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Symposium on the Development of the Plastics Fabrication Industry in Latin America

Bogotà, Colombia, 20 November - 1 December 1972

THE USE OF CELLULAR PLASTICS FOR THE IMPROVEMENT OF SOIL STRUCTURE (PLASTOPONICS) 1/

by

Heinz Baumann
UF Chemicals
Frankenthal
Fed. Rep. of Germany

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SUMMARY

THE USE OF CELLULAR PLASTICS FOR THE IMPROVEMENT OF SOIL STRUCTURE (PLASTOPONICS) 1/

by

Heinz Baumann
UF Chemicals
Frankenthal, FRG.

In the light of world-wide mal-nutrition it is proposed that attention should be paid to the possibility of decreasing the extent of arid and semi-arid regions by the incorporation of urea-formaldehyde resin foams into their top-soils as a means of effecting the necessary degree of water and air retentivity. This technique first proposed in 1948 as a possible means for the disposal of waste foam scrap, arose as a development of hydroponics and is referred to as "PLASTOPONICS".

The balance of the following aspects of the physical and chemical properties of urea-formaldehyde foams is considered to render appropriately formulated urea-formaldehyde resin compositions suitable:

i. The ratio of closed to open cell - 60 - 70% coupled with a fine capillary structure.

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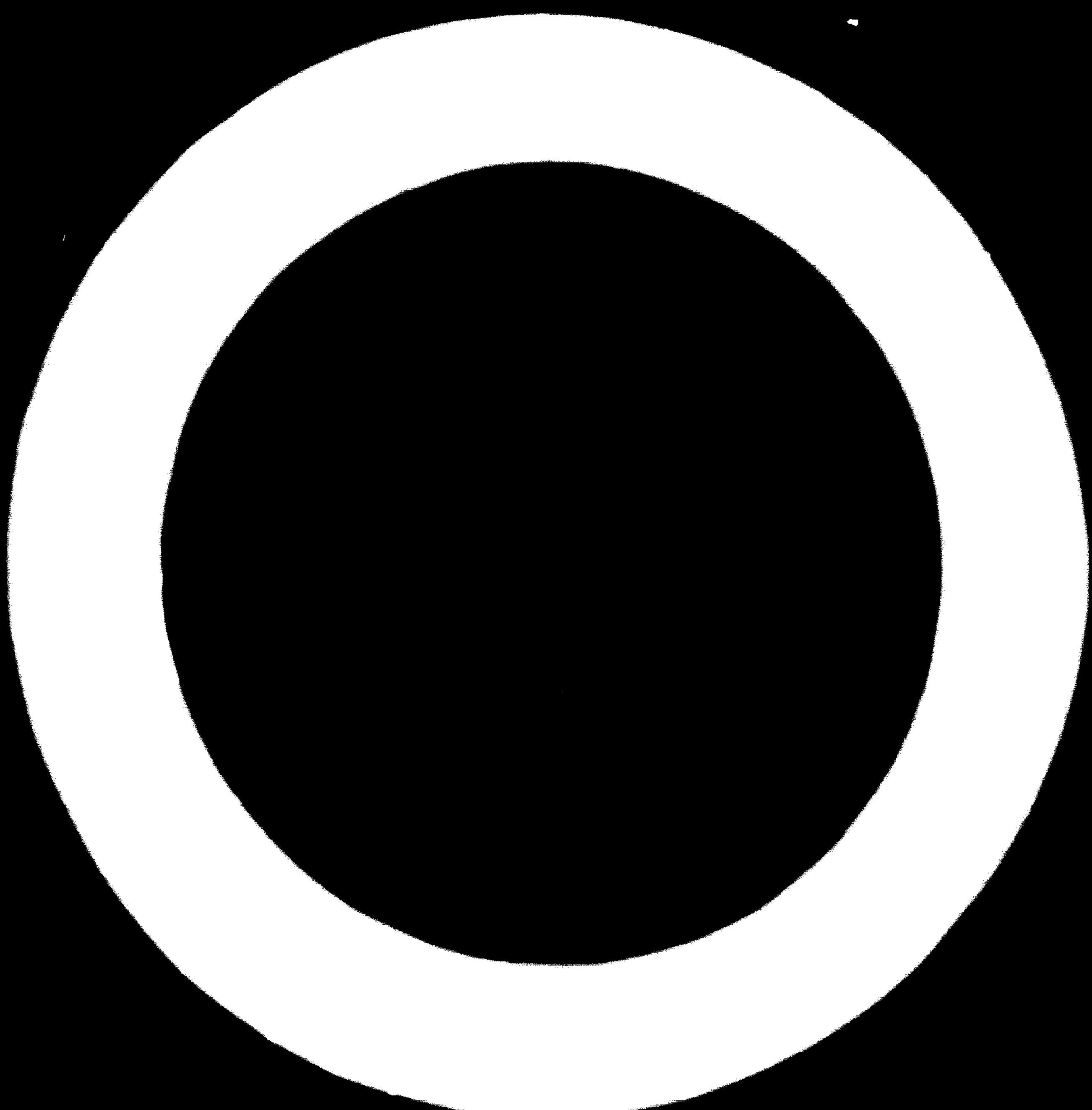


ii. [illegible]

iii. [illegible]

iv. [illegible]

v. [illegible] the enrichment of the soil [illegible] ation.

vi. Although [illegible] transparent U-F foams can be coloured [illegible] plant nutrients can [illegible]

vii. Non-toxic [illegible] animals.

While at present time, the area of North African desert is increasing annually it is known that in ancient times large parts of its area were arable. It is therefore concluded that the use of Plastoponics could contribute to a reversal of this process. Such a technique would be complementary to other methods for the restoration of arability based upon the procurement of adequate water reserves.

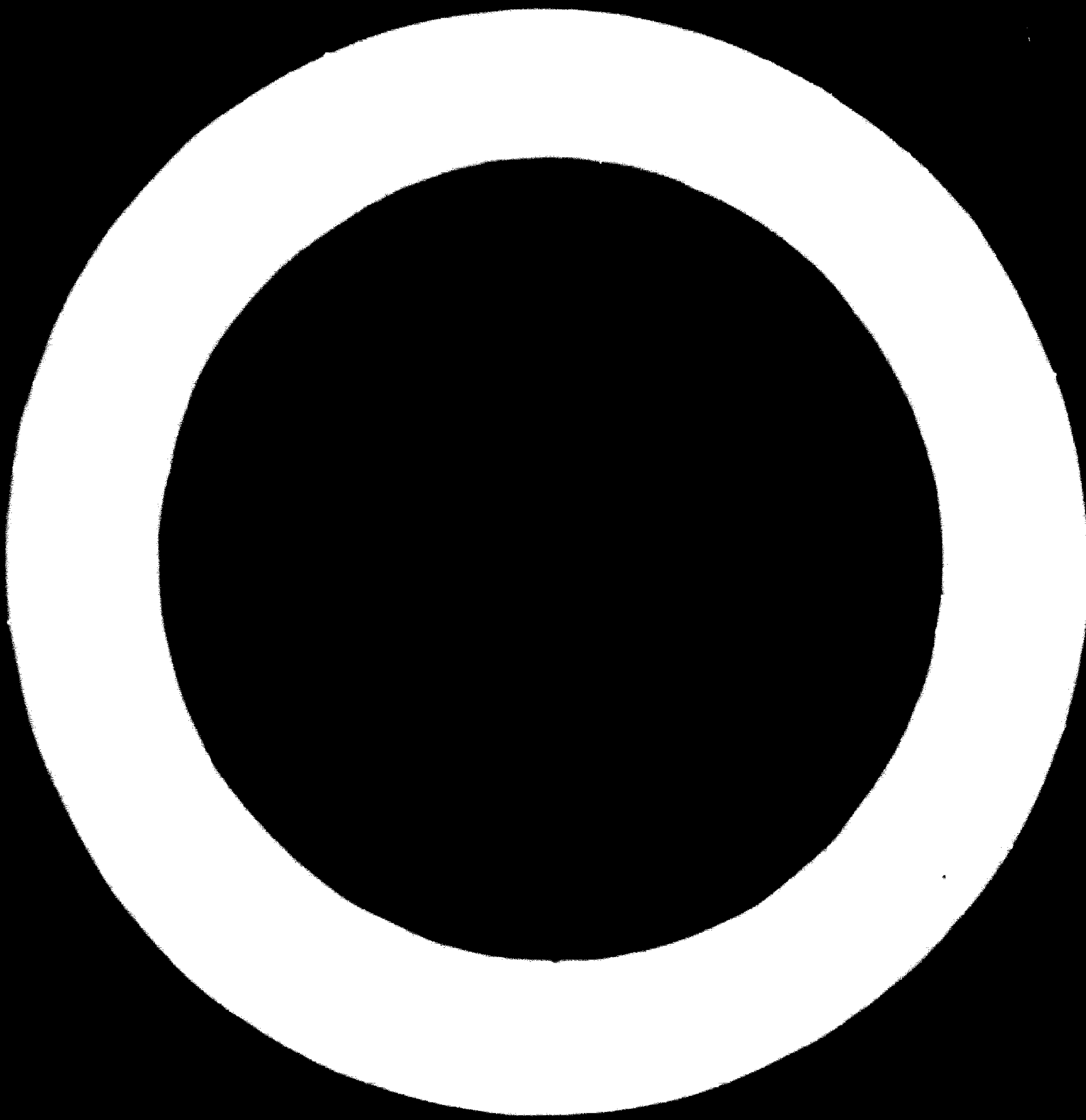
Experiments in the use of plastoponics were conducted in Saudi Arabia during 196[illegible]/6[illegible], embodying the planting of sugar beet, melons, clover and citrus fruits, demonstrated the following features

Soil water retention after [illegible] days at 4[illegible]°C. max. [illegible] temperature	[illegible] without compression [illegible] with tractor compression.
Planted citrus [illegible] survival	Plastoponics treated - 95% Control untreated - 50%
Seeds	Plastoponics gave a high rate of germination.

The foam material in the soil had absorbed ten times its weight of water, which prevented soil binding, after an application of 15 cms. of sand to prevent loss by evaporation during the hottest period.

The development of suitable application equipment has progressed to the manufacture and field testing of a 12 hp. tractor housing a foaming apparatus based upon [illegible] containers.

The properties of phenol-formaldehyde, polystyrene, polyurethane, P.V.C. and mixed synthetic foams are such that although they may find more specialized applications than the U-F in this field they are unlikely to compete in terms of raw-material and investment costs.



Introduction

Cellular plastics have recently entered new fields of application. Their use in agriculture is becoming more widospread and increasingly more significant.

Their greatest task in the near future to act as an upgrading additive for arid and semi-arid soils and thereby help to increase the world food production.

Today, two-thirds of the world inhabitants **suffer from mal-nutrition** and day by day thousands of people die form malnutrition or the consequences thereof. The alleviation of **hunger** must become the foremost task of our society. Daily, the world population increases approx 2oooo people, which means that in ten years from now the 4,5 billion mark will be passed. The problem of coping with this rapidly increasing human population cannot be postponed until than. It mus be dealt with right now.
At the eigth world conference for family planning in Santiago, Chile, in March, 1967, G. Carstairs pleaded for birth control, stating that an uncontrollable population explosion will cause people to become irrational and aggressive. This in turn will cause social and economic upheavals of staggering proportions.

It is obvious that this approach alone even if successful will not solve the food shortage problem which exists right now, as can be seen from the following figures published by the F.A.O. in Rome. According to the food and agricultural organization of the United Nations, food production in Asia dropped by 15 to 2o % (per capita) from 1945 to 1958. The increases registered since 1958 will have to first make up for this loss before they can how an appreciable effect on the human increment added since 1945. The world food conference in 1966 reported that food production in Africa, the far east, and Latin America dropped by 5 % on a per capita basis.

Increased food production alone ist not the whole answer either, since great amounts of food are destroyed by rodents and insects before theyrreach human consumption. It is estimated that rats consume 1/5th of the worlds total vegetable production. Control of insects and rodents ist not only an expensive proposition (nearly 1o,ooo substances have to be tested over a period of 5 to 7 years at a cost of more than 2,5 million dollars) but also a dangerous one since these poisons endanger man as well.

Amelioration and improvement of soils for higher crop yields in semi-arid zones will present a staggering task to the chemical industry. If only 1o % of the potentially arable land were to be treated, with one kilogram of cellular plastics per square meter the resulting demand would exceed 1o billion tons. It would take 33,ooo years to fill this order at present world chemical capacity.

HISTORY:

There has always been the objective to grow plants utilizing hydrocultural systems.

1860 war the birthdate of soil-less plant growth; plants were raised for the first time in acquous mineral salt solutions. In 1929, Gerricke reported on large scale experiments using water culture as a method of raising foodstuffs. He firstly used the term Hydroponics as a parallel to Geoponics. (agriculture). While he was still experimenting, several water cultures were already in operation in Europe. The results from the unit at the Plodoinstitute in Russia were applied in practice during the Russian polar expedition in 1937. Furthermore, Polish hydroponic units were in operation to the South of Lwow and Hungarian ones in the Carpathian mountains at an altitude of approximately 6000 feet. There, although daytime temperatures during the summer sometimes reached 100°F, the ground was seldom free of snow and frost. The units there produced results that were remarkable better than those achieved in the Hungarian plains. The fruits were better in taste and quality than those raised on land during the summe . The explanation is to be found in the fact that, at these elevations there ist more sunshine than in the valleys and prairies which are often covered with low lying clouds and fog.

The first German Hydroponic unit was built in 1938. Parallel to that the chemical industry developed the foundation for efficient fertilization which was preceded by the achievement of amonia synthesis, by Haber and Bosch.

Additional to the advanced art of fertilization, the search for soil improvement and substitutes was continued. This was necessitated by the need to cultivate previously barren land and transform it into pastures and plow land. In order to retain lands, it was necessary to protect them against wind and soil erosion by the use of special plants. We cannot delve into this aspect in detail. However, we are interested in a proposal for soil improvement made in the year 1948. It proposed the use of foamed waste materials based on Urea-Formaldehyde resins, which became available during the manufacturing process of an insulation foam. These wastes, mixed with fertilizers and other substances such as manure, humus, and peat moss, could be plowed into the soil in flake form.

III. FOAM PLASTICS:

Most plactic foams have cellular structure. Their cell walls consist of more or less strong membranes. The cells can be closed, and filled with air or a gas. They can also have open inter-communicating cells, in which case they are permeable to gases. We distinguish between globular, hexagonal and polyhedral cell structures. There can be closed celled, open celled, or open/closed celled foams. The volume of air in the foam determines its density. We also distinguish between rigid and flexible foams. Flexible foams act as cushions; rigid foams can have high or low compressive strengths. Further descriptions of cellular plastics may be looked up in the technical literature.

The growing of plants utilizing hydrophilic, physiologically compatible, plant nutrient and trace element containing or accepting foamed plastics, we call

PLASTOPONICS

Thereunder we also understand the growing of plants in connection with foamed plastics in general, whether in flake or other form, as a continuous or discontinuous layer on or in soils in which normal plant growth is impossible or in which improvement is desired.

Foamed plastics can be applied in agriculture, hydroponics, and plastoponics.

A. Urea-formaldehyde foams (U.F. foams)

1) Properties and Production

U.F. foam is a mixed cell foam, approximately 6o-6o % open celled and 3o-4o % closed celled. Its appearance is cotton-like; however, at a enlargement of 1:15o, the cellular structure becomes clearly visible. U.F. foam "breathes" because the open cells communicate. The cell structure is polyhedral. The fine cell walls are pipe-like in appearance and have capillar structure which is partly open and filled with air (so called Gibbs Channels). This structure makes U.F. foam suitable for agriculture use because it can never be completely soaked with water; the hairlike roots can utilize the air in the capillars, thus preventing plant suffocation.

Despite their open cell structure, originally U.F. foams were hydrophobic, i. e. repelled water, Only after extensive research work, however methods were introduced by which U.F. foam became hydrophilic respectively water-absorbing characteristics. The 6o % (by volume) water absorbed by U. F. Foam is entirely available to the plant, whereas peat moss, which also is capable of holding up to 6o % water by volume, binds 3o % thereof so strongly that it cannot be utilized by the plant.

Plant growth in U.F. foam, without water, is impossible.

Water is vital not only as a means of transport and as a solvent, but also as a nutrient and serves for colloidal expansion. Without water, plants cannot grow - no life is possible.

U. F. foam has a high content of air, and air in the soil plays a vital part in plant growth. A muddy soil surface does not allow penetration of air into the soil. Too higher a water content will replace the air, and subsequently plant roots suffer from lack of oxygen. In such cases , the life supporting micre and macro organisms compete with the plant for the remaining oxygen supply.

U.F. foam can be produced in densities from 7,5 kg/m^3 to 40 kg/m^3. The raw materials for U. F. foam for agricultural purposes differ from those used for insulation in the building industry, i. e., they are modified for their particular use. Foams can be produced with suitable apparatus at the site where they are needed. This greatly reduces the problem of transportation. 2o liters of liquid resin and approx. the same quantity of foaming agent, when foamed with compressed air, yield to approx. 1ooo liters of foam; whereas earth, and other substances which do not change their volume are bulky and expensive to transport.

U.F. foam is very light, yet it does not lack a certain stability. Its resistance against soil acidity, weathering, and pressure, is sufficient to last for many years. When it finally decomposes, it will enrich the soil with nitrogen.

The fine cellular structure of the foam acts as thermal insulation so that water inside and underneath cannot evaporate. It is compressable like natural turf, but without mesilience. Resilience would result in destruction of the fine root by tearing them apart as the turf returns to its original shape.

Plant nutrients should incorplanted and available for assimilation, otherwise the plant roots will try to utilize other neighbouring substances which require more energy to be assimilated and therefore slow down growth and reduce yield.

U.F. foam is acidic when first produced, but may subsequently be adjusted to any p_H value required for the particular plants to be grown.

Table I.

Optimum p_H values for plant growth

Plant	
peas	3,6 - 5,7
beans	4,o - 6,o
potatoes	5,5 - 6,3
tomatoes	5,5 - 6,4
lettuce	6,o - 6,8
sugar beets	6,5 - 7,o
carrots	6,5 - 7,o

U. F. foam can be colored as desired. Color plays an important role in plant growth. U. F. Foam is normally white and transparent to light. Therefore, only seeds germinating in light can be grown unless counter measures are taken, such as adding colorants, or covering the foam with a protective layer like dirt, etc. The same applies where roots are phototropic, i.e., light sensitive, and where , in uncovered foam, the roots would tend to grow down into darker substructer out of the reach radiation.

The standard U. F. foam formulation does not contain any plant nutrients or other additives. These can be added to the foampremix prior to foaming process, or added later by conventional methods. Nutrient concentration in water by absorption is extremly low. The main storage of nutrient and/or other additives from where they are conveyed to the plants through branches and rootes. The nutrient salt solution holding capacity of U. F. foam can be increased considerably by the addition of the mineral Montmorillonite, or ion exchange resins which are presently used for desalinization.

Impregnation of the foam which higher concentration of nutrient is impractical since salt solution may have a toxis and therefore destructive effect on the plants.

Based on its properties and the results of the work done to date, it can be said that U. F. foam is suitable for the following applications:

reclamation of land,
stopping the spread of desert,
prevention of soil erosion,
afforestation in southern as well as in northern latitudes
reinforcement of dune and flanks,
growing and cultivating of seeds,
planting of grapes,
growing of flowers,
protection of orchards and vineyards against frost,
securing highway embankments against wash-outs,
roof-gardens,
and the general improvement of soil structure.

U.F. foam ist produced from:
modified U. F. resin premix and
foaming agents.

the foam can be applied in layers or strips. Dried, it can be flaked or ground to powder. Its various possible applications will be described later.

U. F. foam is harmless to animals that live in the soil. It is also harmless to man: from the same basic foam material, suitably modified, we manufacture wound dressings and cosmetic powders.

Plastsoil for arid and semi-arid soils

From old maps that show vegetation, one can see how seriously soil and water conditions have deteriorated in the past 1ooo years. A plant needs 5oo to 12oo l of water in order to produce 1 kilo of dry substance. All through history, a sufficient water supply could be said to p arallel the cultural development of any area. Wells constructed in ancient times are still in use today. Water has always been sought, and its acquisition always precedes economic and cultural developments. Moreover, the problem of obtaining sweet water from sea water by means of sun distillation, ion exchange, or other methods, is as large in magnitude as the problem of soil improvement.

Eighteen million square kilometers of the surface of the earth are desert - eighteen million square kilometers of barren, unused land. These desert areas are outside of the normal sphere of man's activity, although he is at the brink of conquering outer space.

Aside from a few nomadic people who live a life of squalor and poverty wandering in these areas, the desert is generally prohibitive to human life, except for natural or artificial oases, where oil,metals,and other minerals are being extracted. Today, it is more important than ever to open up these deserts for economic exploitation. Deserts are vegetation-less areas.

They may exist because of a lack of water the land has sufficient heat. Therefore one has to distinguish between "dry" and "cold" deserts. Neither "cold" deserts, nor extremely arid desert areas were the subjects of experiments treated here.

We are not in an age of the retreat of deserts. On the contrary, we know that the Sahara advances every year approximately 1.5 kilometers to the south, destroying in its path the little vegetation that it meets.

The fact that large parts of desert in the north of Africa were, in ancient times, agricultural soils, and that artesian wells are still functioning there, confirms the existence of large underground water reservoirs and leads us to believe that the plastoponic method may have excellent use potential in these areas.

There are at present no lack of plans to reconquer old agricultural lands, or even more than that, to turn sterils desert into fertile agricultural land. However, these projects are all aimed in one direction, i. e. the production or precurement of sufficient water reserves. The question of better water handling and preservation, as well as the problem of converting sterile, sandy soil into fertile plow land remains unanswered. Nevertheless, a structural change methode adaptable to the desert soil would make possible a implement large scale program for the restoration of unfertile areas.

The largest land reserves are located primarily in sandy areas, in the Steppes and the Savannahs. It is worthwhile to enumerate them here, so as to obtain a pic ture of these vast reserves.

Africa: The rims of large forests in the north and south, areas of Abyssinia, large parts of northern Sudan, Somaliland, and of southeast and the southwest (Kalahari).

America: Southern Brazil, northern Argentina (pampas), southernArgentina, the plains and the prairies from Mexico through the U.S. A. to Canada, the northern gulf of California, and adjoining areas in Texas, Arizona and New Mexico.

Asia: Sections of Asia-Minor, Arabia, Iran, Iraq, Afghanistan, west of the Caspian, to the Indus, and from the Caspian sea to China, the highlands of Tibet, China.

Australia: The middle and southwesterly parts, eastern Australia, all of the east.

Europe: Eastern and southern Europe

Conservative estimates show that the Sahara, alone, could supply six billion people with 25o grams of bread daily, if only 5% of its huge area were to be converted into useful plough land.

While plans are being made with regard to how agricultural production can be introduced to semi-arid areas, man, out of ignorance and a lack of understanding, continues to destroy the soil that could support him. This damage is often irreparable. The burning or clearing of forests for plow land, over-exploitation of forests by industry and the destruction of trees by animals in arid zones, to metion only the most common errors, have, in the course of hundreds of years, significantly increased barren and desert land areas, consequently causing **considerable** reduction in the agriculturally usable surface of the earth. In the desert and semi-desert, deterioration advances steadily. The wandering nomads, in their search for fire wood, spare neither tree nor bush. Herds of animals that, in certain cases, are not even economically exploitable, are often kept only for the prestige of the owner. These herds destroy the few green plants that are left; goats not only eat leafy plant growth, but also devour the roots of the plants. The camel has a special predilliction for young trees and destroys them quite efficiently.

In rainforests, one method often used to fertilize the soil is the burning of vegetation. However, after only two years, the plant nutrient thus gained for the soil is exhausted. This necessitates further deforestation, and the cycle is repeated until finally only depleted soil remains.

The methods proposed and predicted in 1959 for the reclamation of arid lands, are accepted today, especially in view of the fact that humus, which stores water and plant nutrients, cannot be transported to these remote desert areas. First, the transportation costs would be staggering, and secondly, the sun would destroy the soil bacteria and dehydrate the soil too rapidly.

Experiments with Plastsoil in Saudi-Arab a

In cooperation with the Mannesmann-Regner Corporation in Duesseldorf, we performed the following experiments during 1962. From these experiments, we hoped to obtain information about the performance of Plastsoil under extreme climatic conditions. The primary consideration was the water-retention of Plastsoil. The following plants were planted:

a) sugar beets,

b) melons,

c) clover, of the Alexdrian variety.

The test area for a) and c) was 9 m^2 each and for b) 2ooo m^2. In addition 2oo citrus trees were planted with Plastsoil and 2oo specimers under normal conventional conditions. The soil was of high density, clay and sand.

Application technique:

The test areas a), b) and c), were foamed with plastsoil at the Thickness of 3 to 4 cm and subsequently covered with 1o to 15 cm of the clay earth.
In the holes to be planted with citrus trees, Plastsoil was foamed directly into the bottom of the hole. The plant

holes were dug in the conventional manner, namely 4o x 4o x 4o cm at the bottoms of these holes a 5 cm Plastsoil layer was foamed in the form of a dish, thus providing a better receptacle for water. The trees were planted one week after the application of Plastsoil.

The areas treated with Plastsoil were watered every 2o days, with 6,5 liters water/m^2. After 2o days, during which the temperatures reached 45°C (113°F) in the shadow, the Plastsoil still contained 2,6 l/m^2. The Plastsoil that had been compressed by tractor tracks contained 1,8 l/m^2.

<u>Results:</u>

The tests on Groups a), b) and c) were done twice in an 18 mo period. The three groups showed a normal and healthy growth. The citrus were obviously intended as a permanent planting; so planting was not repeated. 5o % of the control citrus died by the time the third leaf appeared. The root development of the trees growing in Plastsoil was excellent - they showed more root branches than the ones planted under conventional Conditions. 95 % of the citrus trees planted in Plastsoil flourished, whereas only 5o % of the other ones survived.

The director of the experiment reported as follows:

" A higher rate of germination seemed to me to be the most important success of the experiment. Plastsoil prevents hardening of the earth and facilitates the germination of seeds (plastsoil as peat moss replacement). Plastsoil, which had absorbed 1o times its own weight in water,

was covered with 15 cm of sand during the month of July, when average temperatures during the day were 42°C (1o7°F) After 1o days, Plastsoil still contained 4 times its own weight in water, whereas the earth not treated with Plastsoil was completely dry.
Therefore to consider the use of Plastsoil for improvement of soils and especially as a water reservoirs seems to be fully justified. It also seems to be certain, that by using Plastsoil, large areas can be irrigated and thus provide addtional sources for agricultural exploitation."

Plastsoil as a substitute for peat moss and compost.

In the Soviet, ammonia, alcohol, organic acids, and other products are derived from the gassification of peat moss. Peat moss contains twice as much nitrogen as stable manure. However, the greater part of the nitrogen contained in peat moss is not available to plants; but the phosphate and potassium content in stable manure is approximately ten times higher than in peat moss. Therefore, peat moss is not a fertilizer, but rather a soil structure improvement medium. It decomposes more slowly than stable manure, thus loosening the soil and improving aeration and draimage.

German Peat moss reserves are estimated to be about ten billion tons. Exploitation of these reserves is difficult because removal of the peat moss is dependent upon good weather conditions. Rising labor costs also contribute to an increase in the price.

The properties of Plastsoil, its ease of manufacture at any convenient site, coupled with the lack of further need for processing, make it an ideal substitute for peat moss.

Decomposed organic matter is called compost. Composting is a duplication of nature's processes that take place in forests, where layer upon layer of leaves decompose to form humus.

In order to be able to compost successfully, the following conditions must be met:

a) sufficient aeration
b) suffiecient moisture.

Plastsoil fulfills these conditions by the nature of its structure. It further enhances the living conditions of aerobic bacteria and prevents the develcpment of anaerobic ones.

Development of Apparatus and Machinery for Plastsoil applications

Om 1948, H. Scheuermann developed an apparatus with which U. F. foam slaps could be produced on a continuous basis. With this device, cellular plastics of synthetic resins an glues, etc. are produced by mixing a watery solution of foaming agent into a foam and thean adding a synthetic resin or glue. The foam thus obtained is extruded in large sheets and and then hardened and dried in suitable curing chambers. Two years later in 195o, H. Scheuermann and J. Lenz introduced an improved apparatus. This improved apparatus was based on a method in which in a mixing chamber, air and a foaming agent are treated until foamy. The mixture ist then fed into another chamder where resins are added. Under further stirring the components are ejected and formed into a shaped artional. Air pressure transports the foam through the apparatures. This method permits the foam to be extruded through various orifices, which form appropriate types of continuous layers.

Various apparatuses were developed during that time, among them an apparatus for production of U.F. foam flakes from freshly foamed material, and an apparatus for the heat fusion of these flakes when powdered. Although these foaming apparatuses were heavier than the apparatus now used, they still were mobile.

In 1953, W. Bauer developed the first lightweight foaming apparatus, with which it was possible to produce U.F. foam at any desired location. This process gained a wide recognition on the insulation market and has been extensively used.

Compressed air is the propellant for this portable foam-producing apparatus, and high velocity air acts a mixer. A foaming agent creates foam in one chamber; it then enters into a second chamber where the resin is added through a wideangle spray nozzle, thus assuring thorough mixing. The contact between the resin and the foaming agent, which contains a catalyst or hardening agent, causes the foam to set and harden in less than one minute. This assures the preservation of a fine microscopic cellular structure.

In September 1955, additional proposals were made for specific mixing chamber configurations. The Bauer apparatus was tested for agricultural purposes at the experimental station Limburgerhof. Based on the results obtained H. Schmidt, in cooperation with the firm Agria, in Moeckmuehl, built a modified standard apparatus for agricultural purposes. This was also tested at the Limburgerhof. Further development of apparatus was then taken over by Chemische Fabrik Frankenthal. Based on the proposals of M. Roeder, the Steel engineering Co. built a catarpiliar powered with a 12 hp diesel, into which a complete foaming apparatus was mounted, including two 3oo-liter containers. This apparatus was field tested extensively.

The Bauer foaming gun has a productive capacity of 1,2 liters foam per second (2,5 cfm), whereas the agricultural foaming guns developed have capacities of up to 12 liters per second; they can be further enlarged if so desired.

Phenol-formaldehyde Foams

Phenolformaldehyde foams are made from phenol-formaldehyde, which, when mixed with a volatile solvent and a hardening agent, foam up to set the foam. Two precesses are known:
cold setting and thermosetting.
These foamed resings are hard and brittle, with a mixed cellular structure of approximately 75 % closed and 25 % open cells. Their specific gravity varies between 4o and 1oo kilograms per cubic meter. Becauce of their predominately closed cell structure, they are not yet suitable for plastoponics.

However, these foams are extremely well suited for flower arrangement blocks, provided that they are mixed and extruded with urea formaldehyde resins. It can then take up to 9o % to 95 % water by volume, thus supplying water to the cut flowers that are stuck into it.

Polystyrene Foams

In this chapter, only the processes of Styropor and Styrofoam will be discussed.
In the first process, Polystyrene beads, containing a liquid volatile propellant are heated to approximately $100^{o}C$ thereby expanding into larger cellular beads. These expanded beads are in turn fused together in a heated mold. This produces a compact, stable foam which conforms to the shape of the mold.

The second process, Styrofoam, uses molten polystyrene expanded with gaseous propellants under normal temperatures. The extruded foam is shaped into slaps on a continuous basis.
During the past few years, BASF, has brought a foamed polystyrene to the market under the trade name of Styromull which was developed at the BASF experimental station at Limburgerhof. This products consists of flakes, 4 to 12 mm in diameter, with a closed cell structure. These cells are capable of loosening and aerating compacted and water-logged soils. The air content of Styromull reaches nearly 98 % by volume. Individual flakes can bind water only on their surface, but are incapable of storing it within their cells. These properties have both a draining and an aerating effect on the soil. Therefore, soils treated with Styromull warm up and thaw out quickly, and are easy to plow and cultivate. Styromull does not

does not rot, which means that its ameliorating effect will last for many seasons It must be plowed under during complete wind stillness in order to prevent drifting. This method of application is well suited for heavy soils, such as limey or clay soil, where 2 to 4 cu m of Styromull produce distinct soil improvements. Experience showed that Styromull did not deteriorate in depths up to 40 cm, and similarly, it did not become water-logged, as did many soils treated with organic substances.

This material is especially applicable in cultivating orchards, to loosen soils where agricultural apparatus traffic has caused compaction. Other applications are in gardening, and in the propagation of cuttings. For example, orchard raising can be simplified and the use of special orchard compost can be eliminated with the introduction of mixtures of Styromull, Sphagnum, and peat moss. However, being mindful that Styromull does not contain plant nutrients, it is necessary to add these either in granular or liquid form. It is also advantageous to mix Styromull and peat moss at a ratio of 1:1; this reduces the frequency of necessary irrigation. The Styromull content prevents water-logging of the substrate. It is interesting to note here that potted plants grown in such peat moss/ Styromull mixtures were not subjected to attack by snails.

Extruded Polystyrene foams are used as cut flower arrangement blocks. It is also possible to make Polystyrene u.f. foam mixtures that could serve the dual purpose of water retention and soil aeration.

Polyurethane Foams

The basic components of Polyurethane plastic foam are polyesters or polyethers, with free hydroxy groups, which are mixed di- or polylsocyanates. Water or fluorinated hydrocarbons in addition to catalysts and hardeners cause the mixture to develop gasses, which are entrained in the material. This creates a cellular foam without the help of mechanical mixing or the application of heat. Depending on the starting materials and their ratios, one can obtain either hard or sofr foams, with densities ranging from one to sixty pounds per cubic foot. The soft, flexible foams are partially open celled, whereas the hard foams are more or less closed celled.

Hard urethane foams are very well suited as bases for orchard husbandry. Flaked, soft and hard foam can be used for soil tilth. Comparative tests between urethane, Polystyrene, Plastsoil conducted over several vegetation periods cannot be published at the present time because their evaluation if not yet completed.

Polyvinylchloride foams

PVC foams may be produced without pressure, with low pressure or high pressure. Depending on the method of production, one can obtain foams ranging from soft to hard, with a corresponding range of closed to open cells. Their densities will range from 2 to 7o pounds per cubic foot.

Open celled PVC foams can be used in thin sheets to cover the topsoil. This improves soil bacteria growth and prevents water evaporation. PVC foams are very similar to polyurethane foams; they can be used for floating garden arrangements and as bases for plants raised in Plastsoil. It should be mentioned that highly flexible synthetic foams are not suitable as a root matrix because when compressed, they spring back to their original shape with a force strong enough to tear off and damage root branches.
Development work is presently being done to overcome the hydrophobic characteristics of hard synthetic foams

Mixed Synthetic Foams

It is possible to mix a number of synthetic foams with other organic and inorganic substances to create a plant growth medium. It is possible to mix flaked polystyrene, polyurethane, vermiculite, and fibers for instance, and use them with suitable glues into plant substrates with resilience and good water retention. German patent 1, 221, 484)

Other foamed Plastics

Many other plastics can be made into foam, as for example silicones, acetates, polyamides and polyethylene. However plant physiological data on these foamed plastics is non-existent or very scarce. The development of suitable foaming equipment, logistics, and price plays an important role in the use of foamed plastics in agriculture.

Investments and product costs:

	UF	PF	PU	PS	PVC
Minimum capacity (jato) for a commercial producing	1000	3000	15000	12000	6000
Investments for the producing of the raw materials per 1000 jato ('000 US Dollar)	100	175	325	225	275
Investments for the Equipments 1.000 jato ('000 US Dollar)	10	75	115	200	175
price of the raw materials (US Dollar:kg)	-,40	-,52	-,70	-,30	-,33
convertion cost (Us Dollar/kg)	-,10	-,25	-,25	-,15	-, 20

UF = urea formaldehyde foam

PF = phenolformadehyde foam

PU = polyurethane foam

PS = polystyrene foam

PVC = Polyvinylchloride foam

Looking at these figures it is obvious that U. F. foams as far as the final costing is concerned is definitively ahead of the other materials mentioned. Additionally it has to be noted, that the farm-out of the know how and process technology is comparitively simple since the relative equipment has been in operation for approximately ten years and training facilities are available in Europe and the United States.

Conclusions:

After taking into careful consideration all the facts and findings regarding the use of plastic foams as a soil improving media it becomes obvious that the urea formaldehyde foams technologally and commercially offer properties which could not be obtained at least for time being from any other plastic material.

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