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Why use PAM?
(PAM is polyacrylamide)
Different purposes sometimes require different
application procedures.

PAM stabilizes soil structure:

1. Increases water infiltration (up to 50%).
2. Increases soil aeration and drainage.
3. Decreases water run-off.
4. Prevents crusting and compaction.
5. Stops wind and water erosion (up to 99%).
6. Makes friable soil that is easy to cultivate.
7. Makes soil workable sooner after rain or irrigation.
8. Increases bulk density of soil.

These can translate to:

1. Runoff of sediment containing soil, pesticides, some nutrients, weed seed, and microbes is prevented.
2. Increased crop yields (up to 57%).
3. Decreased water usage (up to 50%).
4. Earlier germination and crop maturity (3 to 20 days).
5. Increased plant size and population.
6. More vigorous plants with more extensive root systems.
7. Greater response to fertilizers and amendments (33% or more).
8. Increased value from added organic matter.
9. Less plant disease related to poor soil aeration.
10. Decreased energy requirements for tillage.
11. Enhanced quality of produce.
12. Decreased dust down to near zero.
13. Decreased adverse effects of sodicity.
14. Soil salt easier to leach from soil.
15. Near 100% success in tree and shrub transplanting.
16. Root crops harvest cleaner.
17. Clay soils are easier to manage.

Financial value of PAM can be several times the cost of treatment. As high as 25 times have been reported and around 10 times is very common.

Why use the Micronized form of PAM? (small particle sizes)

1. It goes into solution almost instantaneously depending on particle size.
2. When used dry, there are more particles mixed into a pound of soil.
3. When made into a slurry it is more potent than when put into various solutions.

Some ways to use PAM and Micronized PAM

1. In irrigation water- sprinkler and furrow irrigation.
2. Tilled into soil.
3. In a hydroseeder.
4. On seed.
5. With anhydrite gypsum.
6. With fertilizer solution.
7. In drip irrigation.
8. In transplant holes.

What are PAM and Micronized PAM?

PAM or polyacrylamide is a polymer meaning that several simple molecules are joined together to make a long chain of them. Examples of polymers in nature are starch and proteins. Microbes produce polymers called polysaccharides that function in soil to improve the ability of plants to grow in soil. PAM is much more effective than polysaccharides. PAM is a mixture of two simple molecules combined so that about 200,000 of them make one long molecule. It is a copolymer because of the two different kinds of simple molecules that are used. Micronized
PAM is a very small particle size of PAM in micron size of 28 to 150 microns.

Those currently involved at Wallace Laboratories and those previously at (Arthur Wallace's laboratory at UCLA (1949 -1989) started using Krilium, the ,precursor of polyacrylamide (PAM), in the early 1960s. We soon learned of its potential value if used correctly. Our group was perhaps the only one that used nursery plant production. This was possible because of a large supply of Krilium that had become available when the manufacturer, the producer Monsanto, stopped marketing it. In 1960 Krilium as a soil conditioner was too costly, too hard to use, and inconsistent. In the early 1980s, things started to change rapidly with abundant ,production of polyacrylamide abbreviated PAM. Many uses of PAM in agriculture had been developed for its use prior to 1980 especially in Europe.

Most spectacular of recent developments is the finding that such small quantities of PAM can do so much good. Water-soluble PAM conserves water supplies in several different ways. It results in more crop yield for a given supply of water so that the water needed for l unit of crop is less.

Turf that has been planted in soil previously conditioned with water-soluble PAM often needs only half as much irrigation water as some turf with I conventional planting procedures. Runoff is prevented. Roots use the full tillage depth. The grass is healthier. Even fertilizer use is more efficient. A lawn started eight years ago with water-soluble PAM and organics is still bouncy and has never needed aeration.

Use of water-soluble PAM in field agriculture is not prohibitively expensive. A potato grower in Washington State applied three pounds per acre to a potato field through a center-pivot irrigation system. Material costs were less than $15 per acre. The advantages as always were multiple. The yield increase was over six tons per acre. Water efficiency was increased. Potatoes graded higher. Less fertilizer was left in the land at harvest time to leach to groundwater. There was no soil erosion. This farmer gained around $400 an acre in addition to the environmental values for the $15 per acre invested.

Water-soluble PAM can even help slow down the global greenhouse warming. The carbon dioxide level in the atmosphere is increasing at a rate of , about one percent per year. The major sources of the extra carbon dioxide are; loss of soil organic matter, burning of fossil fuels, industrialization, and n deforestation. As no surprise, trees planted with water-soluble PAM in the transplant holes have survived at a rate of near 100 percent and have grown from two to four times faster in the first year than trees not treated. Cost can be much less that one penny for a small tree which is economical anywhere in the world.

Movie actor Eddie Albert claimed that use of water-soluble PAM added 50 to 100 pounds additional weight to each of his giant pumpkins. This allowed him to win first prize for largest pumpkin in Sonoma County California more than once.

Yields of strawberries were doubled when a soil moderately high in clay was conditioned with water-soluble polymer. The same grower used the PAM in a water-sprinkling truck to settle dust on his farm roads to keep dust off the strawberry plants. One pound was used for each thousand gallons of water. Less can be effective and gypsum should be applied simultaneously.

Carrots on a high-clay soil were twice as long when soil was treated with the water-soluble PAM. Beets, beans, tomatoes, com and other crops also responded vigorously.

In western states in the past few years, over a million of acres have been treated with water-soluble PAM to decrease erosion in irrigated furrows. Two or fewer pounds per acre prevent over 90 percent of the erosion.

TOXICITY FROM POLYMERS (PAM) NOT LIKELY

The water-soluble PAM in use for soils today, at least by us, is food grade (Wallace and Nelson 1986). All comply with the legal maximum limit of less than 0.05 percent of monomer acrylamide (Seybold 1994). Similar products are used by municipalities in water purification and by food industries to remove turbidity from fruit juices. Water-soluble PAM degrade slowly mostly by physical means (Seybold 1994) in soil to harmless carbon dioxide, water and ammonia. It does take years for the breakdown to be complete so that there is some carry over from year to year in beneficial effects. For most agricultural uses, however, treatments need to be made annually, unless soil is massively improved.

Differences and Similarities Between Cross Linked Polymer Gels For Water Absorption And Linear, Water-Soluble (PAM) For Enhanced Soil Properties

The two different types of polymers used in landscaping and horticulture may cause confusion (Complete Green ·Co. 1987). Unfortunately, there is confusion about each. Water absorbing, gel forming polymers, commonly known as super slurpers, are an aid for increasing water holding capacity of sandy soils on well drained synthetic potting media which do not have the ability to hold as much moisture as the loam or clay soils. The advantages of the gel polymers are that they reduce the frequency of irrigation and the available soil moisture becomes more constant. A more constant supply of soil moisture will help encourage good plant growth. These super absorbing polymers are manufactured from similar materials as are the water-soluble polymers used for soil improvement. The gels store water in soil and, in contrast, the water-soluble polymers bind soil particles for structural soil enhancement. For gels, the polymers are bridged between adjacent molecules and are thus cross-linked to make them insoluble so that they act like sponges. They absorb 50 to 400 times of their weight in water depending on purity of water. These super slurpers are also used at the rate of 200 million pounds annually for consumer products such as baby diapers and related products. Because of the large manufacturers seeking to increase their sales, many brands of water absorbing polymers exist in the landscape.

The water-soluble linear polymer (PAM) is a long single chain with an enormous number of repeating units. These polymers are designed to bind together thousands of soil particles and form a lattice work in and around soil crumbs. In time, this polymer also becomes water-insoluble in the soil. The function of the soil-enhancing polymer is not to absorb water - rather the function is to stabilize cultivated soil by maintaining soil in a loose and friable state; the ;oil particles become "water-stable."
Lastly, the available soil moisture reserve for plants is proportional to the depth of the roots. Turf rooted to a six-inch depth can have 6 times the moisture reserves as turf rooted to a one inch depth. In lieu of a daily irrigation requirement, deeply rooted plants can be watered weekly or even less frequently. Since roots do not grow deeper than where oxygen can penetrate, plants will not root deeply in dense soils. Good soil structure, concomitant with aeration, low bulk density and porosity, needs to be maintained. The best technique for creating good soil is through the use of soil enhancing linear polymers, the best of which so far is PAM. The function is to enhance physical properties of soil.

The gels or cross-linked polymers do have some useful purposes but soil conditioning is not one of them.

Gypsum is Almost A Universal Soil Enhancement

Agriculture has failed to be sustainable several times in the History of the world-because of soil failure (Rush, 1987) thousands of years ago. Irrigated land eventually leads to sodicity and salinity unless extreme care is taken. Gypsum is a key ingredient for the maintenance of agriculture on many types of soils and over a wide pH range including sodicity. Waste-product gypsum is available in a large number of locations at very little or no cost. Advantages of gypsum in addition to prevention and correction of sodicity include greater stability of soil organic matter, more stable soil aggregates, improved water penetration into soil, and more rapid seed emergence. The need for gypsum In amounts varying from small to large is almost universal. Gypsum, water soluble polymers, and organics magnify the value of each other. Together they have an important role in making a better environment, especially for growing plants.

Gypsum is calcium sulfate. The most common form of it is the dihydrate which means that each molecule of calcium sulfate has two water molecules associated with it. It is expressed as CaS04 . 2H20. The plaster of Paris used commercially has only one-half water and another form called anhydrite gypsum has no water. Much of the gypsum used in agriculture is mined and then pulverized to desirable particle sizes. The smaller sizes go into solution more rapidly than do large sizes. Gypsum is also a by-product of various manufacturing operations. Gypsum and PAM together result in much soil improvement.

Gypsum Improves Soil Structure.

Gypsum Helps Reclaim Sodic Soils.

Gypsum Prevents Crusting of Soil and Aids Seed Emergence.

Gypsum Improves Low-Solute Irrigation Water.

Gypsum Improves Compacted Soil.

Gypsum Makes Slightly Wet Soils Easier To Till.

Gypsum Stops Water Runoff and Erosion.

Gypsum Decreases pH of Sodic Soils.

Gypsum Increases the pH of Some Acidic Soils.

Gypsum, Improves Swelling Clays.

Gypsum Prevents Water Logging of Soil.

Gypsum Can Help Remove Excess Boron from Sodic Soil.

Gypsum Increases the Stability of Soil Organic Matter.

Gypsum Makes Water-Soluble Polymer Soil Conditioners More Effectiv

Gypsum complements or even magnifies the beneficial effects of watersoluble polymers used as amendments to improve soil structure (Wallace and Nelson 1986). Like for organic matter, calcium coming from gypsum is one of the mechanisms for binding of the water-soluble PAM to the clay.

Gypsum Makes Excess Magnesium Non-Toxic.

Gypsum Corrects Subsoil Acidity.

Gypsum Can Further Enhance the Values of Liming.

Gypsum Improves Water-Use Efficiency.

Gypsum Creates Favorable Soil EC.

Gypsum Makes it Possible to Efficiently Use Low Quality Irrigation Water.

Gypsum Decreases Dust Erosion.

Gypsum Helps Plants Absorb Plant Nutrients.

Gypsum Decreases Heavy-Metal Toxicity.

Gypsum Increases Value of Organics.

Gypsum Improves Fruit Quality and Prevents Some Plant Diseases.

Gypsum is a Source of Sulfur.

Gypsum Helps Prepare Soil for No-Till Management.

Gypsum Decreases Bulk Density of Soil.

Gypsum Decreases the Toxic Effect of NaCI Salinity.

Gypsum Multiplies the Value of Other Inputs.

Gypsum Can Decrease pH of Rhizosphere.

Gypsum Helps Keep Clay Off Tuber and Root Crops. .

Gypsum Decreases Loss of Fertilizer Nitrogen to the Air.

Gypsum Can be a Source of Oxygen for Plants.

Gypsum Helps Earthworms to Flourish.

Gypsum Can Increase Water Retention in Soil.

Gypsum Can Decrease the Incidence of Soil-borne Plant Diseases

Gypsum Can Improve Plants that are Suffering From Iron Chlorosis Deficiency Caused by Bicarbonate

Gypsum Makes Use of Iron Chelates More Effective

Gypsum Can Increase Heat Tolerance in Plants

Gypsum Can Enhance the Rooting of Some Woody Species in Nurseries.

Gypsum Can Increase Crop Yields

Gypsum Can Be Included with NPK Fertilizers

Will Your Soil Be Responsive to Gypsum?
Yes, if
(a) soil pH is over about 8.2 and maybe even if it is less
(b) ESP is over 3 and definitely if it is over 9
(c) Water puddles on it
(d) The particles slake or disperse when added to water
(e) The subsoil pH is lower than 5
(f) There is water logging In the soil
(g) There 1S a crust on the soil after a rain or irrigation
(h) There is excessive cracking of the soil after rain or irrigation
(i) The soil contains clay that is hard or dusty when dry
(j) Irrigation water contains substantial amounts of bicarbonate, however, beware of caliche forming in the subsoil
(k) intense rain falls on soil and where all solutes may be leached from the soil surface
(l) No-till is used.

Reasons For Applying PAM (Water-Soluble Polyacrylamide) And Gypsum Together In Irrigation Water

1. Both increase water penetration into soil and together they do it better than either alone.

2. Both decrease soil erosion from water and together they do it better than either alone.

3. Both can increase crop yields and together they do it better than either alone.

4. Together they can decrease soil crusting or sealing so that better seed emergence results.

5. The earlier seed emergence and initial good start with both together can enhance crop maturity by several days to give a better chance to reach early market.

6. Leaching of sodic soils can be more efficient with both together than with gypsum alone.

7. Gypsum helps PAM to bind to clay and the calcium in gypsum helps bind soil organic matter to clay. Synergism can be involved

8. Both together can result in better aerated soil so that plants root grow deeper to give better water-use efficiency and to allow roots to explore a larger volume of soil for nutrients.

9. Both together partially compensate for not having enough soil organic matter and, when some organic amendments are available, both together can enhance the value of organics .

10. Both together protect farmland from strong winds which create nuisance dust and loss of soil.

11. Both together make use of effluent water more successful.

TWELVE WAYS THAT WATER-SOLUBLE POLYACRYLAMIDE CAN INCREASE WATER-USE EFFICIENCY (Wallace 1991)

Some sobering facts we have to live with that require increased water conservation:
1. California and other western states often have many consecutive years of drought, and there is no guarantee that any year won't be another.

2. Urban growth and industrialization have been so great in California and some other states that there may never again be sufficient water for the liberal uses to which most westerners have become accustomed. However, the problem is not confined to the west.

3. There is a growing realization that some past water practices may not be conducive to best long-term interests and quality of life.

4. Cost of water for all users will increase dramatically in the coming years. Two- and three-fold increases are expected. Any desalinization will cost about five times current water prices; that is not an option until cost of energy decreases dramatically.

5. As irrigation levels are decreased for a given parcel of land, salt accumulation in soil will become an increasingly important and troublesome problem.

6. It will be necessary in the future to use more and more reclaimed waste water for irrigation of landscape and field plantings.

Soil preparation with a water-soluble polymer (a co-polymer of polyacrylamde, WS-PAM) material and preferably with 'a modest amount of organic matter and gypsum creates a stable soil that is permeable to water and is very easy to cultivate. With soil so prepared, it is possible to efficiently get by with half or less as much irrigation water in landscapes.
Caution: WS-PAM is not the same product as the superabsorbent polymer gels which swell up and deliver stored water to plant roots. We are talking about a much different technique. WS-PAM does not swell in the presence of water; instead, WS-PAM creates a much better soil.

Twelve ways in which WS-PAM can help save water are:

1. WS-PAM reacts with the clay in soil and with synergistic effects with soluble calcium and organic matter in soil to give water-stable soil particles which do not crust after an irrigation. Water then runs into the soil instead of off it into streets and gutters or tail water and elsewhere. Also, a larger percentage of rain water will move into the soil instead of flooding away when prepared with WS-P AM.

2. Roots will grow deeper into soil well prepared with WS-PAM and, therefore, plants use water nore efficiently. With deep rooting, there can be longer periods between irrigation which means less loss of water to the air that result from evaporation with frequent irrigations.

3. The crumbly mulch on the surface of soil prepared with WS-PAM decreases the evaporative loss of water from soil. Soils become tillable or plantable sooner after a rain or irrigation to reduce water loss by evaporation for several days before a crop is planted.

4. Turf grown over soil prepared with WS-PAM is less likely to form a thatch because the roots need not growth above the soil surface as happens over hard, compacted soil. There is no or little thatch then to be a deterrent to water penetration.

5. Soil prepared with WS-PAM or even application of WS-PAM with the first irrigation at the time of planting can prevent crusting of the soil surface so that extra irrigations will not be necessary for seed emergence.

6. Where soils contain clay that swells in the presence of low solute water, like rainwater, soil preparation with WS-PAM and gypsum will permit satisfactory water penetration. WS-PAM can protect the integrity of cracks in soil to improve water penetration.

7 . Soil preparation with WS- P AM on slopes will better permit applied water or rain water to penetrate into the soil before water runs off.

8. Where salts and sodium are soil problems, treatment and leaching are more easily accomplished and with less irrigation water when soils are prepared with WS-PAM.

9. Use of WS-PAM makes it possible to more easily use reclaimed waste water for irrigation without causing compaction of the soil. The WS-PAM also makes it possible to more efficiently use any low-quality water for irrigation. Application to newly tilled or cultivated soil is necessary.

10. Use of WS-PAM as a light drench can effectively control dust so that less water is used for dust abatement on fallow land or on some farm roads.

11. Faster growth with closing of the canopy with WS-PAM treatment means less evaporation of water from the soil surface.

12. Increased yield means that less water was used per unit of plant produced.

Other material benefits from use of WS-PAM are:
1. Near 100 per cent survival of tree and shrub transplants.
2. Improved plant growth; greater yields of fruits and vegetables.
3. Less lime-induced chlorosis (less iron deficiency).
4. Greater efficiency in use of fertilizers~ less need to be added.
5. Soils easier to cultivate~ weeds easier to remove.
6. Soils can be cultivated sooner in the springtime or after a rainstorm.
7. Earlier seed emergence means earlier crop maturity in gardens or farms.
8. Better aerated soil means fewer soil-borne plant diseases.
9. Soil erosion is virtually stopped.

How long will a treatment last?
Levels of WS-PAM used in landscaping will generally last for many years. Water-soluble polymer placed under turf should last indefinitely. In tilled areas, such as groundcover and annual areas, a modest amount of additional WS-PAM may be reapplied every year because breakdown rate under cultivation is about ten per cent per year. In field agriculture, levels used are for one crop season only.

REASONS FOR USING WATER-SOLUBLE POLYACRYLAMIDE IN SOIL PREPARATION, ESPECIALLY FOR TURF

l. Better aerated soil means deeper rooting, better water penetration, more efficient use of nutrients.

2. Deeper rooting of plants means greater water-use efficiency and less chance for nutrients to escape to ground water.

3. Treated soils have less compaction to give fewer aeration problems. They do not remain overly wet after rain or irrigation.

4. Anaerobic conditions with production of toxic substances from decay of organic matter, sulfates and nitrates do not develop under treated conditions.

5. Fewer soil borne microbial diseases occur. Plants are healthier.

6. Initial success of the planting is virtually assured whether planting is from seed or from sod.

7 . Irrigation with reclaimed water or low quality water is more easily accomplished.

8. Protection against thinning of the turf and from subsequent soil erosion is obtained.

9. The turf will successfully last for many additional years.

10. Clay, sodic and other harsh soils can be successfully developed for turf.

11. Avoid failures that result in costly redos.

12. Maximize the value of the soil which is available.

13. Enhance the value of the organic amendments used.

14. To make bad soil good and good soil better.

Notes: ,The water-soluble polyacrylamide is best used together with gypsum (and lime if necessary) and with some source of quality organic matter. Use of water-soluble' polyacrylamide for starting turf is very economical.