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Additives to Enhance Seed Quality & Field Performance

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ADDITIVES TO ENHANCE SEED QUALITY & FIELD PERFORMANCE

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During previous discussions, we have heard of the different aspects and approaches necessary to determine seed quality. As we continue through this and the remaining discussions, these shared fundamentals of seed quality can be utilized in seed production, conditioning, storage, and marketing. As a society becomes more technologically based, there are many basic guidelines that are often forgotten and/or regarded with less importance than is necessary. This may be the case with seed quality; therefore, the basic parameters discussed throughout this, the 36th Short Course For Seedsmen, become essential to enable a company to be recognized as a marketer of quality seeds.

Seed quality is at its highest level when the seeds have reached physiological maturity. Once metabolic deterioration begins, it is irreversible and can only be arrested. At this point, factors become additive and may easily increase the decline in potential seed performance to sub-standard levels. The micro- and macro-environment of the seeds at this point can influence overall seed performance and seedling development.

The micro-environment (on or within the seeds) of the seeds can vary dramatically from one seed to another even within the same seed lot. I could use the remainder of my allotted time discussing this issue alone, but will summarize this by identifying in general the factors which may influence quality alone or in various combinations.

Microenvironmental Factors

* Seed coat (Testa) damage (causes - mechanical, insect, genetics, weathering, drying, etc.)
* Seed-borne diseases (bacteria, virus, fungi) (external and/or internal)
* Seed-borne insects (external and/or internal)
* Dormancy (genetic, physical, and/or physiological)

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The micro-environmental factors can be the simplest and often the easiest area to address with corrective measures to maintain seed quality. Many of the factors are inherent with the seed type and/or varieties being produced. This is an area that many plant breeders often do not address in the initial steps of varietal development and, thus, can lead to many disappointments when a new release is placed into production hands. This is true when a variety is selected to be produced in a specific geographical area and then carried into a totally different area for production. Seed coat damage and susceptibility to seed-borne diseases and insects can be greatly increased, thus lowering the seed quality. It is essential that one consider the agronomic parameters of the variety prior to the initiation of seed and/or crop production. This point is illustrated by two recent new crop entries - the super-sweet, sweet corn hybrids and canola (oil rape).

The super-sweet, sweet corn varieties are extremely low in vigor because of genetic and physiological reasons. In addition, the importance of both the micro- and macro-environment in relationship to the inherent low viability of these inbreds and hybrids becomes apparent. Even under optimum conditions for emergence, the percent survival is often very marginal and less than optimum. Post-emergence damping-off is very common as a result of <u>Penicillium</u> <u>spp</u>. and <u>Fusarium</u> <u>spp</u>. systemic infections. New seed treatments have demonstrated exceptional efficacy against these diseases. The introduction of new technological breakthroughs in seed priming and biological additives are being investigated to determine if these may also provide protection in getting these preferred sweet corn varieties to the consumer at a reasonable cost from the grower.

Canola for oil production is being expanded in the U.S. This crop is viewed as an alternative crop to small grain, sunflower, sugar beet, and soybean production in many areas of the country. Since the crop is new, no chemical tolerances have been approved for this crop by EPA that will allow immediate use in the herbicide, insecticide, and/or fungicide areas. Having a basic understanding of production in other areas of the world; for example: Canada, Europe, and Russia, we know that the potential for attack by seed and seedling diseases and insects is great. Therefore, it will become very important to establish chemical tolerances in the immediate future so that varietal yield potentials can be adequately addressed. Only until we are able to address the genetic and chemical interactions, can we determine what will be required to maximize production.

The macro-environmental influences represent, in most cases, the most significant impact on the potential of the seed to perform at its maximum level. The seed, upon planting, is placed in a very hostile environment which can dramatically influence the enzymatic and physiological development within the critical 0-72 hours germination period. These influences may be generalized as follows:

Macro-environmental Influences

* Soil temperature (too high or too low)
* Soil texture, chemical balance, & pH
* Soil moisture (too high or too low)
* Planting depth & plant populations
* Soil compaction

From a seed-additive viewpoint, this is the area that presents the largest number of variables. This vast number of variables make it impossible to prescribe a simple procedure to guarantee optimum performance under the full range of macro-environmental conditions. We have seen through USDA and individual state research that production models have been devised which profile cultural and production schemes that address the geographic macro-environmental influences for each production area. Information is available for most crops on planting dates, soil temperature ranges, planting depth and plant density/acre or foot of row, herbicide and insecticide requirements, and fungicide use. Above all, the emphasis on maximum seed quality and recommended seed treatments normally tops the list of these recommendations.

With this introduction to the world of a seed, we will now discuss some of the additives that are presently available to be utilized in maintaining seed quality and optimizing field performance. Seed additives can be categorized into four groups. These are as follow: (1) genetic, (2) chemical, (3) physical, and (4) biological. No single additive represents the ultimate in addressing the issues of the micro- and macro-environmental influences; therefore, these have to function collectively and in concert with each other. For discussion purposes, I will address these individually and will summarize by bringing these all into perspective.

Genetic Additives

Conventional plant breeding for desired traits; for example: yield, disease and/or insect tolerance or resistance, maturity, and product quality has in the past (7-10 years) been slow and very expensive. With the development of tissue culture and somatic technologies, this process will be significantly reduced. Within the very near future, new plant forms and types will become very common place; for example: oil producing crops that can be genetically engineered to produce specific types and quantities of specific grades and types of edible oils, and crops that produce and yield high levels of protein. The future for food, fiber, and natural fuel production is exciting and will dramatically affect agriculture in the 21st Century. The seeds for many commodity crops will become more valuable and expensive to the end user.

Chemical Additives

Chemicals have been utilized on seeds intentionally since the early Seventeenth Century. For some crops, the need for chemical use is not recognized as being important. This is true for those crops that represent a cheap commodity and, therefore, planting rates can be compensated to provide adequate plant populations. The benefits of seed treatment fungicides and insecticides have been documented through the years and for most crops yield improvements are common. The return-on-investment in favor of seed treatments has been calculated to be one of the highest of any practice a grower can utilize. This has been observed through the years and will become more evident as we see the increased use of minimum tillage and soil conservation and as these become more commonly accepted. With these practices, the opportunity will exist for increased pathogen and insect carryover on crop residues and subsequent attack on the seeds and developing seedlings of the new crop. The use of control agents for the hostile macro-environment will become more commonplace for many crops. A significant change in cultural practices (conventional tillage versus minimum tillage) will also significantly affect other areas of production; for example: planting dates, herbicide programs, planting depths and row spacing, and selection of the crops planted.

Many products have been utilized through the years as seed additives. Single chemicals provide activity on a limited basis; therefore, most products provided to the grower are combinations of two or more of these chemicals. In some crops, as many as five to six individual chemicals are used. Tables 1-9 list the various chemical compounds presently registered for use. These have been listed by category of activity and for product selection. Contact the respective manufacturer or a Gustafson representative for information.

There is concern throughout the chemical industry regarding the implementation of the EPA re-registration policies for all existing chemical registrations. Each product will have to undergo testing under GLP (Good Laboratory Practices) and have the many new tests required for new products coming in for registration. This is quite significant for many of the seed treatment chemicals as most products are 20-30 years old, have gone off patent, and will require $3 to $4 million of investigation. Due to the market value of this area and the small market percentage that each of the products have, in some cases the expense is too great making it unrealistic to have

Table 1. Protectant fungicides.

Compound	Technical Source	Crops	Spectrum of Activity
BOTRAN®	NORAM	Peanuts	Rhizopus, Aspergillus
Captan	ICI Chevron	Most crops	Broad spectrum seed and soil-borne diseases
Heavy metal fungicides and bactericides (coppers)	Kocide	Most seed types	Seed-borne blights, broad spectrum soil diseases
Maneb & related zinc mixtures	Pennwalt Rohm & Haas	Most crops	Broad spectrum
TERRAZOLE®	Uniroyal	Cereal grains, cotton, sugar beets, turf	Broad spectrum, Rhizoctonia
Thiram	Gustafson Uniroyal Pennwalt	Most crops	Broad spectrum, seed and soil-borne diseases

Table 2. Local systemic fungicides.

Compound	Technical Source	Crops	Spectrum of Activity
DEMOSAN®	Kincaid	Cotton, edible beans, soybeans	Rhizoctonia, Sclerotium
1 prodione (EPIC FL)	Rhone-Poulenc	U.S. registrations turf, ornamentals	Broad spectrum, does not control Pythium
TERRACLOR® (PCNB)	Uniroyal	Cereal grains, most crops	Bunt Rhizoctonia Rhizopus

Table 3. True systemic fungicides.

Compound	Technical Source	Crops	Spectrum of Activity
ANCHOR™	Sandoz	Registration pending	Similar activity as APRON®
APRON®	Ciba-Geigy	Most crops	Pythium Phytophthora Downy mildew
BAYTAN®	Mobay	Small grains (registration pending on small grains and corn)	Smuts, bunts, leaf rusts, take-all suppression; corn head smuts
BENLATE®	DuPont	Crucifers	Black-leg
IMAZALIL®	Janssen	Cotton Barley Wheat Sweet Corn	Thielaviopsis Verticillium Helminthosporium Penicillium spp.
MERTECT®	Merck	Wheat Soybeans	Dwarf bunt Common bunt Fusarium Phomopsis
TOPSIN®-M (TOPS 2.5% Potato Dust)	Pennwalt	Potatoes	Rhizoctonia Fusarium
VITAVAX®	Uniroyal	Cereal grains Cotton Rice Corn Peanuts Soybeans Edible beans	Smut of cereals, Rhizoctonia Helminthosporium Phomopsis Fusarium

Table 4. Bacterial seed treatments.

Compound	Technical Source	Crops	Spectrum of Activity
Streptomycin	Pfizer Merck	Edible beans Potato	Halo blight of beans Bacterial decay

Table 5. Contact insecticides.

Compound	Technical Source	Crops	Spectrum of Activity
ACTELLIC®	I.C.I.	Seed and edible grains, pending	Storage insecticide
Diatomaceous Earth	Mined silicates	Exempt from registration	Primary storage insects
DIAZINON®	Ciba-Geigy	Edible beans Peas Sweet corn Field corn	Soil insects Seed corn maggot
Lindane	Rhone-Poulenc	Several grain and vegetable crops	Soil insects such as wireworm, seed corn beetles and maggots
LORSBAN®	Dow	Cotton Edible beans Sweet corn Field corn	Soil insects Seed corn maggot Seed corn beetles
Malathion	American Cyanamid and others	Seed and edible grains	Storage insecticide Lepidoptera, short residual
Methoxychlor	DuPont and others	Most seed	Storage insecticide Coleoptera
Pyrethrums	Natural occurring plant extracts	Grains	Storage insecticide short activity
RELDAN®	Gustafson	Seed and edible grains	Storage insecticide long residual at 6ppm

Table 6. Systemic insecticides.

Compound	Technical Source	Crops	Spectrum of Activity
DI-SYSTON®	Mobay	Cotton	Post emergent insects, aphids, thrips, mites
ISOPHENFOS®	Not disclosed	Experimental	Wireworms, seed corn maggot at low rates
MAGNUM™	Rhone-Poulenc	Experimental Many crops	Nematodes, cutworms corn root worms, wireworms, fall armywormns, and seed corn maggot and also a PGR (Plant Growth Regulator)
ORTHENE®	Chevron	Cotton	Aphids, thrips, cut-worms

Table 7. Biological seed treatments.

Product	Technical Source	Crops	Spectrum of Activity
DIPEL® (Bacillus thuringensis)	Abbott	Several grains	Storage insecticide Lepidoptera
PGPR (Plant Growth Promoting Rhizobacteria)	Allelix	Canola Cotton Peanuts Sweet corn	Beneficial PGR effects on developing seedlings
QUANTUM™ 4000 (Bacillus subtilis)	Abbott	Peanuts	Rhizoctonia Fusarium
Rhizobia Inoculants	Several	Small seeded legumes and soybeans	Nitrogen fixation

Table 8. Herbicide safeners.

Compound	Technical Source	Crops	Spectrum of Activity
CONCEP II®	Ciba-Geigy	Sorghum	Safeners against Herbicide DUAL
SCREEN	Monsanto	Sorghum	Safeners against Herbicide LASSO

Table 9. Miscellaneous seed treatment applications.

Function	Compound and/or Application
Growth Regulants	GA3; natural enzymes and auxins
Herbicides	Eptam on alfalfa
Osmotic Conditioning	LPP-Liquid Phase Priming SMP-Solid Matrix Priming
Seed Coating	Microfilm polymer coatings
Seed Pelleting	Clays and other inert systems
Trace Elements	Sodium molybdate on soybeans; zinc compounds on rice; starter fertilizers; calcium

the investigations carried out. Therefore, in the near future we will see some of the uses for many of these products withdrawn and in some instances the use of the chemical will be lost completely. To assure that seed additives are available, research of possible replacements (both chemical and biological) is being carried out. This also involves many other disciplines; for example: osmo-conditioning (priming) and equipment development. Extensive investigations are being conducted to determine whether physical and biological manipulation of the seeds can alter the need for using chemical additives.

Physical Additives

Through the years, we have known that by physically altering the seed coat we can overcome specific limitations in seed performance. In cotton, we expose the seeds to certain acids to remove lint and, in this process, a certain amount of the wax and lignin is removed. This reduces the amount of hard seeds and dormancy potential. In many legume crops, mechanical scarification is used to scratch the seedcoat to improve moisture and gas uptake during germination. Many grasses are passed through a de-bearder to remove the glumes that remain attached to the seeds during harvest. This alone can result in significant seedcoat damage, thus making it a deterimental rather than a beneficial process.

New avenues of research include investigation of seed priming or seed enhancement as a means to minimize both the micro- and macro-environmental influences on seed performance. The field performance of the seeds, regardless of seed quality, is most critical during the initial germination period of 0-96 hours. If there is a means to place the seeds in a favorable environment and carry out the processes of germination prior to introducing the seeds to the field, the performance potentials can be greatly enhanced and plant establishment and seedling health significantly improved. Commercial seed priming and/or enhancement has been done for a number of years in the vegetable area. This has been accomplished by utilizing the LPP (Liquid Phase Priming) technologies. Each company has defined and selected a process that best fits into its production scheme for a given seed type. Regardless of the technique used, initial seed quality is the most important aspect of the system. On the other hand, the seed priming process does have some inherent problems that are not impossible to resolve and must be addressed. Upon initiation of the seed priming process, many biochemical systems within the seeds are activated. Some seed types can be manipulated at this point, but others can not. Presently, the companies using seed enhancement are carrying out this process, drying the seeds back, and packaging it for delivery to the grower. If the procedures and the timing are not carefully monitored, seed quality can be greatly impaired; but under optimal conditions, osmo-conditioning can result in the following benefits:

Benefits of Osmo-conditioning

* Increased germination rate

* More uniform emergence

* Increased germination & emergence rates under a broader range of temperature and moisture

* Improved seedling vigor/growth

* Higher percentage of saleable/marketable plants

To make this process commercially and grower acceptable in additional cropping areas, the issues of process technology have to be addressed. One has to consider presenting a simplified process to the grower so that he can prime the seeds on his timetable for planting. It is important to remember that when the priming process is initiated, it may be arrested but it cannot be reversed. Therefore, the easiest and greatest benefit would be to have the seeds primed to the optimum level at the time of planting.

A new approach, SMP (Solid Matrix Priming), is presently being investigated by Gustafson, Kamterter, and several universities. This technology has recently been filed for patent and, therefore, will not be discussed in detail. The objective in developing this technology is to overcome the limitations inherent with the LPP system and to utilize this as a means for introducing bacteria [Plant Group Promoting Rhizobacteria (PGPR) and Rhizobia] to the seeds. Preliminary investigations have indicated that this process is capable of meeting these objectives, as demonstrated in Table 10.

Needless to say, many issues have yet to be addressed at this point, but expedited research is in progress. At this time, the potential possibilities for this technology are unlimited.

Other physical additives being used successfully include conventional treatments; for example: trace elements, repellents, plant growth regulators, and herbicide safeners. Seed coatings, either microfilms or pelleting, are becoming a buzz word throughout the industry. The European seed industry has become the leader in commercializing seed coatings. This has occurred as a result of governmental pressure and, also, the size of the specialty crops being coated.

We have had an ongoing coatings research project at Gustafson since 1980. The logic for being involved in this area is based on several objectives.

Table 10. Cucumbers rated 9 days post-plant (University of Florida - 1988).

Treatment	Root Weight	Shoot Weight	Total Weight
	----------	Grams	----------
Untreated	64	285	355
SMP (only)	81	327	408
SMP with Bacteria	84	369	453
SMP (Post-Add Bacteria)	65	309	371
Bacteria (only)	56	289	357

Seed Coating Objectives

* Improved worker handling safety

* Improved uniform and homogeneous placement of chemicals and colorants on the seed surface with less dust-off potential

* Improved ability to place higher loads and more chemical combinations on the seed surface

* Safen the seeds against possible phytotoxic chemicals that are toxic only during the germination phase

* Prolong the activity of chemicals that have low stability in ultra-violet light or in the soil

* Buffer the pH of the seed surface

* Improve plantability of the seeds

* Cosmetic appeal

* Osmotic regulators

We have determined from our investigations that it will be impossible to have a universal coating for all uses. The seed type and the additives to be placed in the coating will dictate the types and numbers of polymers used. The guidelines and general characteristics for most coatings are the following:

* Should be a water-based polymer system

* Have a low viscosity range

* Have a high concentration of solids

* Adjustable hydrophillic-hydrophobic balance

* Form a hard film upon drying

* A finished coating that will provide:

  - Excellent plantability

  - No dust-off of additives

  - Excellent germination under all macro-environmental conditions.

To meet the needs of coating the large volumes of seeds required to plant the U.S. acreages, it will be necessary to have a continuous coating process rather than a batch system. Most of the European technology is based on batch application technology and is, therefore, not adaptable to our needs in the U.S. Gustafson has developed a system which lends itself to the continuous coating of sorghum seeds and incorporates the use of a Gustafson "ACCU-TREAT treater" as the application system. This work was reported to the 34th Seedsmen Short Course.

Biological Additives

Today biotechnology is placing, in the market place, products that have resulted from major investment dollars spent on research over the past five years. Estimates of $1.2 billion of investment have been published. Bacterial products providing disease, insect, weed, and frost damage control are entering the market place. In addition to these indigenous bacteria, major strides in development of genetically altered bacteria for specific purposes have also occurred and will soon be entering the world of agriculture. To identify the areas of potential seed and seedling response to these products, I will define the following terms:

Ectophytic - living on the surface of the seeds and/or seedling

Endophytic - living within the plant system

Rhizosphere - area of influence of the root.

For years, man has utilized Rhizobia bacteria and its nitrogen fixation ability on legume crops. In the very near future, we will see significant improvement in yield potential of these crops through genetically engineered Rhizobia and process technology. Similar investigations on grasses are also being conducted. New technological breakthroughs in selection of mycorrhiza will also impact the forestry industry and provide new agricultural uses for these products. The areas of greatest interest involve the use of biologicals capable of production and exudation of natural compounds having bactericidal, fungicidal, insecticidal, or detoxification activity either endophytically or ectophytically to the plant system. These biologicals would, therefore, be capable of protecting the plant against various pests or diseases. We know that this may also occur naturally; for example: the endophyte of Fescue, Acremonium spp., acts as an insecticide. In New Zealand, they selectively utilize endophyte-infected plants for turf and the endophyte-free seeds for forage and grazing. As new products enter the market, we may find product fragmentation similar to this for other crops. This in itself will add value to the seeds, therefore making it more important to increase the additives placed on the seeds to enhance seed and seedling performance.

The challenges ahead are many. Truly, we have entered into a new era of seed additive utilization. The tools and new technological advances will have a dramatic effect on the future of agriculture world-wide. The statement "First the Seed" still remains true and will become even more important as the seeds represent the delivery point for the new technological achievements into the agricultural community.