is the **MIGRATION** into the film of metals found in the framework of the greenhouse itself. A greenhouse built of galvanized iron piping will release zinc (from the coating of galvanization) into the film if there is direct contact between the plastic film and the metal structure.

In fact, if we analyze in the laboratory samples taken from the plastic film in consecutively more and more distant sections of the film from the actual point of contact, we will find a decreasing gradient of concentration of the metal and a concomitant decreasing gradient of degradation indicators (such as the carbonyl percentage) at each consecutive point which we elect to examine.

We, as "convertors" (we convert polymer resins into plastic sheets or other products for the ultimate consumer), repeat over and over again, in writing and in public forums by word of mouth, that the grower must **physically separate the metal (or wooden) structure from direct contact with the plastic film cover**. The separation can be accomplished through the use of cloth or plastic or other insulating material or by applying a coat of white acrylic paint on all the upper surfaces of the metal tubes which are liable to come into contact with the plastic film.

It is a pity for a grower to pay for an excellent greenhouse cover guaranteed for 4 years of performance in the field and find that it is "cracking" along the contact points with the framework of the greenhouse after 18 months and must be replaced, due to negligence on his part.

It Can Rain On The Plants Inside The Greenhouse Even On A Sunny Day

Water is the medium through which all the vital chemical reactions take place in plants and animals. As a result, all of what we are engaged in doing, raising food for consumption of man or animals or cultivating ornamentals, involves the profuse, constant use of water. The plants transport their nutrients against the pull of gravity in a mass flow of water from the soil to the apex. They are synthesizing their enzymes in a bath of water and so on and so forth.

It is natural to expect that when we enclose a space with a transparent cover and devote that space to the cultivation of plants, the space will usually have a high level of relative humidity, not very far from saturation. We can also assume that when the temperature declines (especially at night) the R.H. will reach saturation and we will face condensation and mist formation problems.

The excess water in the form of condensation and/ or mist poses a threat to the well-being of the greenhouse. Large drops of water, in addition to serving as reflectors of incoming sunlight causing a decrease of as much as 20% of the radiation in the P A R, if and when they fall on the leaves are focal points for the propagation of fungal and bacterial plagues. The drops can and do concentrate the sun's rays on the leaves and serve as initiators of burned necrotic spots on leaves and stems.

The large drops form on the inner surfaces of the films because the plastic film is by nature antagonistic to the water. It is "hydrophobic" while the water is "hydrophilic" If we desire to reduce or eliminate entirely this "hydrophobicity" of the inner surface of the film (and avoid getting these large drops forming) we must change the chemical nature of the film surface.

There are a few ways to accomplish this change, but the currently most popular means employed by the producers of greenhouse covers is the use of surfactant additive **IN THE RESIN MIXTURE WHICH GOES THROUGH THE EXTRUDER TO FORM THE FILM**. Then we have the problems of 1) preventing the migration of the surfactant to the upper surface of the film where it is not wanted 2) extending the performance of the additive to as close as possible as the entire life of the film in the field



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Like all surface –active compounds, the anti drip additives are molecules with both a hydrophobic (lipid) part and a hydrophilic part (which does the work of "wetting" the inner film surface with the thin layer of minuscule droplets). The art of synthesizing these surfactants is to have the lipid end of the molecule so compatible with the polymer matrix as to be "anchored into it" to prevent the entire molecule from being "leached out" of the plastic by the very water on which it is doing its job while at the same time providing a dense enough hydrophilic active end to really do its job and leave a large part of the condensed moisture in the form of large drops which may endanger the well being of the plants

This is called "attaining the proper hydrophobic hydrophilic balance" in the molecule. Alas, in spite of all the know how and experience, most of the films containing anti drip additives on the market give between a few months to a year and a half of true performance before they cease to do their job.

Long chain fatty acids are traditionally used as the hydrophobic "anchors" of the surfactant molecules. These are esterified to glycerol and/or to sorbitol, in which the free hydroxyl groups actually make the film surface more "hydrophilic" friendly to the condensed water. However, there is a new generation of surfactants based on a different chemistry and in the preliminary simulation tests and the first field trials, they look very promising and perhaps are harbingers of a break through.

There are a few exceptions to the run of the mill performance in the field and their producers have perfected whatever technological secret they have. It must be noted that there are many on the ground conditions which determine the efficacy of anti drip performance in greenhouse covers, most of the them conditions which depend on the grower and not the film "convertor".

Without divulging any real proprietary information , we can categorically state that compartmentalization of the film structure (multi layer films) makes a large contribution to the long term performance of the anti drip property which can be witnessed in certain films in the field for , at the moment of writing these words, over three years in Western Europe.

Preventing The Formation of Mist (Fog) In The Greenhouse

Growers have learned from their own experience that a film which performs well against the phenomenon of "drip" will inevitably give rise to the appearance of mist in the greenhouse when relative humidity , resulting from temperature reduction, usually at night, reaches saturation. If the excess moisture has no cold, free surface on which to condense, mist will form . This hovering fog will cover the plants not only on the upper surfaces. A layer of moisture enveloping all the plant parts will result .

If the anti drip property begins to disappear , often after one year of activity in a poorly formulated film,, the mist phenomenon will also disappear. This is an ironic situation in which the grower was able to benefit either from one of the two , good anti drip with the accompanied fog or no fog with the formation of large drops of water.

Today it is possible to enjoy both worlds, using a film enhanced by the cutting edge technology of anti drip additives without incurring the risk of mist formation, due to the availability of anti-mist additives which prevent mist from forming. However, one should take note of the fact that , although the anti mist property is beyond the experimental stage, we are still learning how to make a film with an anti mist property which will perform in the field longer that two years.

Before the appearance on the market of these anti mist additives the grower could rid the greenhouse of the mist either by aggressively ventilating , often in the middle of the night, or by heating the greenhouse to raise the temperature and thus lower the relative humidity. Both of these strategies could be viewed as, at best, the lesser of the evils.

In fact, in parts of Western Europe, many growers, not yet aware of the existence of the anti mist property, prefer using a film with no anti drip. They feel that somehow, through aeration of the greenhouse, they will



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manage to mitigate the damage caused by the dripping phenomenon, rather than to bring upon themselves the devastating effects of the greenhouse fog.

In Northern China, on the other hand, the indigenous Chinese grower, operating in a locally designed "greenhouse" (actually a "half-tunnel") with no facilities for aeration and almost always without accessory heating mechanisms, must cover his structure with a film which contains both anti drip and anti mist, if he hopes to market his vegetables free of fungal disease.

An Arsenal of Resins From Which To Choose To Improve The Physical (And Optical) Properties Of Our Film

In addition to the current "supermarket of additives" at our disposal, we can choose from an array of resins which have been developed by the giant firms who operate in the petrochemical industry. Since the advent of Linear Low Density Polyethylene, over 20 years ago, an enormous breakthrough at the time (rewarded with a Nobel Prize), which enabled us to provide the end user with a very strong film at highly reduced thickness (and highly reduced weight as well as reduced cost), we have been fortunate to have at our disposal today the relatively new **Metalocene Linear Low Density resins**.

If the Linear L. D. resins were for our industry like the telephone was for communications, the Metalocene L. L.D. resins are analogous to wireless broadcasting, if not more. Their price has come down to where there is no reason not to use them, even as a thin layer in a multi layer film, to provide superb tear and impact resistance.

Add to that the vast choice of Ethylene Vinyl Acetate copolymer resins available of any percentage of vinyl acetate imaginable with high viscosity (low melt flow indices). These EVA films contribute to enhanced transparency in the film to visible light, excellent elasticity, resistance to tear by impact plus thermicity . They are also instrumental in slowing down, if not preventing, the rapid migration of certain additives (those which are chemically "polar" such as the anti drip surfactants).

There are nucleating agents available which can dramatically increase transparency of a film by facilitating the formation of multiple tiny crystals of substances in the film which might otherwise slowly form large crystals which could cause the appearance of haze (diffused light transmittance).

Multi-Layer Films Made By Multi-Layer Extruders

How many layers should a greenhouse cover have?

This question reminds us of the question reputed to have been posed to the legendary Abraham Lincoln , "how long should a man's legs be?". Long legged Abe quickly replied , " long enough to reach the ground."

A greenhouse cover should have as many layers as are required in order to get optimal performance of the properties with which the cover is endowed. Sometimes, in a very sophisticated film, these properties can be numerous. It is not difficult to demonstrate that the **best film would be the one with a separate layer for (almost) each property**. Of course such a machine, with its prohibitive cost and its complex technology is simply a parable to exaggerate the point which is; that multiple layer machines are intrinsically superior to single or double or even three layer extruders.

What is the reasoning behind this argument?

Being that today the only large size commercial 5 layer extruder for producing greenhouse covers is working at Ginegar Plastic Products , Israel, it might seem counter productive for us to extol the virtues of this machine and encourage others to enter the competition.



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But the truth is that we can produce any film made on a mono, two or three layer machine in an improved version on our five layer machine. The reasoning stems from a concept called "compartmentalization" which means the ability to, as much as is possible, allocate a separate "compartment" (layer) for as many of the components of the film as possible.

This is especially true for cases which fall under the following headings:

- When two or more materials (resins and/or additives) are totally incompatible
- When two or more materials cause secondary undesirable ramifications if they are together in the same layer (such as haze or other optical phenomena)
- When we want to confine an additive to a certain part of the film and limit its migration
- When it is sufficient to have a very thin layer of a substance in order to benefit from its effect in the entire film (such as barrier resins ; nylon, EVOH etc)
- When we require tie-layers in order to achieve adhesion between two adjacent layers

What is the optimum number of layers which should be in a greenhouse cover?

Most probably the five layer extruder is not the last stop in this journey.

Challenges On Our Agenda To Solve – Or At Least To Think About In The Meanwhile

Some of the major challenges, as yet unconquered, are as follows, not necessarily in their order of importance to the industry.

- Finding (synthesizing) a stabilizer which is not affected by sulfur and halogens.
- Perfecting a U V absorber (or system of absorbing or blocking) which would work in the field for the entire length of the film's performance period
- Finding (synthesizing) a selective absorber or blocker for the reduction or elimination of Near Infra Red (N I R) radiation which might enter through the cover film into the greenhouse.
- Synthesizing an improved I R additive which contributes thermicity without adding any haze whatsoever.
- Perfecting a system of anti-mist + anti drip which will function four consecutive years in a 200 micron film.
- Developing a system for the total prevention of the accumulation of dust and algae on the upper film surface for the length of the life of the film in the field.

In the meanwhile we will have to make do with what we have as of today.

Yehudah Ashkenazi

Ginegar Plastic Products Ltd. (Israel)