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Seed Quality Improvement Strategies

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SEED QUALITY IMPROVEMENT STRATEGIES

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The technical literature on seeds is voluminous. It has been accumulating at an ever increasing rate since the second half of the 19th century. In our time - about 100 years later - the number and variety of research papers on seeds has increased to the extent where a specialized abstracting journal was justified and established.

In the restricted but still rather broad area of seed quality, major emphasis in research and development (R&D) during the past 100 years has been given to identifying the significant attributes of quality and establishing their relative importance, developing and improving quality evaluation methodologies, and devising production, harvesting, and conditioning systems and facilities for maintaining seed quality from maturation to planting time. In other terms, a quality maintenance strategy has been pursued almost exclusively in R&D until very recently. The quality maintenance strategy was - and is - soundly based on a very substantial body of evidence and experience that most kinds of seeds in most production environments do attain a high level of quality at physiological maturity. The quality of the seeds, however, can be and frequently is rapidly eroded except under the most ideal conditions for production and storage. Seed quality or performance, therefore, can be rather dramatically "improved" by procedures and systems that reduce the rate of quality loss or deterioration, i.e., implementation of the quality maintenance strategy.

Quality Maintenance Strategy

The quality maintenance strategy is still valid and should continue to guide seed quality related R&D, but it should not command exclusive attention and claim most of the resources available. The sea changes underway in the technology and economics of crop and plant production require much broader and more ambitious approaches based on multiple strategies. Before looking at some of the supplemental R&D strategies for improving the quality and performance of seeds, some

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major accomplishments and unfinished business under the quality maintenance strategy should be noted.

Agriculture has been well served by the long term implementation of the seed quality maintenance strategy. Successful systems have been developed for the production and supply of seeds for all sorts of crops ranging from peanuts to hybrid petunias. In many cases, these systems represent a sort of direct and wholesale application of the quality maintenance strategy. Consider the locations of seed production in the U.S. and worldwide! Where possible, seed production for crops such as the forages, ornamentals and vegetables is concentrated in arid, irrigated areas or in areas with distinctive wet/dry seasons. The quantity of production is much greater under the full sunlight and scheduled water supply of the arid, irrigated areas, but that is not the main reason for the concentration of seed production. Seeds are produced in arid or wet/dry season areas because it is easy to maintain the quality of the seeds. The "weathering" that is the scourge of seed production in areas well watered by rain throughout the year is not a factor. Consider the case of cottonseed. When just about everything that could feasibly be done to maintain the quality of cottonseed produced under the usual "rainy" conditions in the mid-South or Southeast had been done, the results were still not satisfactory. So, a major portion of cottonseed production was shifted to the West where seed quality could be maintained and assured.

It has, of course, not been feasible or possible to shift all seed production to the arid, irrigated areas in the West to maintain quality through avoidance of weathering. Seeds of many major crops have to be and are satisfactorily produced in the areas of commercial production. Soybean seeds, for example, are produced throughout the areas of commercial production by close adherence to an array of tactics deployed under the quality maintenance strategy such as early harvest to minimize field exposure, careful harvest to minimize mechanical damage, good aeration and storage conditions to reduce deterioration during storage, and so on.

The achievements in terms of seed quality in both the arid, irrigated areas and the areas of rainfed crop production, i.e., soybeans, however, are not now fully meeting expectations. To be sure, the difference between the seed quality level maintained and the seed quality level expected or desired is greatest for seeds produced in the rainfed crop areas. But, some planters expect and are beginning to strongly demand seed performance levels greater than can be naturally achieved even under the sunny, blue skies of the irrigated arid lands of the West. In a very real sense, therefore, the quality maintenance strategy has achieved about all that can be achieved without fully satisfying requirements in an increasing number of cases or situations. Other approaches, other strategies, must come on full stream.

Although the quality maintenance strategy is not able to assure delivery of the level of seed quality and performance needed by some planters, it is not obsolete and ready for discard. As pointed out at the beginning, the strategy is still valid; indeed, it is basic. Successful development and implementation of other strategies for improving seed quality and performance will be wholly dependent on rigorous adherence to traditional quality maintenance and assurance systems. Regardless of the strategies followed, every thing is lost if seed quality is not maintained. The other strategies for improving seed quality considered below are not alternatives, they are supplemental and represent logical progressions of the quality maintenance strategy.

There is still great scope and fertile grounds for high payoff R&D under the quality maintenance strategy. Indeed, at least half of available resources should be devoted to developing and/or improving methodologies and technologies for maintaining seed quality through the production cycle, especially, from physiological maturity of the seeds through planting. Although the agenda of unfinished business is still lengthy, some areas that have been neglected for too long deserve a larger slice of the pie, while the excessive fine tuning in some long and well tilled areas should be reduced.

Unfinished Business

There is much unfinished business within the scope of the seed quality maintenance strategy. As suggested above, at least half of the resources available for seed related R&D should be devoted to developing and/or improving methodologies and technologies from maintaining seed quality through the cycle from physiological maturity to the next planting season. Only a few of the areas that need attention - or more attention - can be considered here, and in only a rather general way.

Seed Health

The relationships of field and storage fungi and seedborne diseases to the performance capabilities of seeds appear to be a very fruitful area for research. Presently in the U.S., only a very few plant pathologists and/or micro-biologists devote most of their time to seed related research. In Europe and other regions such as South Asia (e.g., India), there is a relatively large number of seed microbiologists and/or pathologists. And, as a group, they are relatively prolific publishers. The relevance of much of this work to U.S. agriculture, however, is uncertain, and its significance in crop production is not at all clear.

There does appear to be a growing awareness in the U.S. seed industry and some of the Universities that seed health has been much neglected and just might be an important limiting factor in economical crop production. Some of the large seed companies have fully established seed microbiology/pathology labs staffed with well trained personnel. But, more needs to be done, especially in the University and Agricultural Experiment Station R&D programs.

Varietal Purity Testing

The great proliferation in the number of crop varieties has placed heavy burdens on internal quality assurance programs and seed regulatory agencies. Internal quality assurance has the task of maintaining and assuring the genetic quality of the seed marketed, i.e., varietal purity, while seed regulatory agencies have the responsibility for enforcement of the provisions of seed laws that relate to varietal purity. The job confronting both groups, however, is much bigger than the tools and budgets presently allocated in the public and private sector components of the seed industry. Considering the many articles on the methodologies, technologies and strategies for assuring and checking varietal purity in the trade magazines, there might be the perception that hi-tech and bio-tech have the matter well in hand. This is not the case. Reliable and sensitive technologies have been and are being developed, but they have not been installed in many laboratories. Varietal identification work must be continuous because the number and genetic structure of varieties are changing and new technologies will surely be needed.

Seed Quality and Crop Performance

Knowledge of the level of quality in seeds that must be maintained to assure that the seeds planted are not a limiting factor in production would appear to be central to the quality maintenance strategy. Yet, relatively little data are available on the influence of seed quality on the establishment, growth and productivity of crops, and much of what is available is controversial. Most workers would agree that the quality of seeds planted can influence the growth and productivity of crops, but there would be much disagreement on the circumstances under which such responses are manifested and their significance in terms of yield. So, work on the relationships of seed quality to crop growth and performance is mostly limited to the emergence or stand establishment periods. The implication from this situation is, of course, that the influence of physiological seed quality does not extend beyond the stand establishment phase. The validity of this implication, however, is a matter of great importance in devising and implementing seed quality maintenance strategies.

Rapid Viability Tests

A good portion of seed related R&D is devoted to development and evaluation of methods for evaluating and monitoring seed quality. And, this has been the case for about the last 100 years. Many tests for evaluating seed quality have been developed and standardized. But, there is still need for more sensitive and more rapid methods. The development of a reliable, rapid method for determining the viability of seeds remains an elusive goal. Forty years ago the tetrazolium test appeared to meet the essential requirements of speed and reliability. Even under the best circumstances, however, the TZ test requires about 4 hours (more often 16 hours) - and that's too long. Seedsmen need a test that can reliably estimate viability within an hour; 10 minutes would be better, and a rapidity equivalent to that of the electric seed moisture testers would be just ideal. Development of a "real" rapid test for seed viability is among the major items on the quality maintenance R&D agenda.

Mechanical Damage

Reductions in seed quality related to mechanical abuse are perennially important in some crops and periodically significant for others. During the past season (1987) a substantial portion of the soybean seeds harvested for seed were damaged to the extent that they were not fit for planting purposes. The problem was exceptionally dry weather which led to rapid and excessive drying of the seeds before harvest. The mechanical damage problem is chronic, although it's severity seldom approaches that in 1987. There is need for a more substantial R&D effort to identify and/or devise operational procedures that reduce mechanical damage to seeds to a minimum. Good progress appears possible in the handling and conveying area, but there is only a limited amount of work underway on modification of conveying equipment to minimize damage. There is also need to critically examine the coverings of seeds of crop lines to identify structural features related to resistance to mechanical damage which might be useful in developing improved crop varieties with superior quality maintenance.

Systems Approach

Application of "systems" theory and procedures to the task of maintenance of seed quality is a step that must soon be taken. Adaptation of the systems approach and procedures to quality assurance in the seed industry could result in marked improvements in the quality of seeds available for marketing by reducing the attrition in quality from the many minor causes of damage, deterioration, and mixtures.

Yes, much remains to be done to maintain seed quality, but just maintenance is not enough in modern agriculture. The quality of seeds needs to be upgraded and enhanced.

The seed quality maintenance strategy even when fully implemented does not meet the needs and expectations of a substantial portion of seed users. Many crop producers must substantially reduce costs and minimize risks to maintain their operations at profitable status. Since establishment of an optimum population of vigorous, uniform seedlings is the first and crucial step in economically successful crop production, producers would like to ensure that stand establishment is as fail-safe as feasible. Other crop and plant producers are involved in supplying intensely competitive and quality conscious markets where the failure of seeds to germinate and emerge uniformly has severe consequences in terms of quality and acceptability of the product, i.e., seedlings industry. In both groups there is the strong feeling that the high quality and performance seeds needed are not generally available.

The seeds supply issuing from the quality maintenance strategy is not adequately meeting the requirements of today, and it will fall critically short of meeting the future needs and expectations in a biotechnologically driven agriculture for zero defect, fail safe seeds. New approaches - new strategies are needed. The strategies with the greatest potential for meeting the needs of crop agriculture today and tomorrow are the genetic potential elevation and the quality enhancement strategies.

Genetic Potential Elevation Strategy

The "maximum" quality and performance potential of a seed kind is established by inheritance. If the inherent performance level for seeds of modern crop varieties is not adequate, a seed imposed constraint on gains in productivity has to continue to be accepted, <u>or</u> the inherent and/or physiological capabilities of the seeds have to be elevated or enhanced. Improvements in the qualities and performance of seeds through breeding have been more-or-less neglected for all but a few crops. Indeed, in many cases improvements in yield and produce quality have seemingly been at the expense of the propagative qualities of the seeds. While losses in the qualities of crop seeds during long periods of improvement by man appear to be the result of "unconscious" rather than conscious selection, the consequences in terms of reduced seed capabilities are the same. Fortunately, this situation appears to be changing. Many plant breeders and biotechnologists are very concerned about the stand establishment capabilities of seeds of the crops they are trying to improve and have installed seed quality improvement as a major objective in their over-all crop improvement programs.

There is ample evidence of very substantial variation in the species and related populations of most crops for seed longevity, the environmental conditions for germination/emergence, resistance to weathering and mechanical abuse, and so on. Traits associated with superior seed qualities and performance capabilities have been identified in many old and obsolete varieties, exotic strains and wild relatives. Where possible and not to the detriment of essential crop characteristics such as produce quality, superior seed quality and performance traits should be transferred to modern varieties. In corn improvement, as an example, breeders have made great strides in improving the capabilities of the seed for emergence under conditions that were considered as very marginal in earlier times. Examples of the transfer of specific traits from obsolete varieties and exotic strains to modern types include the relatively recent works in soybean and cotton. In soybean, it has been firmly established that the hardseeded character common in many "wild" strains and obsolete forage varieties is closely associated with resistance to weathering and adverse storage conditions. Varying "doses" of this trait are being incorporated into several modern varieties to improve maintenance of seed and grain quality under severe weathering pressure. Likewise, a reduced permeability to water trait in cotton - very common in wild types - has been transferred to experimental and breeding lines. A relative impermeability of the seed covering to water in cotton is associated with resistance of the mature crop to weathering and the seeds to adverse storage conditions. While several other examples could be cited of improvements in the qualities of seeds through breeding, or of programs underway with seed quality improvement as an objective, the level of effort is still not commensurate with the needs and expectations. Much more needs to be done. In addition to improving the inherent resistance of seeds to weathering and adverse storage conditions as already mentioned, improvements are needed in capabilities of the seeds for germination and emergence under marginal conditions of temperatures and moisture, and under stress levels of toxic minerals including salinity. There are also needs and opportunities to alter the mechanical and geometrical properties of some crop seeds to improve their resistance to mechanical abuse and emergence-ability under mechanical impedance in the seed bed.

The genetic potential elevation strategy for improving the qualities and capabilities of seeds appears to be most suitable in terms of cost-effectiveness and environmental neutrality. However, it is also long-term and the improvements needed in some critical areas might be too long in coming on-stream. Thus, a shorter-term, or interim approach is indicated for which the quality upgrading strategy appears ideally suited.

Quality Upgrading Strategy

The "upgrading" strategy for improvement of seed quality has long been practiced. It has especially been employed by seedsmen desperate to raise germ "just a few points"! The strategy is sound. Many defective and low quality seeds are visually evident in lots. If these are separated from the "good looking" seeds in a lot then, LO and BEHOLD, the average germ will increase that "few points" or even a lot of points. The problem is: how can the defective low quality seeds be removed effectively and economically?

The crucial requirements for upgrading seed quality through removal of the low quality seeds in the population are: first, there must be some physical difference between the bad and the good seeds; secondly, there must be some device that can economically separate the good seeds from the bad seeds on the basis of their difference(s). Unfortunately, low germinating and/or low vigor seeds are often indistinguishable from the good seeds by readily available methodologies. The bad seeds don't always wear black hats. But, sometimes they are distinguishable and upgrading is possible and frequently economically feasible.

The most common devices used to upgrade the quality of seed lots are human eyes and hands. Hand sorting is still widely used even in the U.S. to improve the quality of the seeds genetically by removing obvious off-type or other variety seeds, aphysically and/or biologically by removing weed seeds, and physiologically by removing discolored, bleached, moldy, diseased, and immature seeds. In countries where labor is plentiful and low cost, hand separation of seeds is a major conditioning procedure. I have seen literally scores of people - usually women and children - sitting on drying floors in many countries cleaning and sorting corn, bean, pea and other relatively large seeds by hand.

The various conditioning machines can and do separate low quality seeds from those of higher quality. The air systems in the air-screen cleaner remove shriveled and other immature seeds and even some of the low density, rotten seeds. The screens can also contribute to upgrading. The largest and smallest seeds in a population or lot are usually lower in quality than those between them in size. Removal of the smallest and largest seeds with the top and bottom screens can upgrade germination and vigor. Other sieving devices such as the precision width, thickness and length separators can be and are used to improve the germination of seed lots. Even the roll mill and magnetic help by removing some mechanically damaged seed. Every seed conditioners knows and expects that basic cleaning will increase the germination percentage of the average seed lot by 2-5%, maybe more.

Color sorters or separators are used very effectively to improve the genetic and physiological qualities of seed lots. Peanut seeds after shelling are color sorted to remove seeds with damaged seed coats which perform poorly in the field. Seeds of lima beans and other kinds of large seeded legumes are colored sorted to remove discolored, low germinating and low vigor seeds from the lots. Color sorters have even been used to improve the germination of small lots of clover seeds by removal of the deteriorated seeds that develop a dark brown color. There are many other possible upgrading separations utilizing color sorting methodologies, but most, unfortunately, are not economical.

Density is the physical property most consistently associated with seed germination and vigor. In average, current year lots (i.e., not carry-over) with germination 70% or above, the high density seeds can germinate above 90% with good vigor, while the lower density seeds can germinate in the 60s or less with low vigor. The economics of the separation are determined by the amount of high density seeds in the lot or, put another way, by the percentage of seeds that have to be discarded to elevate germination/vigor to the desired level. Obviously, separations where the baby has to be thrown away with the bath water to met standards are not practical.

Density separations are made with aspirators, pneumatic separators, and gravity tables. The gravity table is, perhaps, the most effective density separator for most kinds of seeds. With proper arrangements for handling the middling fraction from the separation, and/or combined with air separators, the gravity table can significantly upgrade the germination and vigor of many seed lots. It is routinely used in cotton seed conditioning to remove low density, low quality seed, and it is used for the same purposes in conditioning of seeds of corn, soybean, sorghum, sunflower and many other crops, although the results are usually not as dramatic as they are for cotton seed.

There are other possibilities for upgrading the physiological quality of seed lots. Electrostatic and fluid separations hold the greatest potential. Electrostatic separations are tricky and would require some seed moisture conditioning. Fluid or hydraulic methodologies would permit the most rigorous separation of seeds on the basis of specific gravity or density, but would require wetting of the seeds which would then have to be followed by drying, and so on. Despite these disadvantages, fluid separations are likely to be increasingly employed to fractionate seed lots into density groups in connection with other quality enhancement methodologies.

Quality Enhancement Strategy

When inherent improvements in seed quality are still in the making, and all that can be done to maintain and upgrade seed quality has been done without fully meeting customer expectations regarding performance, what options are left? This is not a rhetorical question. There is a still small but growing segment of the seeds market with requirements for levels of seed performance that cannot be consistently met by traditional quality maintenance/upgrading procedures. The core of this market segment consists of the seedling/plant and greenhouse cropping industries, but others are joining in including many vegetable growers and even some planters of field crops.

In the seedling industry the failure of seeds planted to produce healthy seedlings has direct, very apparent consequences.

Blanks occupy as much space and require the same "care" as seedlings, and substantial costs are involved in replacing or discarding blanks. The consequences of seed performance failure in the vegetable produce and processing industries are as important but somewhat less obvious. Vegetable crops are space planted, and, again, blanks or weak plants reduce the marketable produce in direct proportion of their number.

In field crops as diverse as cotton and sugarbeets the rapidity and uniformity of emergence has a substantial influence on yield. High performance seeds are also becoming widely recognized by farmers as one of the most cost effective means of minimizing and/or managing risks when they can be obtained. When high performance seeds are just not available, many farmers still have the strong perception that things would be much, much better if they could obtain some for planting.

What options remain when the quality maintenance and upgrading strategies have been fully implemented and the inherent improvements in seed quality are still upstream? There are two: the quality enhancement approach, and seedbed improvements. Both approaches improve quality in terms of enhanced performance. The seed bed improvements, of course, are not a seed quality improvement strategy, although their effects mimic quality improvement.

Seed quality enhancement generally refers to enhancement of seed performance (e.g., germination, emergence) above the level set by "natural" responses and inheritance. This is achieved by treatment of rigorously selected seed populations or sub-populations with various materials in various ways.

During a recent discussion of seed performance enhancement, several persons raised questions relating to the need and feasibility of enhancing performance when germination is near 100%. The questions were fair and needed to be addressed. They were. There are many ways performance of 100% germination seeds might be improved with very significant benefits in terms of crop production and production efficiency.

The influence of uniformity of emergence on various aspects of production has been well established in a variety of crops from lettuce to cotton. Performance could be significantly enhanced, therefore, by treatments that synchronize emergence. Similarly, earlier establishment of a stand - even by a few days - can significantly affect the growth and yield of crops with maturity about the length of the growing season. Enhancement of both the rapidity and uniformity of emergence would be a big plus in crop production.

Microenvironmental conditions in the seedbed are often very stressful and even hostile. Enhancement of seed emergence under marginal conditions of moisture, temperature and oxygen supply would decrease the probability of stand failures and inadequate stands and, thus, greatly reduce one of the first and most important risks in crop production. Similarly, enhancement of stand establishment under chemical stresses, e.g., herbicides, insecticides, elements at toxic concentrations, salinity and so on, would be of great benefit in many areas and for many crops. Maintenance of a healthy condition of the seed/seedling through enhancement treatments, especially under marginal conditions, can contribute as much to productivity as 10 years or more of expert breeding, or a host of applied chemicals.

The various ways seed performance can be significantly enhanced are not independent of each other. Most often a full complement of the enhanced performance attributes is needed to adequately address the limitations and stresses in crop stand establishment.

The crucial tactic in the seed quality enhancement strategy is rigorous selection of the seed lots or portions thereof for enhancement. The enhancement strategy can not and must not be looked on as a way of salvaging poor quality seeds. Even if that were possible, it would usually not be economical and there would seldom be any enhancement of performance. It is one thing to raise lab germ a few points and quite another to improve the way seeds perform in the seedbed. The enhancement strategy makes sense - economically and otherwise - only when the highest quality seed lots or fractions thereof are selected for enhancement. After all, the strategy is called into play only when deployment of the other strategies falls short of providing seeds with the desired level of performance. Since the best is not good enough, it has to be the starting point.

Steven W. Cull, Petoseed Co., Inc., defined <u>seed quality enhancement</u> in terms of expectations during discussions at the 1988 Mississippi Short Course for Seedsmen (April). The expectations include at least one but usually several of the following: higher % germination; increased rapidity of germination; more uniform germination; more vigorous seedlings; higher germination under stresses; and higher % of normal plants. Cull pointed out that all of the expectations of enhanced performance save one were directly related to that seed quality attribute termed vigor. This is not surprising. Quality enhancement is applicable only to germinable seeds just as the concept of vigor is applicable only to germinable seeds. A non-germinable seed, i.e., a dead seed or abnormal seedling, by definition has zero vigor and no quality to enhance. Even the "higher % germination" expectation excepted by Cull has to be related to vigor rather than germinability unless some sort of restoration of germinability is assumed.

Since quality enhancement is intended to improve vigor which determines the performance of the seeds, the enhancement strategy makes sense - as pointed out previously - only when the level of seed quality achievable through deployment of the other strategies still does not satisfy consumer expectations regarding performance.

The general principles, methods and treatments for enhancing seed performance are well established. But, the specific treatments and procedures used for specific kinds of seed by the different companies are more-or-less confidential. The basic principle is to start with the best quality seeds. The best quality seeds are then upgraded to the extent possible by removal of low density seeds with a gravity table, air or fluid separator. Removal of the low density seeds from a lot (population) improves performance of the lot, but not of the individual seeds; thus, it is properly a preparatory treatment rather than an enhancement treatment <u>per se</u>.

The second step is controlled rehydration of the seeds up to a level just short of the critical level of hydration for germination. This is accomplished by so-called priming or osmo-conditioning, processes I characterized as "metabolic brinksmanship" in the Oct. 1985 issue of SEEDSMEN'S DIGEST. Controlled rehydration is carried out under cool conditions. Metabolic processes involved in germination are initiated or accelerated and allowed to proceed to the <u>brink</u> - the point just short of emergence of the rootlet. Germination of primed seeds on release from the hydration control or even after dehydration and a period of storage is much faster and more uniform than of unprimed seeds. A very rough analogy is the faster acceleration of a warmed-up car on a cold morning as compared to starting from scratch. Primed seeds are cranked up and read to go. Priming involves brinkmanship because if it is carried too far - over the brink - the results can be catastrophic rather than enhancing. Much work is currently underway to develop optimal systems for the controlled rehydration process, some of which involve proprietary technology.

Priming alone accelerates germination and emergence and expands the range of conditions under which germination/emergence takes place. In most cases, however, the seeds are treated during or after priming with one or a combination of phytohormones and/or phytoactive chemicals, including some fungicides, to speed up and modify germinative behavior. Some of the phytoactive chemicals applied improve germination/emergence under marginal conditions.

The concept of seed quality enhancement is relatively new. The methodologies and technologies for enhancement are in the development stage. They are being rapidly perfected along with essential quality assurance procedures. The market for enhanced seed continues to grow, especially in the specialty areas, and the number of suppliers is increasing. While the concept of seed quality or performance enhancement has been mostly applied to vegetable seeds, some break-thrus into agronomic crop seeds, e.g., cotton, can be expected in the next few years. In time, enhancement will be as routinely deployed as the other strategies for improving seed quality.

Summary

Although there are many strategies for improving seed quality, they do not constitute a stacked deck. Much remains to be done on the theoretical and practical levels.