

Session 4

THE IMPORTANCE OF QUALITY SEED IN AGRICULTURE

Chairperson: Mrs. KATALIN ERTSEY, President of the International Seed Testing Association (ISTA) and Director plant production and horticulture, Central Agriculture Office (OMMI) (Hungary)

▶ **What is seed quality and how to measure it?**

Mrs. ALISON POWELL, Honorary Senior Lecturer, University of Aberdeen (United Kingdom)

▶ **The influence of seed quality on crop productivity**

Mrs. RITA ZECCHINELLI, Head of ENSE Seed Testing Laboratory, Tavazzano (Italy)

▶ **The evolution of seed testing**

Mr. MICHAEL MUSCHICK, Secretary General, ISTA

▶ **Building capacity in seed quality assurance in developing countries**

Mr. MICHAEL LARINDE, Senior Agricultural Officer (Seed Production), Plant Production and Protection Division (AGP), Agriculture and Consumer Protection Department, FAO

▶ **Raising seed quality: what is in the pipeline?**

Mr. JOOST VAN DER BURG, Seed scientist, Agrosystems Research, Plant Research International (Netherlands)

▶ **Maintaining capacity in seed technology and seed testing**

Mr. JOHN HAMPTON, Director Bio Protection and Ecology Division, Professor of Seed Technology, Lincoln University (New Zealand)

General discussion

Conclusion, presented by the Chairperson

WHAT IS SEED QUALITY AND HOW TO MEASURE IT?

Mrs. ALISON A POWELL*

Introduction

Throughout the world, farmers and growers have clear demands of the seeds that they sow. Firstly, they want the species and variety to be consistent with what they believe they have bought. Secondly they want that seed to achieve uniform and successful establishment of a weed-free crop that will develop without the incidence of diseases that result from seed-borne infection. Achievement of these requirements is assisted by the methodologies of seed quality testing that are developed and standardized by the International Seed Testing Association. These seed-testing methods can be used during seed production and marketing to ensure that seed quality is maintained. This paper will consider the different testing methods that are available to help fulfill the requirements of farmers and growers.

The first two aspects of seed testing to consider, variety and purity testing, are those that ensure that a farmer sows the species and variety he wants without contamination with weed seeds or seeds of other crop species. A point to be made at the outset is that all tests are done on samples drawn from the seed lot, which is the population that will be sown. Methods for seed sampling are described in the ISTA Rules for Seed Testing (ISTA, 2009a), with further background and detail in the ISTA Handbook on Seed Sampling (ISTA, 2004).

Variety Testing

There are two aspects to variety testing. The first is to ensure that a sample is the required species or variety and the second to ensure the purity of the variety, that is, that the variety is not contaminated by the seed of other varieties. Varietal purity can mean checking whether a variety is, for example, completely of the F1 variety it is claimed to be, or whether a conventional variety is contaminated by GM seeds or vice versa. Traditional methods of variety testing include morphological methods. In such methods the characteristics of the seeds may be compared; for example, differences in seed color may reveal that varieties have been mixed. Alternatively the characteristics of seedlings may be observed in the laboratory or in the field, or other plant or fruit characteristics may be observed in the field.

More modern methods of variety testing can involve a range of biochemical and molecular techniques. Biochemical methods include analysis of the protein reserves of the seeds by electrophoresis, an approach useful in the comparison of F1 hybrids and the parental lines. Molecular methods include the use of molecular markers. These methods involve extraction of the DNA and the polymerase chain reaction (PCR) in which selected DNA is multiplied. Another approach is the use of microsatellites and single sequence repeats (SSRs).

Detection of genetically modified seed material is an area of seed testing that has aroused considerable interest and debate over the last few years. Many methods have been employed including bioassays, protein-based methods such as ELISA and DNA-based methods, specifically end-point and real-time PCR.

Analytical Purity

The analysis of the analytical purity of the seed examines the extent to which a seed sample is contaminated with other seeds (weeds and other crops) and other plant and inert material. It therefore reveals the extent to which the seed that a farmer buys is actually the desired seed.

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The methods of purity analysis involve observation of seed samples using lenses and microscopes and separation of the seed into different portions. Hand lenses or binocular microscopes help identification and separation of small seed units and fractions of seed; sieves may be used to separate trash, soil, small pieces of seed and other small particles; blowers remove light material such as chaff and empty florets from grass seed samples. The test result for analytical purity reveals the percentage by weight of pure seed that is present in a sample, the other seeds (which are identified) and the inert material.

Assuming that the seed is the correct variety, the farmer now wants it to achieve a uniform and successful establishment. Two aspects of seed quality influence this, the ability of seed to germinate and the seed vigor. The germination of a seed sample is most commonly assessed in germination tests, although if a rapid assessment of potential germination (viability) is required, a tetrazolium test may be used.

Germination Tests

The aim of a germination test is to provide ideal conditions for germination so that the maximum potential of the seed is revealed. The ideal conditions for germination of different species may differ in terms of the substrate, temperature and time. The substrate for germination may be sand, an organic medium, on top of paper or between papers. Temperatures for germination are either constant or alternating, where one temperature is applied for a specified length of time, followed by another temperature for the rest of a 24-hour period. Finally the time allowed for germination in agricultural and vegetable species can range from as short as five days for jute (*Cochorus olitorius* and *C. sativum*) to as long as 28 days for *Panicum maximum* (guinea grass) and 35 days for *Tetragonia tetragonoides* (New Zealand spinach). The germination requirements for seeds of over 320 agricultural and vegetable species, 190 tree and shrub species and 350 flower species are found in the ISTA Rules for Seed Testing (ISTA, 2009a).

Another characteristic of seed to be considered in a germination test is seed dormancy. In many plant species the presence of dormancy means that the viable seeds will not germinate even when the ideal conditions are present unless they have received a specific environmental cue. This evolutionary trait is a survival strategy which ensures that seed will only germinate when the environmental conditions are suitable for seedling growth and plant establishment and also spreads the germination over a period of time. There are detailed descriptions of different types of dormancy (Baskin and Baskin, 2000), but they can be simply described as being of two types, physiological and physical. Thus, in addition to the requirements for a germination test, the pre-treatments necessary to break the dormancy of many species have also been identified. Treatments to break physiological dormancy include dry storage, which usually applies to species that have a short period of dormancy; moist pre-chilling, usually at temperatures of 5-10°C for agricultural and vegetable seed and 1-5°C for tree seeds; pre-heating; light; and potassium nitrate or gibberellic acid provided during germination. Physical dormancy arises due to a hard seed coat that prevents the uptake of water at the beginning of germination. This so-called 'hard-seededness' can be broken by soaking in water for 24-48 hours, mechanical scarification or acid scarification.

The treatments required to break dormancy before or during a germination test are also given in the ISTA Rules (ISTA 2009a). Dormancy is not often seen in many crops, having been selected out by the act of cultivation over thousands of years. There can be problems however in years when the weather causes problems during harvest or in species brought into cultivation more recently

At the end of a germination test, a seed is said to have germinated successfully if it has developed to the stage where the appearance of the seedling indicates whether or not it is able to produce a satisfactory plant in favorable field conditions. Such a seedling is described as a normal seedling. If a normal seedling is not produced, the seedling is described as abnormal and would not be expected to produce a plant in the field. The result of a germination test is reported as a percentage of normal seedlings, abnormal seedlings, hard (unimbibed), fresh (i.e. moist but firm) and dead seeds (ISTA, 2009a).

Tetrazolium Tests

The tetrazolium test is a biochemical test that provides a rapid assessment of the viability of the seed by assessing the degree to which the tissue of the embryo of the seed is living by using a stain. The stain used is 2, 3, 5 triphenyl tetrazolium chloride, which reacts with active respiratory enzymes in the seed tissue to produce a red color. Thus, if a tissue stains red, it is living. Work over many years has identified the extent to which different tissues in the seed of many species must be alive to enable the production of a normal seed. The essential structures for germination should be stained in a viable seed, but, experience has shown that, depending on the species, small amounts of dead tissue are acceptable even on these parts of the seed. Assessment of a whole seed sample gives percentage viability for a seed lot.

The tetrazolium test is particularly useful in cases where a rapid assessment of the viability of a seed lot is required and a germination test would take too long. This may be when seeds have to be sown soon after harvest, in seeds with deep dormancy, when seeds show very slow germination, or when a very quick estimate of the germination potential is required. It can also be useful at the end of a germination test to determine the viability of seeds that have failed to germinate and may be dormant but not dead. The test is used to detect damage during harvesting and processing, such as heat and mechanical damage, and has been used to help develop less-damaging production techniques.

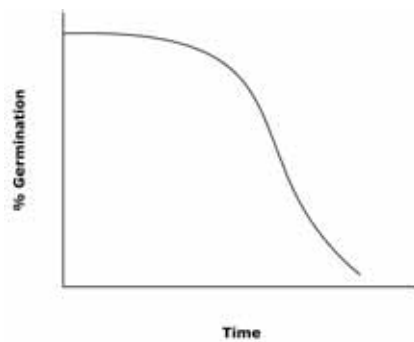
Specific details of preparation of the seed, stain concentration and time and temperature of staining can be found in the ISTA Rules (ISTA 2009a), with further information in the ISTA Working Sheets on Tetrazolium Testing (ISTA, 2007a, b).

Vigor Tests

Germination tests are the primary assessment of the ability of seed to germinate and emerge in the field. However, although the results of the standard germination test give a good correlation between germination and field emergence in favorable conditions, germination can fail to indicate the ability of a seed lot to establish a crop in poor field conditions, for example, cold, wet soils. There have been instances described in a wide range of species where seed lots having equally high laboratory germinations show wide differences in field emergence. This has been shown to be a problem in a number of species, including grain legumes (Powell et al., 1984); small seeded vegetable species, (Matthews, 1980); a range of vegetables and cucurbit species (Perry, 1973); sugar beet (Perry, 1973; Akeson and Widner, 1980; Matthews, 1980); maize (Nijenstein, 1986; Bekendam et al., 1987; Lovato and Balboni, 1997).

This failure of the germination test to predict differences in field emergence, particularly in poor field conditions, suggested that there is a further physiological aspect to seed quality, which has come to be referred to as seed vigor (ISTA, 1995). Seed lots having high germination, but poor emergence are referred to as low-vigor seeds, whereas those giving good emergence are termed high-vigor seeds. Vigor is also reflected in the rate of germination and seedling growth, in both favorable and unfavorable conditions for germination and emergence. Low-vigor seeds germinate slowly over a long period of time to produce a range of seedling sizes, whereas high vigor seeds germinate rapidly and synchronously to produce large and uniform seedlings. Furthermore, high vigor seeds have good storage potential while low vigor seeds lose the ability to germinate more rapidly during the storage period.

Differences in the vigor of germinable seed can be explained by the process of seed aging. The seed survival curve (Fig. 1) shows the changes in germination of a seed lot over a period of time. There is a long period when germination falls only slowly but during which seeds are aging. Subsequently the incidence of death in the seed population increases and the percentage germination falls rapidly. Vigor differences arise due to the position of a seed lot on the slow decline in germination. A seed lot at the beginning of the decline is physiologically young and has high vigor; a lot at the end of the decline is physiologically old and has low vigor.

Fig. 1 The seed survival curve

Tests to identify differences in seed vigor exploit the fact that aging is the major cause of vigor differences. This is the case for the two tests that are currently in the ISTA Rules (ISTA, 2009a). The electrical conductivity test measures the leakage of solutes from seeds of *Pisum sativum* and *Phaseolus vulgaris*, with low-vigor (aged) seeds showing high levels of leakage in comparison with high-vigor seeds. The accelerated aging test for *Glycine max* (ISTA 2009a) and the controlled deterioration test for *Brassica* spp. (which will appear in the ISTA Rules 2010) subject a sample of seed to an additional period of aging to determine the initial position of the seed on the survival curve and hence its vigor.

The results of a vigor test give a farmer more information about the potential of a seed to perform in a range of soil conditions; a seed company information for managing its seed stocks, both in store and in marketing; a seed producer guidance regarding where seed quality may be reduced and how this can be minimized.

Seed Health Tests

Seed health tests to detect whether seeds are contaminated with or infected by a plant pathogen are important for a number of reasons. The presence of seed-borne inoculum may cause disease within a crop giving an opportunity for very rapid spread of disease, may introduce a new disease into new regions or countries and may reduce the germination of seeds by reducing the percentage of normal seedlings produced. In addition, the results of testing can indicate the need for seed treatments.

The term “seed health” includes the incidence in the seed lot of fungi, bacteria, viruses, and animal pests such as nematodes and insects. The test used depends on the organism being tested for and the purpose of the test quality assurance or phytosanitary purposes when seed is exported.

Methods of seed-health testing range from direct visual observation to highly sophisticated tests. Direct examination of the seed may be enough to identify an infected lot if diseased seeds are clearly discolored or have an uneven shape. Alternatively pathogen structures such as fruiting bodies may be identifiable from direct examination, or washing of the seed can remove fungal spores from the surface and enable identification, e.g. spores of *Ustilago nuda* (loose smut).

A further common method of testing is incubation of the seed on moist germination paper or a nutrient medium to allow growth of the pathogen and subsequent identification. Fungi may be identified by their fruiting bodies and color of their growth (the mycelium), bacteria by the color, shape and texture of their colonies. An extension of this approach to health testing is the grow-out test whereby seeds are allowed to germinate and the seedlings are examined for symptoms of infection.

Immunoassays present a more sophisticated approach to testing, with Enzyme Linked Immunosorbent Assays (ELISA) and immunofluorescence being most common. In ELISA tests, an antibody to a specific protein (antigen) in the pathogen is added to a sample and the reaction between them reflected in a color change which indicates infection. For example, soybean mosaic virus, bean pod mottle and other viruses can be detected using ELISA.

Finally there are DNA-based molecular techniques, the most common being the polymerase chain reaction (PCR), which selectively increases pathogen DNA. Electrophoresis is then used to separate the

DNA into different sizes, followed by staining. The incidence of pathogen DNA can be identified by comparisons with known samples.

The Annex to Chapter 7 (Seed Health) of the ISTA Rules (ISTA, 2009b) describes the 25 seed-health testing methods that have been validated by ISTA.

Seed Moisture Content

The moisture content (MC) of the seed is an additional characteristic that does not have an immediate, direct effect on quality, but is highly important. Tests of seed MC fulfill three main purposes. Firstly to prepare the seed for long- and short-term storage, secondly, the seed MC will influence the price paid for a weight of seed and thirdly the MC will determine the response of seeds to dormancy-breaking techniques and vigor tests.

The most significant effect of MC is on the rate of seed aging and hence the rate of decline in seed quality during storage. Thus, as the seed MC increases, the rate of aging also increases. As a rough guide, Harrington (1960) suggested that an increase in seed MC of 1% will double the rate at which germination declines. The MC therefore influences the time period over which the seed survival curve (Fig. 1) takes place. During storage the MC of the seed moves into equilibrium with the relative humidity (RH) of the store, therefore the RH during storage has a crucial effect on the MC and seed aging. In addition the storage temperature affects the rate of aging, with an increase of 50 C doubling the rate of aging (Harrington, 1960). The impact of MC and temperature on seed quality are therefore of particular significance in tropical countries where ambient conditions will tend to lead to rapid loss in seed quality. Inexpensive methods of storing seeds to minimize this decline in quality are therefore needed in areas where food security may be a problem.

An increase in the storage RH not only leads to more rapid seed aging, but the activity of saprophytic fungi, insects and mites also increases as the RH and seed MC increase. Thus the growth of the fungus *Aspergillus* will begin at 65-85% RH, *Penicillium* at >80% RH and *Alternaria* at >90% RH. The growth of these fungi leads to a further increase in seed MC and an increase in temperature, both of which enhance the rate of deterioration. In addition, they produce toxins that destroy cells which then provide the substrate for fungal growth. When seed MC increases to 15% and above, the activity of weevils, flour beetles and seed borers also increases. This places emphasis on the importance of storage conditions to maintain the seed MC and also minimize activity of storage fungi and pests.

Seed-moisture content is assessed by the removal of water through heating either the intact seed or after grinding. Comparison of the seed weight before and after heating gives the weight of water in the seed which is expressed as a percentage of the initial seed weight. This process can also be completed automatically by using one of many moisture meters that are available, although it is important that such meters are accurate and calibrated at least once each year.

Uniformity in Seed Testing

ISTA's vision is to have uniformity in seed testing, since this leads to the repeatability of results within a laboratory and reproducibility of results when different laboratories test the same samples. The successful fulfillment of this vision means that there can be confidence in the information provided by seed testing to give reassurance to those in the seed trade and the end user. Work towards ISTA's fulfillment of this vision is achieved in three main ways.

Firstly, there are the ISTA publications. The International Rules for Seed Testing (ISTA 2009a) provide detailed protocols for the completion of methods that have been accepted into the Rules as being fit for purpose and giving repeatable and reproducible results. The Rules are supported by a range of ISTA Handbooks, produced by the different Technical Committees. The Handbooks provide additional background to the tests and also further information that helps in their completion. For example, the Seedling Evaluation Handbook, includes diagrams and photographs of normal and abnormal seedlings to assist in their identification in the germination test and the Handbook on Moisture Determination

(ISTA, 2007) gives details about the importance and role of water in seeds, the importance of MC in other tests and guidance on the completion of the test.

Secondly, workshops and seminars are organized by the Technical Committees. These enable participants to learn from experts in each topic, more about specific tests or testing particular groups of species and to complete practical work. Face-to-face discussion both with the experts and other seed analysts from many countries provides a stimulating and informative experience. Furthermore, since attendance at the workshops and seminars is not limited to ISTA members, non-members can attend and begin to learn more about the importance of aspects of seed quality and methods of testing.

Thirdly, the ability of laboratories to satisfactorily complete specific aspects of seed testing on defined species is recognized by ISTA through the accreditation of laboratories. This means that the laboratories are audited regularly by both systems and technical auditors to ensure that ISTA methods are being applied correctly. Accredited laboratories must also participate in proficiency testing. This involves all the accredited laboratories testing the same samples and analysis of the resulting data to determine whether or not the results from each laboratory are within acceptable limits of all other results. In this way, the quality assurance of ISTA accredited laboratories is maintained.

Test Development

The ISTA Rules are not a static publication, since seed-testing methods and hence the Rules are continuously evolving. Further modification of existing tests and the development of new ones is part of the work of the Technical Committees. In addition, ISTA may appoint a task force to focus on a new and specific testing need. For example, this was the approach to the demand for testing for genetically modified organisms, with the appointment of a GM Task Force.

The work of a Technical Committee may lead to the production of evidence that an existing test could be modified to improve its performance or extend its species range, or a new test may be developed. At this point data is submitted to the ISTA Method Validation Programme (ISTA, 2009c), during which both technical and statistical reviewers examine the validity of the data. Successful completion of method validation usually leads to a new Rules Proposal, which ISTA members must approve before it is introduced into the next edition of the ISTA Rules.

Test development is also supported and stimulated by the seed science research that goes on within ISTA, by individual members and in the Technical Committees. This research has an outlet in both the triennial ISTA Seed Symposium and the ISTA Journal of Seed Science and Technology.

Concluding Comments

Seed quality is the sum of multiple components. The most important of these are species and cultivar purity, analytical purity and germination, while other significant components of seed quality are seed vigor, seed health and moisture content. Assessments of seed quality are possible through field tests and a range of laboratory tests that have been validated by the International Seed Testing Association to ensure the reliability and uniformity of test results from different laboratories. The modification and extension of the current tests and development of new ones is continuous within the ISTA Technical Committees. The completion of such tests provides information about a seed lot that is useful to the seed producer, the seed company and the farmer, to guide decisions during seed production, marketing and storage with the ultimate aim of achieving successful and efficient crop production.

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DISCUSSION

KATALIN ERTSEY: I have one question please: We have only a few methods for vigour tests in the ISTA Rules. What do you think Alison, what is the future possibility of general application of other vigour tests?

ALISON POWELL: Vigour tests will only be relevant where there is a problem of seed vigour within a species. Not all species will show differences in vigour for a variety of reasons. It is not relevant to apply vigour tests to all species without a problem of emergence or storage potential having been described in that species. You could also think about vigour tests being generally applied by having a single test for all species. We are not at that stage at the moment, but I think there is potential for two types of test for more general application. One is the conductivity test which is very attractive to people because it is rapid: there is potential for applying it to more species. The other is a new test that we are working on validation for at the moment and that is the rate of germination test. We hope to put in validation papers for that soon.

THE INFLUENCE OF SEED QUALITY ON CROP PRODUCTIVITY

Mrs. RITA ZECCHINELLI*

Summary

In all agricultural systems, the seed used for cultivation is considered one of the means of production. Moreover, the seed is the starting point, the first determinant of the future plant development and consequently the master key to success with its cultivation.

The expression “seed quality” is used in practice to describe the overall value of the seed for its intended purposes. It is a multiple concept resulting from the genetic characteristics of the seed and from other factors affecting its development, maturation and storability. Seed quality is a combination of different characteristics. Focusing on the effect of seed quality on crop productivity, the paper discusses the most relevant components identified in the choice of a suitable variety and in the characteristics affecting potential productivity, i.e. yield and market quality of the products derived from the cultivation. Seed storability is also mentioned, being an additional factor affecting seed quality and consequently crop productivity.

As secure seed supply systems are needed all over the world, a general overview on seed quality assurance is also provided, referring to the certification schemes established at international level, and to the need for uniform application of procedures and methods for seed sampling and testing.

Introduction

In the cultivation of plants for agricultural purposes, satisfactory results are reflected in a high yield of valuable products, resulting in economic benefits for the farmer and others involved in the agri-food chain.

Many production factors may affect the results of cultivation. Some of these factors depend on the geographical area, such as environmental conditions and soil characteristics; others on the economical framework, such as agronomic management (tillage, watering, fertilization, treatments). The farmer her/himself is a key factor, due to her/his skills, as far as she/he can take the relevant decisions and have access to suitable means of production. In the end, the market value affects the final result of the cultivation, depending both on local and global trends.

Wherever we are and whichever crop is cultivated, the quality of the seed used is the starting point and the most important factor for successful production. The seed is the first determinant of the future plant development and consequently of successful cultivation. Only the use of good quality seed will ensure that the advantages expected after the application of other means of production, such as watering or fertilization, are achieved. In addition, the use of good quality seed can prevent – or at least reduce - the use of costly inputs, such as chemical treatments aimed at controlling diseases or weeds, reducing at the same time the potential risks for the environment and human health. In a word, only the use of good quality seed will ensure satisfactory results from cultivation.

This is the reason why secure seed supply systems are needed all over the world, in order to get available seed of good quality to all the agricultural communities.

This is also the basis of different seed certification schemes established at national or international level and of the Quality Declared Seed System published by FAO in 1993 and revised in 2006 (1).

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Seed quality results from the functioning of the genome and from other factors occurring before and after the harvest (2). Seed quality is therefore a multiple concept, a combination of different characteristics and in practice it is used to describe the overall value of the seed for its intended purpose (3). Focusing on the effect of seed quality on crop productivity, the most relevant components may be identified in the choice and the availability of a suitable variety, in the characteristics affecting the amount of products derived from cultivation, in the quality of these products and in seed storage.

Seed Quality Factors Affecting Crop Productivity

To get satisfactory results from cultivation the seed needs to meet the requirements of the farmer in terms of the genetic characteristics of the variety, the potential yield and the marketable quality of the end product. Moreover, the good quality of the seed should be maintained up to the time of sowing.

Genetic Characteristics

Seed is the first critical input needed by farmers to improve and maintain their crop productivity. On this basis, seed security has been defined as the availability of the appropriate variety, at the right place and time, in sufficient quantity and quality (4). It is critical that any seed sold is the correct stated variety, for two reasons.

Firstly, the target of plant breeders is to introduce new varieties, the general purpose being to improve the cultivation and/or the yield and/or the quality of the derived products. It is interesting to remember that around 40 per cent of the total increase in agricultural production registered in the last 50 years at a global level has derived from the introduction of new varieties. Between 1929 and 1990 the yield produced by the cultivation of maize worldwide became four times greater and 75 per cent of this increased production has been derived from the introduction of new hybrid varieties (5). For the same period, Table 1 shows the increase in productivity recorded in Italy for maize and wheat. Compared to the years 1931-1935 (yield index = 100), the average yield per hectare rose in 50 years to a yield index of 416 (more than four times greater) for maize and to 201 for wheat (double) (6).

However, the potential of any new variety will not be realized or recognized if poor quality seed of that variety is released onto the market.

Table 1 Yield index (1931-35 = 100) for maize and wheat in Italy from the 1930s to the 1980s

(Table modified from Lorenzetti et al, 1994 (6))

	1931-35	1941-45	1951-55	1961-65	1966-70	1971-75	1976-80	1981-85
Maize	100	91	135	194	239	326	408	416
Wheat	100	87	121	143	163	183	195	201

Secondly, the farmer decides to select a variety on the basis of its agricultural characteristics, such as resistance to stress or disease, or its productivity and the recognized value of its products. He has therefore selected the variety for a specific situation and purpose, so it is essential that he has the correct variety.

Thus, the expected potential of a new variety or any well-known variety will not be expressed in actual advantages and profits if poor quality seed is used. This can be due to a deficiency in physical or physiological requirements, such as physical purity, germination, vigour, seed health, or to low genetic purity of the seed lot or even to a mis-identification of the variety.

Variety testing represents the most useful tool to evaluate the genetic quality of the seed and may be aimed at identifying the variety, to discriminate between different varieties, to check for genetic purity or to provide a characterization of the variety. The variety characterization is particularly significant for any new variety aimed at being registered in varietal catalogues in order to check its distinctness and to provide a description to be used for future needs. The possibility of evaluating a seed lot, identifying the variety to which it belongs, checking its purity, and discriminating between different varieties are crucial points for the seed trade and for seed certification schemes.

Various varietal testing methods have been developed and selected depending on the purpose of the test and on the part of the plant that is examined; seeds or seedlings (laboratory tests) or the whole plant during the course of its entire life cycle (field trials). Moreover, different approaches may be suitable for different species. Thus a wide range of solutions is available (7).

The list includes traditional methods based on the observation of morphological characteristics or on chemical reactions, biochemical methods (analysis of seed proteins or isozymes by electrophoresis) and the more recent DNA-based methods.

Crop Yield

The correlation between the quality of the seed used for cultivation and the yield obtained from this cultivation is universally recognized. Depending on the type of crop, the relationship between seed quality and crop yield is different and differently relevant. In general, germination capability and seed vigour represent the master keys to achieve the rapid germination and good emergence needed to ensure an appropriate plant population. Close-spaced crops that can tiller can compensate, to a certain extent, for the reduced emergence that results from lowered germination capability or seed vigour. Thus, tillering in cereals such as wheat, barley and rice can maintain a constant yield (production of seeds or grains per unit area) over a range in plant population (8). Of course, a very poor level of germination or very low seed vigour will affect the yield even in these crops, even more significantly if associated with other undesirable features (e.g. presence of weed seeds or seed-transmitted pathogens).

Germination and seed vigour are however more important for wide-spaced crops (e.g. maize, sugar beet, cotton, sunflower). Fig. 1 gives the different field emergence shown by samples belonging to different seed lots – all sown at the same time - when sowing is done in poor conditions (cold and wet weather).

Fig. 1 Maize Plot Trial (Italy, 2009): Field Emergence of Seed Lots with Different Seed Vigour



Germination and seed vigour are also highly significant for crops harvested during vegetative growth or before full reproductive maturity, such as many vegetable species. In these cases there is no compensatory growth, so a small reduction in the plant population can be the reason for a reduced yield (9).

Table 2 shows how emergence and seedling growth in Brassica species is affected by seed vigour. All samples in the laboratory showed high germination rates, while after controlled deterioration, the samples showed differences in seed vigour.

The lower seed vigour (lower CD germination) explains the higher emergence time (MET), the lower final emergence rate and the reduced seedling growth observed in the transplant modules (10).

Table 2 Effect of Brassica seed quality (CD germination = seed vigour determined by a germination test after controlled deterioration) on mean emergence time (MET), final emergence and seedling growth in transplant modules
(Table modified from Powell et al, 1991 (10))

Species	Sample	Laboratory germination (%)	CD germination (%)	MET (days)	Final emergence (%)	Plant height at 1st leaf stage (mm)	Coefficient of variation of plant height
Cauliflower	1	98	99	4.4 (4)	92	26.7	21.5
	2	90	37	6.2 (14)	88	19.8	25.9
Brussels sprouts	1	98	100	4.2 (3)	100	30.8	23.9
	2	100	57	4.7(3)	50	27.2	19.7
Dutch cabbage	1	98	95	4.4 (4)	98	21.8	27.0
	2	93	66	5.3 (6)	92	18.2	36.9
Red cabbage	1	97	97	4.6 (5)	98	25.6	22.1
	2	85	32	5.7 (7)	100	16.8	32.5
Calabrese	1	99	100	4.1 (9)	96	21.0	14.7
	2	93	54	4.1 (13)	92	21.0	20.5

Crop yield and productivity are also influenced by seed hygiene, that is, seed health, weed and insect contamination and high quality standards always have a positive effect. On the contrary, a noxious weed infestation or the occurrence of plant diseases can reduce the yield in all crops, directly, or as a result of competition for physical resources or exploitation of plant resources.

Of course, some circumstances make the presence of noxious weed or of pathogens a more serious issue. This is the case of organic farming, where the agricultural practice limits the use of chemical treatments and the possible risk of contamination with weeds and pathogens transmitted by the seed become greater than in conventional systems (11).

This is also the case in some areas where the availability or the costs of herbicides and other chemicals represent a challenge.

Here it is worth mentioning that for some seed-borne pathogens (e.g. bacteria) no effective chemical methods are available and the most suitable way to prevent disease is the use of healthy seed.

In order to ensure high yields worldwide and to maintain high productive standards, seed testing again plays a very important role. Evaluation of seed quality by purity and germination tests have been common practice since the beginning of the history of seed testing, when Prof. Nobbe founded in Germany the first seed testing station in 1869. Purity and germination still represent the most popular kinds of test many seed testing laboratories are asked to carry out with the aim of ensuring high germination and freedom from undesirable weed seeds. The physical purity test is carried out with the aim of evaluating the percentage of pure seed, of seeds belonging to other species and of inert matter. The identification of the other seeds retrieved is also required. The object of the germination test is the evaluation of the maximum germination potential of the pure seed. The seed is therefore germinated in optimal conditions to allow the maximum expression of its potentiality. To evaluate the planting value of a seed lot in a wide range of environments, providing additional information to the standard germination test, a range of vigour tests is available (12). Worldwide high purity and germination standards are important, while the additional evaluation of seed vigour is often required in more developed agricultural systems.

Many seed certification schemes provide minimum germination and purity standards. These schemes often also include requirements concerning particular species that are considered to be very dangerous, whose presence in the analyzed sample is limited or even banned. Examples are some parasitic plants, such as *Cuscuta* spp (Fig. 2) and *Orobancha* spp.

Seed health testing laboratories are asked to carry out a range of analyses as seeds may be contaminated or infested by different types of pathogens, fungi, bacteria, viruses and nematodes. These tests may be addressed to check quarantine requirements established by phytosanitary regulations with the aim of avoiding the entry of dangerous pathogens in non-infected areas or in general to prevent

the spread of economically important pests. Seed health testing is also required by some certification schemes or carried out routinely for monitoring purposes.

Fig. 2 *Cuscuta* spp in a Seed Sample and in a Field of *Trifolium resupinatum* (Persian Clover)



Quality of the Products derived from Cultivation

The marketable quality recognized in the product obtained from a cultivation contributes to its final economical output. Firstly, this value is once again a consequence of intrinsic features, i.e. the genetic characteristics of the species and the variety. As an example, Triticum species and varieties are characterized by a different grain composition, in particular of the storage proteins, that make the different species and the different varieties suitable for the production of pasta, bread, biscuits or other milled products. Mixtures of species or varieties may reduce the market quality and the quotation recognized to the farmer (Fig. 3).

Fig. 3 *Triticum aestivum* in a Field and in a Seed Sample of *Triticum durum*



Other factors are also important: the occurrence of a seed-borne disease may reduce not only the yield, but also the marketable value of the products showing symptoms of the disease, particularly in horticultural crops.

Low germination as low vigour affects plant density in the field or in the greenhouse and this may cause differences in the growth of the plants. In root vegetables (e.g. carrot, horticultural swede), this situation is translated into varied root size and hence in a reduction of its market value.

Low germination and seed vigour do not allow for the uniform emergence that is necessary in the production of young plants to be transplanted (tomato, pepper, eggplant, cabbage, tobacco, forest species) or in the case of vegetable crops aimed to be harvested at regular and planned times, for example for freezing (peas), or when plants uniform in size and stage of development are required (green vegetables, i.e. lettuce).

Seed Storage

Seed quality is also affected by factors occurring during post-harvest stages. The storage life of seeds depends on storage conditions (temperature, relative humidity), on the initial quality of the seed and on its moisture content.

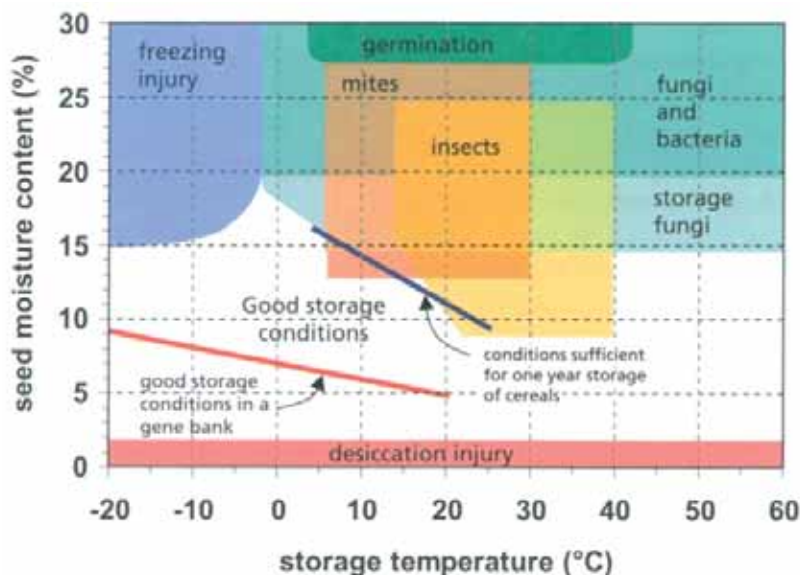
Moisture content may affect seed storability in a different way, depending on the species. Categories of seeds have been proposed to group the species in relation to their post-harvest behaviour, i.e. orthodox, intermediate or recalcitrant. A detailed discussion on this classification, as on other subjects related to the moisture content in seeds, can be found in the ISTA Handbook on Moisture Determination (13). In general, low moisture content promotes the storability of orthodox seeds, while the viability and storability of recalcitrant seeds is affected in a negative way by low moisture content.

Under uncontrolled storage conditions, seed moisture content may show wide variations, depending on ambient conditions. In tropical countries with high humidity and temperatures, orthodox seeds stored in poor conditions lose their ability to germinate: the lower is the initial seed quality, the quicker is the loss of viability.

Seed moisture content also affects the activity of pathogens and in particular of insects and mites, causing additional damages.

Fig. 4 is taken from the ISTA Handbook on Moisture Determination (13). It shows the effects of the combination of seed moisture content and storage temperature on the storability of seeds and the risk of injuries and infestations which can occur in the different conditions.

Fig. 4 Biological Activity in and around Seeds during Storage (13)



For all these reasons, seed moisture content has always been one of the parameters taken into account to determine the market value of seed, and its determination by suitable testing methods is therefore very important. Following the definition provided by the ISTA Rules (10), the moisture content of a sample is the loss in weight when it is dried. It is expressed as a percentage of the weight of the original sample.

Certification as a Means to achieve Good Seed Quality

The relevance of seed quality is recognized by all the seed certification schemes. Moreover, the need for good quality seed is itself the basis of these schemes.

The EU established a seed certification system, starting in the 1960s (the EU Seed Directives may be downloaded from <http://eur-lex.europa.eu>; useful lists and links are also available on the European Seed Association website: <http://www.euroseeds.org/static/worldwide-links>).

EU Seed Directives regulate the marketing of seed of different groups of species (cereals, fodder plants, oil and fibre plants, beet species, vegetable species, seed potatoes). They are based on the assump-

tion that satisfactory results in cultivation depend to a large extent on the use of appropriate seed. The EU certification schemes take into account the characteristics of the variety. Moreover, the EU Seed Directives take into consideration other kinds of requirement such as the requirements checked by lab testing (for the majority of crops, germination, purity, other seed determination).

The objective of the OECD Schemes for the Varietal Certification (six schemes for six groups of agricultural species) or the Control (a scheme for vegetables) of Seed Moving in International Trade is to encourage the use of seed of consistently high quality in participating countries.

The assessment of seed quality, and particularly of its genetic/variety characteristics, is based on agreed principles and rules. Fifty-seven countries from all geographical areas are participating in the OECD seed schemes (http://www.oecd.org/document/0/0,3343,en_2649_33905_1933504_1_1_1_37401,00.html). Both in the case of the EU and OECD schemes, the evidence of certification is given by labels and certificates.

The importance of seed quality assurance is also the basis for ISTA's work and activities in addressing the different aspects of seed quality evaluation.

The ISTA vision is "Uniform in Seed Testing" world wide and its mission describes how to achieve this vision. ISTA's primary purpose is to develop, adopt and publish standard procedures for sampling and testing seeds, and to promote uniform application of these procedures for the evaluation of seeds involved in international trade. The ISTA Rules include standardized methods for seed sampling and testing (e.g. germination conditions and methods are provided for over 1000 species), together with other useful information, such as definitions and instructions for reporting testing results.

FAO recognizes that seed quality assurance is a key factor for establishing food security, particularly in developing countries. Nevertheless in many countries seed and propagating material available to farmers are often of insufficient quality.

For these reasons, FAO decided to support countries in raising the quality of seed produced locally and used by small-scale farmers. In 1993, FAO presented the Quality Declared Seed System, later revised in 2006 (1). The system includes guidelines to be applied in the production of quality seed. It provides an alternative for seed quality assurance, particularly designed for countries with limited resources and it is less demanding than full seed quality control systems but yet guarantees a satisfactory level of seed quality.

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DISCUSSION

PETER LATUS: PETER LATUS FROM THE SWISS FEDERAL OFFICE FOR AGRICULTURE. The first two speakers did not point out the necessity of very good seed sampling, and I would like to point out that the work you do in the laboratory only can be as good as the sample representing the seed lot. So that is what I wanted to say. Thank you.

KATALIN ERTSEY: Thank you for this remark, because it is a very important topic. I underlined also but time is short.

BERT VISSER: My name is Bert Visser from Wageningen University. I have a technical question and this relates to the role of seed moisture to vigour and plant emergence. Is it your view or your opinion or experience that there is a linear relationship in the sense that when seed moisture decreases, seed quality improves and vigour improves and plant emergence improves, or is there an optimum in seed moisture contents? What is your view on that?

KATALIN ERTSEY: I think this question is for two speakers and I think it is a very important question as well and there are also some differences between the really scientific results and also the minimum requirements in the laws; therefore I think we can postpone this question to the general discussion. Thank you. OK?

JACQUES GENNATAS: Thank you Madam. Gennatas from the European Commission. As we got the second talk by Ms. Zecchinelli, I have a short question. You mention the criteria to accredit laboratories. On which base do you accredit laboratories; governmental and non-governmental laboratories? Do you have ISO standard or what are the standards for accreditation? Thank you very much.

RITA ZECCHINELLI: I have to say that I did not mention accreditation in my talk, but nevertheless. I do not understand if your question referred to ISTA accreditation or to the authorisation... No, to ISTA accreditation.

KATALIN ERTSEY: Please, I would like to postpone also this question because the next presentation covers this item and I hope you will get your answer. OK? Thank you.

THE EVOLUTION OF SEED TESTING

Mr. MICHAEL MUSCHICK*

Introduction

With the change from hunting and gathering to agricultural and animal production in the Neolithic revolution, seeds, or to be more precise, healthy seeds, have become one of the most important products for the survival of human beings. The knowledge that seeds are the part of the plant that have the potential to produce new, healthy plants is the key to food production, food security and ultimately survival of the population. It was obvious, very early on that environmental conditions have a major influence on the successful realization of the potential of a seed to produce a healthy plant and in all religions you find examples of praying to God, or the gods, for favorable environmental conditions. However, it took until the beginning of the 19th century before researchers and botanists started to intensively study the morphological characteristics of seed and start investigating their physiology and that of the germination process.

The Origins of Seed Testing

By the 19th century the sale and trade of seed existed in Europe. Merchants were traveling over long distances from market to market to sell seed and local farmers offered seed for sale or barter to their neighbors and at local markets. Nothing was known about the purity of the seed that was traded nor even its potential to produce a crop (Nobbe, 1876).

It was in April 1869, when a Saxon agronomist, the Count of Lippe-Weissenfeld, submitted several grass seed samples, bought on the local market, for botanical recognition to Prof. Dr. Nobbe, a botanist working at the Royal Academy for Foresters and Agronomists at Tharandt, Saxony, Germany (Nobbe, 1876). Surprisingly, one sample tagged "Tall Fescue" turned out to contain only 30% true seeds and other seed samples that were sent to the Academy for growing trials had similar shortcomings and other deficiencies.

Prof. Dr. Nobbe initiated further investigations on the quality of traded seed and found that the situation was far from acceptable. He quickly realized that in addition to the limited knowledge of traders and farmers regarding seed species identification, there was also a lot of cheating, swindling and fraud in the seed market. Consequently, this resulted in his publication in May 1869 entitled: *On the Necessity for Control of the Agricultural Seed Market*.

In terms of seed quality Prof. Dr. Nobbe considered what to measure, how to measure and when to measure. Addressing these questions he proposed that measurements should be made of the true-ness to species, the purity of seeds and the potential the seed has to produce healthy seedlings. He also came up with the revolutionary idea that these measures of quality should be assessed before the seed was sold to farmers so they could be sure that the seed they bought had the potential to give them a good harvest. This inspiration would not only tackle the cheating, swindling and fraud that existed in the seed market, but would also give farmers an assurance that they had the necessary starting material for a successful harvest, provided the environmental factors were reasonably favorable and the farmer used the necessary cultivation and husbandry skills. Implementing Prof. Dr. Nobbe's ideas was the key to an increase in overall plant production.

From a technical point of view many questions arose:

- ▶ How do you obtain a representative sample from a lot that is to be sold?
- ▶ How can one ensure that seed quality results represent the quality of the lot that has been tested?

* Secretary General, ISTA

- ▶ How do you differentiate between the seeds of different species?
- ▶ How do you measure the germination potential of different species?

Answers required an understanding of populations and a detailed knowledge of the morphology of seeds and plant and seed physiology. Prof. Dr. Nobbe immediately rose to the challenge and worked out methodologies for sampling and testing (Nobbe, 1876). This was the starting point for seed testing which consists, in effect, of measurements made to determine the potential and value of seed before it is planted in the field.

International Spread of the Idea and International Collaboration 1869 - 1924

Nobbe's revolutionary ideas spread rapidly around the world. Already, in 1875, 12 seed-testing stations had been established in Germany, Austria-Hungary, Belgium, Denmark and the United States and in the period 1876/77 more than 20 new seed-testing laboratories were founded. In 1896, a good quarter of a century after Nobbe's initiation, there were a total of 119 seed-testing stations in 19 different countries (Steiner and Kruse, 2006).

All of these stations were actively gathering information on the seed market and working on the identification of different species of seed and the development of sampling, purity, germination and moisture methodologies for an increasing group of species. Seed health observations were also being made. It is obvious that this work involved the application of scientific principles and a deep knowledge of plant morphology and physiology was required. This accounts for the fact that nearly all of the heads of these seed-testing laboratories came from academia and had been botanists.

In 1875 a first meeting of directors of seed-testing stations took place in Graz where experiences were shared on the development of the methodologies. It was recommended that the methods in the Handbook of Seed Testing by Nobbe, which would be published in 1876, should be standard use in seed-testing laboratories. A follow-up meeting took place in Hamburg in 1876 and the motto "Uniformity in Seed Testing" was coined and discussions were initiated on how to achieve it (Steiner and Kruse, 2006). Even today this topic continues to be on the agenda.

In 1906 a first Conference for Seed Testing was held in Hamburg, Germany and this can be viewed as the starting point for seed-testing conferences. The second seed-testing conference was held in Münster/Wageningen, Germany/Netherlands in 1910; the third conference took place 1921 in Copenhagen, Denmark and the fourth in 1924 in Cambridge, UK.

Since the first conference in 1906 there has been a desire to work towards standards for seed testing; internationally approved methods; the uniform application of these methods. To help achieve this, the European Seed Testing Association was founded at the 1921 meeting in Copenhagen (MAF, 1925).

1924 – The Founding of the International Seed Testing Association

At the conference in 1924 in Cambridge it was decided to enlarge the scope of the European Seed Testing Association and to extend its activities to all the countries of the world in which the testing of seeds was practiced. It was also decided to re-constitute it under the name of the International Seed Testing Association (MAF, 1925).

Paragraph 1 of the 1924 ISTA Constitution stated:

"Under the name of the International Seed Testing Association, a union of Official Seed Testing Stations with legal domicile at the residence of its President exists for the purpose of advancing all questions connected with the testing and judgment of seeds. The Association seeks to attain this object through:

- (a) Comparative tests and other research directed to achieving more accurate and uniform results than hitherto obtained.

- (b) The formulation of uniform methods and uniform terms in the analysis of seeds in international trade.
- (c) The organization of international congresses attended by representatives of Official Seed Testing Stations for the purpose of mutual deliberation and information, the publication of treaties and reports on seed testing and mutual assistance in the training of technical officers”.

The first President was Mr. K Dorph Petersen from Denmark and the Vice President was Dr. Franck from the Netherlands. In addition to the office holders there were three Executive Committee members: Prof. M.T. Munn, US, (who was also President of the AOSA), Mr. W.V. Petery, Argentina and Mr. A. Eastham, UK.

Nine Committees were established:

1. Research Committee for Countries with a Temperate Climate
2. Research Committee for Countries with a Warm Climate
3. Provenance Determinations
4. Hard Seeds and Broken Seedlings
5. Moisture Content and Drying
6. Investigations of Genuineness of Variety and of Plant Diseases
7. Dodder Committee
8. Publications and Registration
9. Beet Sub-Committee

1931 – The Establishment of the International Rules for Seed Testing 1931

The Chairman of the Research Committee for Countries with a Temperate Climate, Dr. W.J. Franck, Wageningen, Netherlands, presented the first draft of international rules for seed testing at the 5th Seed Testing Conference in Rome (ISTA, 1931). The draft was not, however, approved due to certain disagreements on purity tolerance as well as on the evaluation of germination capacity.

At the 6th International Congress of Seed Testing held in Wageningen, Netherlands on July 17,, 1931 a revised version of the International Rules for Seed Testing was put to the vote and approved (ISTA, 1931).

These rules describe:

- ▶ Sampling
- ▶ Purity testing
- ▶ Germination
- ▶ Additional determinations
 - Sanitary condition
 - Genuineness of variety
 - Provenance
 - Weight determinations
 - Determination of the moisture content
- ▶ Evaluation and reports
- ▶ Tolerances
- ▶ Hard seeds
- ▶ International certificates

Since the establishment of the ISTA International Rules for Seed Testing, discussions have continued in all these different areas of seed testing and new test concepts have also been added to the Rules. Existing chapters have continuously been revised, modified and enhanced to increase uniformity, efficiency and effectiveness.

The historical papers of ISTA and ISTA's journal publications (Proceedings of the International Seed Testing Association which was renamed Seed Science and Technology in 1973) give a detailed insight into the different discussions, developments and important milestones in the area of germination, seed health and purity testing (see Jensen, 2008; Klitgard, 2002; Mathur and Jorgensen, 2002). Today, the ISTA Rules are set out in 16 different chapters and sum up the findings of 140 years of worldwide research and the discussions at 28 seed-testing congresses.

1931 – The Establishment of ISTA International Certificates

With the establishment of the international rules for seed testing and a uniform reporting system, a certificate that facilitated the international trade of seed was established. The 1931 Ordinary Meeting of the Association adopted two different certificates, the Orange International Seed Certificate and the Blue International Seed Certificate. The Orange Certificate gives results representing the average quality of the seed lot which has been sampled according to ISTA Rules. The Blue Certificate gives results that relate to quality of the sample submitted for testing (ISTA, 1931).

1950 – The 9th International Seed Testing Congress in Washington, US

The 8th International Seed Testing Congress took place in 1937 in Zurich, Switzerland. At this Congress, an invitation from the Association of Official Seed Analysts of North America to hold the next congress in North America was submitted and accepted. Unfortunately, however, the war intervened and the Congress had to be postponed. After the end of the war international connections were gradually re-established with the resumption of correspondence between the Executive Committee and other members of the International Seed Testing Association. The need for working towards “Uniformity in Seed Testing” was still obvious and the 9th International Seed Testing Congress was held from May 8 -13, 1950 in Washington, D.C., US. During this Congress, alterations to the existing International Rules for Seed Testing were tabled and a new Constitution of the International Seed Testing Association was proposed, discussed and voted on (ISTA, 1951).

1966 – Introduction of Seed Health Methods in the International Rules for Seed Testing

Already in 1907, Appel had drawn attention to the fact that information on the occurrence of seed-borne pathogens could be obtained during seed testing in the laboratory. In 1919 the Seed Testing Station at Wageningen established a special division for studying the sanitary conditions of seeds. With the foundation of the International Seed Testing Association in 1924 the Committee for Investigation of Genuineness of Variety and of Plant Diseases was founded and in 1928 a separate committee, the Plant Disease Committee (PDC), was founded. In 1928, the Chairman of the PDC suggested to the 5th ISTA Congress that information on the occurrence of certain fungi on seed samples should be reported on ISTA certificates (Mathur and Jorgensen, 2002). The Congress agreed that such information could be of advantage, but also realized that not many seed-testing stations had sufficient experience and before such information could be put on the certificate, a number of comparative examinations should be undertaken to ensure that the results reported by the various stations agreed within reasonable margins.

The aim of the comparative testing program was the establishment of internationally standardized seed health testing procedures. With selecting methods to be included in the ISTA Rules, the results of comparative seed health tests had to be evaluated carefully in order to select methods that gave rise to uniformity of results between laboratories carrying them out. In 1966 the first specific seed health testing methods were included in the ISTA Rules (Mathur and Jorgensen, 2002). Today, the ISTA has standardized 21 seed health testing methods, which are included in the ISTA Rules and can also be downloaded free-of-charge from the ISTA website.

1966 – Introduction of the Topographical Tetrazolium Test in the International Rules for Seed Testing

The topographical tetrazolium test is a biochemical test that may be used to make a rapid assessment of seed viability: when seeds have to be sown shortly after harvest; in seeds with deep dormancy; in seeds showing slow germination or in cases where a very quick estimate of germination potential is required. Biochemical viability tests were introduced to seed testing by Hasegawa and a report was given at the 1937 ISTA congress in Zurich introducing the Eidamnn-Hasagawa method. In 1939, Lakon, at Hohenheim, Germany, started working in this field and made a presentation at the 1950 ISTA Congress with the title: “Further Research regarding the Topographical Tetrazolium Test and the

Determination of the Viability". In 1956, the ISTA Tetrazolium Committee was set up and in 1966 the Tetrazolium test was introduced as a standardized test into the International Rules for Seed Testing (Steiner, 1997).

1995 – The Establishment of an International Accreditation Standard for Seed Testing Laboratories by ISTA

The achievement of accurate results and the uniformity of seed testing results, or to update the language, the reproducibility of results, has been an important point of discussion and consideration since seed testing was started by Prof. Dr. Nobbe in 1869.

Prof. Dr. Nobbe initiated comparative tests in 1877 and method validation has been a part of ISTA's activities since the beginning of seed testing. With the introduction of quality management systems, particularly those for analytical laboratories in the 1970s, quality management became a topic for discussion in seed-testing stations and at seed-testing congresses. The establishment by the OECD of the Guidelines for Good Laboratory Practice (GLP) was a starting point for this development. The aims of the GLP can be described as: the traceability of analysis through documentation; the definition of responsibilities and clear, precise descriptions of the organization; and the production of accurate and reproducible results of products.

The overall development and discussion resulted in the generic standard ISO 17025 for the accreditation of all types of analytical laboratories. Nevertheless, at an early stage seed scientists realized that for seed-testing laboratories special conditions were required and many of the requirements of ISO 17025 had already been realized in seed-testing stations.

An ISTA working group operating in the period 1992-1995 developed the ISTA Accreditation Standard for seed-testing laboratories. This standard was approved at the Ordinary Meeting in 1995. The already existing "referee tests", as they were called at that time, were modified, extended and adopted to become international proficiency tests and an internationally operating accreditation body was founded at the ISTA Secretariat. This body was tasked with carrying out the required three-yearly quality assurance assessments of laboratories that applied to be ISTA-accredited. In addition, the 1995 Ordinary Meeting of ISTA decided that only ISTA-accredited laboratories could issue ISTA certificates from 2001 onwards (ISTA, 1993; ISTA, 1998).

2001 – Introduction of the Vigour Methods into the International Rules for Seed Testing

Seed vigour is the sum of those properties that determine the activity and performance of seed lots of acceptable germination in a wide range of environments, and the objective of a seed vigour test is to provide information about the planting value of seed lots in a wide range of environments and/or their storage potential. Discussion regarding the inclusion of vigour methods in the ISTA rules started during the 26th ISTA Congress in 1998 in Johannesburg, South Africa; however, critical voices were raised and the proposal was withdrawn, revised and forwarded to the 27th ISTA Congress in 2001 at Angers, France. At this Congress, ISTA member governments voted for the inclusion of two vigour methods into the ISTA International Rules for Seed Testing - the conductivity test for *Pisum sativum* and the accelerated aging test for *Glycine max*. At the 2009 Ordinary Meeting of ISTA in Zurich, the conductivity method was extended to include *Phaseolus* beans and the controlled deterioration vigour test method was added for Brassica species (ISTA, 2001).

2004 – The Introduction of Performance-Based Methods for GM Testing

With the introduction of genetically modified varieties and their commercial release in some countries, seed-testing laboratories were being faced with new challenges. Questions on purity of GM seed lots as well as the adventitious presence of GM seed in non-GM seed lots were at the center of the discussions. Since 2000, the ISTA GMO Task Force has discussed intensively these questions. For ISTA, the fundamental question was whether it would be possible to achieve international harmonization of the

testing methodologies. It was concluded that method development in this particular area is so vibrant that the standardization of testing methodology is nearly impossible since by the time agreement for a certain methodology had been achieved the methodology would most likely already be outdated. Furthermore, it was realized that the implementation of a standardized methodology in a laboratory could in this instance create major obstacles and produce a negative effect resulting in less accurate results. For these reasons the concept of performance-based methods was discussed, proposed and accepted for methodologies in this particular area of testing. Under this approach a laboratory is entitled to use any method it considers adequate on condition that the laboratory provides sufficient performance data for the methodology according to clearly defined requirements. This approach received the backing of ISTA member governments and, today, Chapter 8 of the ISTA International Rules for Seed Testing specifies this kind of test principle for bio-molecular tests and bioassays used in testing for the presence of specified traits (ISTA, 2004).

2004 – Opening-up of ISTA's Quality Assurance Program to Private Sector Laboratories including the Issuance of ISTA Certificates

At the 28th ISTA Congress in 2004 in Budapest, Hungary, a proposal was accepted that permitted private sector laboratories to issue ISTA certificates under the same conditions that applied to public sector laboratories, i.e. they must participate in the ISTA Quality Assurance Program, successfully participate in ISTA proficiency tests and achieve ISTA accreditation. Therefore, the focus, for issuing certificates now depends on the individual performance of a laboratory rather than on its status. Strict monitoring guarantees the performance of the labs (ISTA, 2004).

Recent Developments

Since the beginning of the 1990s it has become evident that there has been a reduction in investment in nearly all areas of seed technology at university level and within public seed-testing stations (Jensen, 2008). Since then, important international training programs at university level have ceased (e.g. the training programs in Edinburgh and Mississippi State Universities). This development needs to be seen as a threat to seed work in the public as well as the private sectors. Today, there are almost no universities offering specialized training in seed science and technology. The consequences of this development are unavoidable.

The reduction of capacities in the public sector and in large public seed-testing stations reduces activities in applied seed science. The reduction of resources means that stations' activities are limited to the performance of simple routine control and monitoring tasks and this reduces their ability to provide on-the-job training for seed analysts from developing countries. Furthermore, with the increasing activity of applied seed science in the private sector being used to competitive advantage in business, research results are not published and uniformity in seed testing is threatened. This, without any doubt, could have negative implications for the international seed trade. It is recommended that governments, the public and private sectors carefully consider these developments, draw the right conclusions from them and take appropriate action to address them.

Conclusions

Seed testing, as a concept to determine the value of seed before it is planted in the farmer's field, has spread rapidly throughout the world since its inception in 1869 and is used universally to provide information on the planting value of seed to the farmer and the legislator. An in-depth knowledge of plant and seed morphology, taxonomy and physiology were prerequisites for the development of seed-testing methodologies and leading players in the method development field have been scientists

dealing with the wishes and needs of the seed trade and seed markets. Likewise, research and development activity in different areas of seed science and technology also increased rapidly throughout the world and today's International Rules for Seed Testing are the result of the combined knowledge of 140 years of applied seed science and the essence of the discussions at 28 international seed congresses.

Quality management systems have been successfully introduced and put into practice at the global level. An evaluation of the results of this (e.g. proficiency tests, performance of accredited laboratories compared to non-accredited laboratories) demonstrate that this has been a success in optimizing the performance of laboratories and minimizing the risk of inaccurate testing.

From the founding of ISTA until around 1990, most ISTA seed laboratories received substantial financial support for both the running of their laboratories and for support for international activities in ISTA and similar organizations. Due to decreasing government support and privatization of seed-testing services, the voluntary work within the technical committees of ISTA as well as the transparent sharing of recent research results has become more and more limited. This lack of clarity of responsibility between the public and private sectors and the reduction of resources, as well as the use of recent research work as competitive advantage for single companies, is seen as a threat and the major challenge for successful continuation of the evolution in seed testing: policymakers, the seed industry and farmers should keep this in mind.

It is obvious, that the evolution of seed-testing methodologies has not reached a conclusion:

- ▶ Continuous improvements and research are necessary and are required to enhance efficiency and effectiveness of seed testing and provide the tests needed to meet the changing needs of the market.
- ▶ Quality assurance management needs to be further developed to minimize the risks and give customers confidence.
- ▶ DNA technology will result in progress, new needs and challenges for seed testing.

The evolution of seed testing needs to continue.

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DISCUSSION

ORLANDO DE PONTI: My name is Orlando de Ponti, President of the International Seed Federation. Mr. Muschick I think it is very important that you mentioned in your final slide that we are facing the situation that in the public arena, universities, institutes, there is a decreasing attention/investment in the development of new testing procedures based on latest developments in scientific fields. Yesterday during various sessions we have emphasised the importance of public-private collaboration, and I would like to mention that it is urgent, and I know you are very much aware of it, that within ISF we have what we call the International Seed Health Initiative where scientists, mainly pathologists, from companies are working together - and I would really mention this very clearly - in a non-competitive way, to develop more efficient, more cost effective seed testing procedures. They do this in their own circles and in very close collaboration with ISTA, and, as you know very well, many of those new tests have been adopted by ISTA. And I think it is very important for the audience here that they know that this is an excellent example of public-private collaboration. Thank you.

SAM KUGBEI: Sam Kugbei from FAO. The developments in the last 10 years you indicate, especially in the area of training, that it has gone down very badly. But that has coincided with the rapid development of the private sector in the seed industry. Do you think there is any role the private sector can play in correcting these defects in training?

MICHAEL MUSCHICK: Thank you for this question. It is a very good question. I can imagine that the private sector is playing a role in that, but let me stress very clearly today that we are lacking training and urgent actions are really required. So I am very open and I see a lot of possibilities in the public sector as well as in the private sector to address this gap. But in my opinion the gap needs to be addressed now.

GRETCHEN RECTOR: I am Gretchen Rector from Syngenta and my question is both historically and today in an economic downturn, how do you prioritize which tests are going to research? Is it crop related, is it pathology? How do you prioritize the need for testing?

MICHAEL MUSCHICK: Our priorities are that we are in constant consultation with our stakeholders and from there we are getting the information what is required on the one side to facilitate the seed trade; on the other side there are the needs and the requirements of governments which we are taking into consideration, and this is where we define our priority list; then we use the resources we have to address these questions.

KATALIN ERTSEY: Thank you. I have one more remark about the participation of the private laboratories, because since the 2004 Budapest Congress, the ISTA Accreditation Standard and the ISTA Accreditation and Quality Assurance System are free also and open - not free but open - for the company and private company and independent private laboratories as well. And I think if we follow the results of the proficiency tests and we see the results from the accredited laboratories, then we can see that these participations from the private side, I think it was a benefit also for all the seed sectors. I think that now the share of the private laboratories is about 25% in our Association and I hope we can value this project as well. Thank you.

BUILDING CAPACITY IN SEED QUALITY ASSURANCE IN DEVELOPING COUNTRIES

Mr. MICHAEL LARINDE*

Introduction

In this era of rapidly changing global conditions and increasing food insecurity, improved varieties and good quality seeds are required, more than ever, to confront the challenges that the changes bring. Improved seed is the carrier of technological innovations and serves as an engine for agricultural advancement when available in the required quantities and of the right quality. As in the past, the pivotal role that seed plays in national food security arrangements makes it a commodity for trade and politics. Improved seed is also an important agent for technology transfer. In all its various contexts, however, the quality of seed is crucial if it is to meet the full requirements expected of it. Indeed, in seed production and supply activities, seed quality constitutes a more serious source of concern than seed quantity.

Seed quality assurance is a mechanism put in place to guarantee the quality of seed from production, harvesting, and post-harvest handling through sales. Seed quality assurance is a systematic and planned procedure for ensuring the genetic, physical and physiological integrity of the seed delivered to farmers.

The term “seed quality assurance” implies that agencies charged with seed quality cooperate with and support stakeholders in other areas of the seed industry to assure quality products. Some of the basic objectives of quality assurance are the prevention of chronic troubles, diagnosis of such troubles and development of appropriate remedies for their resolution. Overall, elements covered by seed quality assurance include variety release, proper land selection, field crop inspection, seed testing and seed control (pre- and post-control). In these elements, four important seed quality parameters - genetic purity, physical purity, physiological condition and seed health status - are the focus.

The rationale for seed quality assurance includes, among others, the need to:

- ▶ ensure that the best quality seeds are produced and sold to farmers;
- ▶ prevent the spread of weeds, pests and diseases, particularly the invasive types;
- ▶ meet consumer demands for specified qualities;
- ▶ cater for the needs of specialized farming;
- ▶ comply with mechanization of agriculture; and
- ▶ provide the basis for healthy competition among seed traders.

To carry out effective capacity-building for seed quality assurance, a holistic approach is required. First, the assessment of various components of the seed industry, at whatever stage of development, needs to be properly conducted. Second, there is a need to ensure the development of adequate linkages between the components. Third, a good coordination mechanism needs to be established. Fourth, it is essential to have and pursue a program for human resource development in order to ensure the deployment of the needed skills. Fifth, it is essential to install facilities and equipment, particularly for quality checks. Last but not least, formulation and application of norms, standards and guidelines and legislation where applicable will be essential.

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State Of Quality Assurance Systems in Developing Countries.

In the 1970s through the late 1980s, the green revolution in Asia spurred donors to fund a wide range of seed projects in developing countries. Most of these projects contained a good range of elements of the seed industry; several seed technology institutions in developing countries played prominent roles in the provision of training in this “new field of agronomy”. These training efforts yielded very positive results in advancing the knowledge of seed and fostering the development of the seed sector in developing countries, particularly in Asia.

Unfortunately from the 1990s, resource support to knowledge and training institutions active in seed-technology training, particularly those targeting Africa, started to wane, leading to the discontinuation of the pioneering training efforts. Further, investments in the seed sector in developing countries from donor countries and international organizations decreased, resulting in a rapid degradation of key infrastructures and institutions of the seed sector, particularly seed quality assurance systems, such as seed laboratories and seed-processing plants. Most of the seed technologists trained in the 1970s and 1980s gradually reached retirement age or moved to higher career levels in different fields not related to seed. This created a gap in seed knowledge in developing countries. This gap resulted in reduced capacity and capability in developing countries with consequent decline in the availability of good quality seed to farmers. To fill the technology and knowledge vacuum, the private seed sector, especially the multi-nationals, started to make provision for the training of their staff within their own resources.

In order to assess the capacity-building needs of member countries, FAO has established or collaborated in the establishment of some databases/information systems, shown in Appendix 1. A summary of seed sector analysis in developing countries shows that they are at varying stages of development - between and within sub-regions - on issues related to seed quality assurance. In addition, there is marked variation in the levels of quality control arrangements based on crops – being more elaborate and sophisticated for commercial crops than for non-commercial food security crops.

A recent survey carried out in 22 African countries to assess the stage of seed quality assurance in Africa, reveals a general need for capacity-building in several aspects of the discipline as shown in Table 1 below.

Table 1 Percentage of Countries with their Respective Level of Development in Key Aspects of Seed Quality Assurance (Based on a FAO survey in 22 countries)

<i>Item</i>	<i>Percentage of countries with a reasonably high level of development</i>
Existence of national seed policy	18
Seed legislation	23
Availability of variety development program	55
Variety release system	41
Variety release committee	45
Seed conditioning plants available	59
Seed quality control and certification	68
Official seed-testing laboratories	73
Trained inspectors and lab technicians	59

The survey found that often one aspect of quality control might be over-emphasized while other equally important ones were neglected. In extreme cases, countries make inappropriate seed laws thinking that legislation is the panacea for all seed quality problems. This often results in restriction of inflow of good quality seed from outside or leads to the public sector seed producers being favored at the expense of the private seed sector. This eventually leads to the monopoly of the seed sector by the public sector and resultant inadequacy of good quality seed for farmers. The survey also identified varietal release, legislation and seed crop inspection as components of seed quality assurance which are particularly weak.

Other constraining factors in quality assurance assistance in developing countries relate to inconsistent funding, inadequacies in trained staff and limited equipment.

FAO's Capacity-Building Activities in Developing Countries

FAO's core activities relating to capacity-building in quality assurance include assistance to develop the following:

- ▶ national varietal release system;
- ▶ early-generation seed production system;
- ▶ structured training program for stakeholders of the seed sector;
- ▶ review and drafting of appropriate seed legislation and regulations;
- ▶ national seed policy;
- ▶ harmonization of seed rules and regulation at regional and sub-regional levels;
- ▶ seed quality control schemes, such as certified seeds, Quality Declared Seed (QDS)¹ and Quality Declared Planting Materials (QDPM)².

In regards to the above, FAO interventions, in cooperation with our international partners, target three main areas that must be taken into account in order to achieve a balanced and holistic development. The three areas are a) development of physical structures/facilities, b) human resource development and deployment, c) formulation/review of policy, legislation, guidelines, standards, etc.

FAO cooperates with reputed national and international organizations from both the public and private sector to carry out capacity-building in seed quality control. The partner organizations include the International Seed Testing Association (ISTA), the Seed Schemes of the Organization for Economic Cooperation and Development (OECD), the Union for the Protection of New Varieties of Plants (UPOV) and the International Seed Federation (ISF).

Over the past 10 years, FAO has executed 897 seed-related projects in which capacity-building was a major theme, at a total cost of 822.5 million US dollars.

These interventions include:

1. Emergency Seed Relief and Rehabilitation

FAO has dramatically increased its interventions in emergency situations in the last 10 years. The interventions generally include seed relief operations to restart agricultural production after both man-made and natural disasters. Quality assurance measures are a key element in these operations and are aimed at ensuring that:

- a) seeds of crop varieties adapted to farmers needs are procured for distribution;
- b) the seed lot meets minimum seed quality standards;
- c) seeds comply with phytosanitary requirements in line with the IPPC Convention.

FAO has developed tools for ensuring that the quality of seeds used in emergency seed relief operations meets acceptable minimum quality standards. These standards have been established in consultation with international experts. Also, regional crop calendars have been developed to ensure timely seed delivery and appropriate variety identification. To support the progression from emergency to rehabilitation, efforts have also been made to strengthen in-country seed quality evaluation systems through the establishment of seed laboratories. By such interventions, FAO strengthens technical and logistical capacity/capability of recipient countries. Success stories in this regard include the establishment of private seed enterprises in Afghanistan from the pieces left in the aftermath of two decades of strife; and the restoration of the seed delivery system in Sierra Leone after the war in that country.

¹ FAO designed the Quality Declared Seed as a quality control mechanism which is less demanding on government resources than seed certification but is adequate for providing good quality seed both within countries and in international trade. It is not a substitute for normal seed certification but a system put in place pending the ability of countries to have the requisite facilities and logistics for seed certification. The system relies on four principal points: 1) A list of varieties eligible to be produced as Quality Declared Seed is established. 2) Seed producers are required to register with an appropriate national authority. 3) The national authority will check at least 10 per cent of the seed crops. 4) The national authority will check 10 per cent of seed offered for sale under the designation Quality Declared Seed.

² Quality Declared Planting Material (QDPM) is a process for the production of clean disease-free planting material of vegetatively reproduced crops, primarily implemented by seed producers at community level or field extension workers. It has the final objective of significantly raising the current levels of physiological and phytosanitary quality of the plant reproductive materials available to smallholders, and as a consequence, an increase in agricultural production and productivity.

2. National Seed Program Development

FAO has assisted in the development and rehabilitation of national seed programs, aiming at enhancing the efficiency of the seed delivery system, establishment of an efficient seed quality assurance and assuring the seed security of farmers.

These activities have been organized in cooperation with national governments, regional and international organizations and, lately, also with the private sector. They include:

- a) varietal characterization, registration and release;
- b) development of systematic seed multiplication programs with essential elements of seed quality control;
- c) establishment of both administrative and legal instruments for operating seed quality assurance;
- d) review of seed legislation and regulations;
- e) development of appropriate seed standards;
- f) provision of appropriate equipment; and
- g) provision of appropriate training for the stakeholders concerned.

FAO has trained more than 10,000 beneficiary seed-industry stakeholders in the last 10 years at different levels of seed activities. Various methodologies have been used for the training of seed-industry personnel in building up the capacity in quality assurance in developing countries. These capacity-building efforts included in-country training sessions, regional workshops, and overseas fellowships, including study tours. In addressing training needs, FAO complements its own internal expertise with additional competences from international experts drawn from FAO international partners, such as the International Seed Tasting Association.

3. Harmonization of Quality Assurance Systems

Discrepancies in seed quality standards and regulations are a major constraint to the development of the cross-border seed trade in developing countries. This hampers the development of seed enterprises in developing countries. Therefore, a key activity of the FAO in the last 10 years has been the harmonization of systems for seed quality assurance. Elements of quality assurance that were harmonized include:

- ▶ procedures for varietal release and registration,
- ▶ rules and procedures for seed quality control;
- ▶ plant quarantine procedures; and
- ▶ a plant variety protection system.

A major output of the harmonization activity is the development of the West African Catalogue of Plant Species and Varieties; and the harmonized seed regulatory framework which has been adopted by the ECOWAS Council of Ministers.³ Harmonization of seed regulations has also been supported in the SADC region.

4. Development of Biosafety Programs

FAO has assisted member countries in developing administrative and technological tools for quality assurance of biotechnological products. The outputs included strengthening of seed-testing laboratories to detect adventitious GMO in traded seeds and foods as well as the establishment of procedures to facilitate co-existence of multi-track seed production systems such as conventional /organic/GM crops.

5. Development of Quality Control Schemes

FAO has developed a quality control scheme Quality Declared Seed (QDS), which provides an alternative for seed quality assurance, particularly designed for countries with limited resources, which is less demanding than full seed quality control systems but yet guarantees a satisfactory level of seed quality.

³ www.fao.org/docrep/010/i0062e/i0062e00.htm.

The QDS system, elaborated by FAO in 1993 for agricultural crops and revised in 2006, has been widely used and consulted. The QDS guidelines/protocols are aimed at assisting small farmers, seed producers, field agronomists and agricultural extension personnel in the production of quality seed.

In spite of the fact that systems are available for quality control of crop propagated by true botanical seed, less attention has been paid in the international arenas to the development of good procedures for the supply of vegetative planting materials, particularly of under-utilized crops, including some of the food security crops of developing countries. To address this gap, FAO has partnered with the Potato Improvement Centre (CIP) and other international experts to develop the Quality Declared Planting Materials system (QDPM) of selected vegetatively propagated crops. The 14 vegetatively propagated crops covered by the scheme are potato, cassava, sweet potato, banana, plantain and other musaceae, cocoyam, garlic, oca, ulluco, mashua, konjac, hausa potato, taro and yams. Publication of this scheme is expected in 2009.

Constraints of Capacity-Building and Future Considerations

Constraints

Over the years, FAO capacity-building activities have expanded to cover newly emerged contemporary topics. The main constraints encountered in FAO efforts aimed at capacity-building for seed quality control are:

- ▶ Limited resources to establish/procure necessary infrastructure required to provide essential facility and a critical mass of the workforce required for effective seed quality control.
- ▶ Limited interest shown by many countries and donors in providing necessary financial support for specialized seed institutions including knowledge and learning centers.
- ▶ A lack of opportunity for sponsored training in the areas of importance for seed-industry development.

Much of the future efforts in seed quality assurance for Africa will take place under the newly adopted Africa Seed and Biotechnology Programme (ASBP), which is a continent-wide seed development program and framework under the ambit of the African Union.

Future Considerations

In order to build the capacity for a quality assurance system in developing countries, there will be a need to examine the following issues.

Need for Long-Term Sustainability of Project Outputs

In several instances, serious reverses have occurred upon project termination. There is a need to put good exit strategies into project designs and implementation of the project to enable national efforts to sustain the outputs generated by projects. Often this would require an ambience of facilitating seed policy and effective institutional arrangements. Since the quality assurance effort depends largely on public funding, a systematic incorporation of efforts from the private sector where it is developed will reduce the burden on the state and enhance sustainability.

Appropriate Infrastructure

Data on infrastructure for seed quality assurance, particularly seed-testing laboratories and appropriate storage, indicate gross inadequacies in many parts of developing countries. There is a need for governments to recognize the key role played by quality assurance and to allocate on a priority basis, adequate infrastructure to complement the seed-testing equipment they inherit after the project's activities have ended.

Training

There is serious inadequacy in seed training in the developing countries. Aside from appealing for the resumption of accelerated seed training in developed countries, there is a need to establish credible seed training and knowledge centers in the developing countries, where knowledge and experience with local problems will be an advantage in preparing trainees to fit into the local context.

Regional Networking and Coordination in Laboratory Seed Testing

In view of limited resources, national seed quality assurance programs will achieve much more if they cooperate in referee testing and training within the ambit of harmonized protocols. Often neglected food security crops could benefit from such networking, as would also the intra-regional seed trade.

Policy and Legislation in Relation to Quality Assurance

The formulation and adoption of appropriate policies and legislation establishes the seed quality assurance as the credible basis for the seed sector, provides a level playing field for all actors and can serve to improve investments in the seed sector

Cost-Effective Methodologies for Seed Quality Assurance in the Informal Sector, Participatory Breeding

Since an overwhelming portion of seeds in developing countries emanates from the informal sector, the effective introduction of seed quality assurance to that sector is likely to make a big impact on crop production and strengthen food security. Other areas, which will also benefit from the introduction of good quality assurance activities, are participatory plant breeding, preservation of valuable ecotypes, the operation of community seed banks, etc.

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APPENDIX 1

Selected FAO Tools for Seed Quality Assurance

On-line database of pasture/forage resources in more than 80 countries.

Ecocrop: Identify a suitable crop for a specified environment, identify a crop with a specific habit of growth, identify a crop for a defined use or look up the environmental requirements and uses of a given crop.

Grassland Index: Allows searches of more than 600 grass and forage legume species by genus, Latin name and common name

Hortivar: Database on performances of horticulture cultivars in relation to agro-ecological conditions, cultivation practices, the occurrence of pests and diseases and timing of the production.

Nutrient Response Database: Database allowing for the extraction of yield data per agro-ecological zone for the main food crops in a specific country. The extracted data enable the estimation of fertilizer input and crop output ratios for projection of future fertilizer application to support increased crop yield targets.

World Information and Early Warning System (WIEWS): The World Information and Early Warning System (WIEWS) on Plant Genetic Resources for Food and Agriculture (PGRFA) was established by FAO as a worldwide dynamic mechanism to foster information exchange among member countries. This website gathers and disseminates information on PGRFA, and acts as an instrument for the periodic assessment of the state of the world's PGRFA. It consists of a Global Network of **Country Correspondents on PGRFA's Information Exchange** and a number of relational databases including an ex-situ collection, PGRFA and Seed Laws and Regulations, the World List of Seed Sources and List of Crop Varieties. <http://apps3.fao.org/wiews/wiews.jsp>.

All workshops, training opportunities within capacity-building projects are fully advertised among stakeholders mainly online through the FAO website and through partner websites: <http://www.fao.org/ag/AGPIAGPS/default.htm>.

All biosafety-related capacity-building training courses, projects and workshops are included in the FAO Biotech Newsletter and in the biosafety capacity-building database of the Cartagena Protocol on Biosafety.

All publications such as manuals, methodologies, technical outputs are disseminated to the participants and to the stakeholders.

DISCUSSION

IR HINDARWATI: My name is Hindarwati and I am from Indonesia. I think quality assurance is the most important part of the seed industry, because it is to ensure that the quality of seed is true in terms of variety and also good in terms of quality from the producer to the seed user. Do you have any research done by FAO on how if we have like not just quality assurance, but quality insurance, so then if the quality of seeds is not true for the seed users, then if any of them pay any costs; is there a cost?

MICHAEL LARINDE: Well I must say that this is not - sorry - I must say that this is not handled in the quality assurance, but we handle this through a system to countries in drafting their seed policy and reviewing their seed legislation. Actually I came back from Iraq about 10 days ago to finalise this kind of thing. There must be appropriate seed legislation to make seed quality assurance work in the real sense; in that violators have to face a penalty. And this must be ensured in the law, not in the lab. I don't know if I answered your question. It has to do with the policy of the government as well as the legislation in the country. And this is why in FAO we have a legal department that works together with the seed service and both departments help member countries to review their seed laws and to draft appropriate legislation for them, because you don't want a seed law that will restrict incoming materials into your country. That's counter-productive, but at the same time you need a seed law that ensures equity in that they show that the interest of the consumers as well as the sellers are taken care of. In fact that is the basis of seed testing; one reason seed testing was developed, to ensure that there is this kind of way to judge something and then appropriately take precaution. Thank you.

IR HINDARWATI: I suggest that – excuse me – I suggest FAO will have research on this. Thank you.

KATALIN ERTSEY: I would like to take some additional remarks on this topic, because I think if you can reach to include in your country the quality assurance in the legislation, then after that it is easier to apply for insurance or to reach a reasonable situation, because then in the legislation is included that they should have quality assurance; there is some requirement and you can apply for that. I think so.

ZEWIDIE BISHAW: Zewdie Bishaw from ICARDA. I am seed technologist and I can help out how to leave the situation. I am enough clearly elaborated on the relationship in terms of quality assurance and the need for training in quality assurance. I understand the need for training is clearly elaborated for quality assurance. But would it not be more useful if we broaden the issue of training in terms of seed sector development as a whole, looking into the production and marketing aspects and other issues, not only on quality assurance?

MICHAEL LARINDE: Thank you, Zewdie. Actually we have done a lot of things in this area, but this is not my topic today. That's why I did not make reference to this, but as you know, apart from all those things I listed we have been involved in developing national and regional seed associations, and this is to facilitate communication and collaboration among seed stakeholders and so on and so forth. And also we have done all over the world in each region regional workshops in collaboration with ISTA on GMO seed testing and detection, because we realised even though many countries don't want GMO, if they have adventitious presence of GMO in their seed, they should have this way of testing, and most of these countries don't have. And so in that sense we also have to train them, and also at the seed association level we work very closely with APSA - because APSA is an FAO baby, just like ECOSA has become one - and we facilitate their training for the private seed sector in Asia in the area of seed health testing, in the area of GMO detection, as well as regular seed quality control. So I didn't mention everything, but I am restricted to the topic given to me. Thank you.

OBONGO NYACHAE: Thank you very much. I am Obongo Nyachae from the Seed Trade Association of Kenya, and I also coordinate a programme on harmonization of seed policies and regulations in Eastern Africa. Now I have one question: from your presentation and from the presentations of the previous speakers, it is very clear that to improve productivity - especially I am talking now of Sub-Southern Africa - it is very vital, that FAO as the media organisation which is trusted, and FAO has one good aspect, it is trusted by many countries. Because of that trust, you come up with a system

of quality declared seed and you know very well that maybe you do not have the promoters presented in the history of seed testing. It has taken many, many years here in Europe, in America and elsewhere, to develop a quality assurance system. Why does FAO spend – you put the figure there of 800 million US dollars, nearly 1 billion US dollars, to preach a system that you know very well is only serving that time, that is not sustainable? Why not work with the private sector more, so that if you have to sustain a system then use the government, the systems already established in those countries, seed trade associations, so that seed is actually seed and is not just something called “quality declared”; it should be seed meeting the aspect. So why does FAO spend these enormous resources which do not yield as much fruit?

MICHAEL LARINDE: Thank you for your comment. The point is well taken but I will not agree that it does not bear fruit, for the following reasons: Rome was not built in a day, and you cannot jump – a baby has to crawl before it can walk and before it can run. You have many countries, there is nothing. If you want to develop the classical system of certification, you need a critical mass of trained people, you need massive injections of funds to set up the facilities and you need a programme in place that will sustain the system. As it were, things worked very well in Europe, because many of these things are done on a sustainable basis. In the 1980s I refer to, many of these were donor-funded and some even said you may distribute the seed free. These are some of the things we are trying to amend, we are trying to work and find a way around, and this is why even now we have a programme, where we are trying to link seed production to crop production and to value addition. Because that is the only way for farmers in Africa; when they have the crop, everything they sow that is raw material, and the price goes down, but if you have value addition, then farmers will all be able to make a reasonable profit and they will be willing to buy seed and that's when you can talk of the very top class system. I must add, finally, that even with that system, Afghanistan sat there with quality declared seed, and now they are producing certified seed. Because they have progressed and they are now producing certified seed. Thank you, I am told my time is up.

RAISING SEED QUALITY: WHAT IS IN THE PIPELINE?

Mr. JOOST VAN DER BURG¹

Summary

This presentation gives a short overview of some of the promising technologies that are still under development or that have recently become available. They comprise technologies that are used for seed research, seed testing, seed enhancement and seed sanitation. Recent developments include X-ray research of seeds, chlorophyll fluorescence of dry and imbibing seeds, oxygen production, ethanol production, grass seed priming, and electrification. Molecular technologies are briefly discussed, including flow cytometry, genomics, proteomics and metabolomics.

Introduction

A short inventory has been made of the most promising technologies that are either in the pipeline or have happily emerged and are now available for use. The technologies usually involve quite some investment and they sometimes take a decade or more to mature, so it is understandable that some secrecy surrounds them until the protected product can be shown to the public. So, the overview may be missing out some technologies, either by choice or by unawareness.

What does “raising seed quality” mean? Seed quality includes many aspects such as germination capacity, speed of germination, uniformity of germination, vigor, absence of pathogens, increased natural defense, provision with protectants, etc.

Seed quality has both physical/physiological and genetic elements. Genetic improvement, or breeding, has been dealt with in other papers during this Conference and will therefore not be included here.

Of course there is no better way to produce good seed other than in the field. But failing this, it is up to seed technologists to try to rescue as much as possible.

If we try to categorize the various technologies, then we come to these main entries: tools for seed testing and research; sorting technologies; methods for seed enhancement, sanitation and the addition of chemical compounds, biologicals and the like. Hereafter, you will see that many technologies are combinations of these. In this paper we will present a selection under two headings: seed testing and research and enhancement (which includes sorting, priming and sanitation).

Seed Testing and Research

A large number of exciting technologies are in the pipeline or have come recently to our disposal and we will have a short look at some of them.

X-ray

X-ray research has long been a tool for seed analysts, but it always involved films which needed developing and visual inspection by a person. With the ever-increasing speed and capacity of computers and the development of high-resolution imaging chips, the automation of this process becomes a reality. The systems can be made so fast that sorting of tomato seeds is now possible and offered commercially (Incotec International BV, Fig. 1)

¹ Plant Research International, Wageningen University and Research Centre, in collaboration with Mr. Jan Bergervoet, Mr. Steven Groot, Mr. Henk Jalink, Mr. Jan van der Wolf

² Mr. Johan Van Asbrouck, Astec Global

³ Mr. Bob Legro, Incotec International BV

⁴ Mr. Harry Nijënstein, Innoseeds BV

Fig. 1 Real-Time Sorting Machine using X-rays and Image Analysis (Source: Incotec International BV)

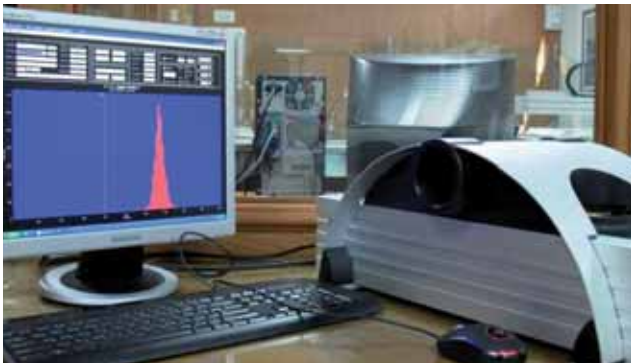


Another application of X-rays in combination with image analysis has been developed for crack detection in maize seed (Cicero et al. 2000).

Chlorophyll Fluorescence of Dry Seeds

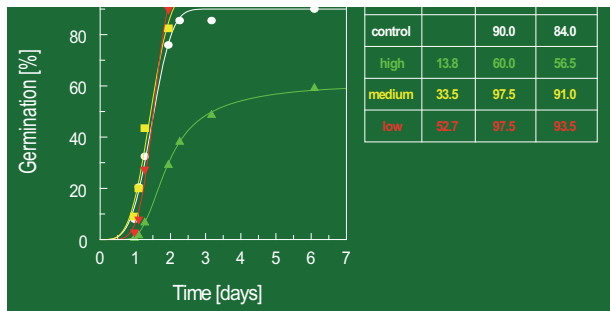
It is a little over 10 years ago that we started research on chlorophyll fluorescence of seeds (Jalink et al. 1998). It was found that with this technology we could detect chlorophyll in almost every seed, and that levels differed considerably. And the good news was that these levels were a measure for something we could not measure before: seed maturity. Since we know that maturity correlates strongly with quality aspects like germination, speed of germination and seed health, this technology could develop into something important. Fig. 2 shows the laboratory analyzer which is commercially available (Astec Global).

Fig. 2 Chlorophyll Fluorescence Tester for Dry Seeds (Source: Astec Global)



The technology is based on exciting seeds with a laser beam and measuring the resulting fluorescence: this fluorescence decreases with maturity. Less mature seeds show higher levels of fluorescence and have therefore higher levels of chlorophyll than fully mature seeds. The technology has now become so fast that we can analyze seed-by-seed in milliseconds and build it in color sorters. Discussions with a manufacturer are at an advanced stage.

Fig. 3 illustrates the importance of seed maturity. A paddy seed lot was separated with an original germination of 90 per cent into three fractions. In the left graph their germination time courses are compared with the white control. The green lower line represents the fraction with high CF, so it consists of the less mature seeds. This fraction represents 13.5 per cent of the lot (Table on the right). It has a germination percentage of only 60 per cent. By removing this fraction from the lot, germination would increase to 97.5 per cent.

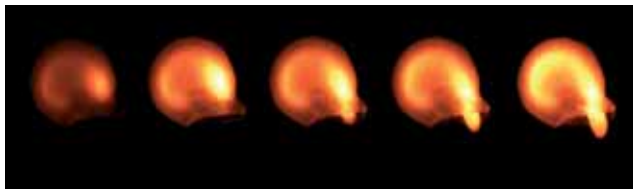
Fig. 3 Germination

Time courses (left) of three CF fractions and the original sample of paddy seed. Results of the germination tests (right): size of the fraction, total germination, percentage normal seedlings. High (green characters and graph) is less mature seed, low (red) represents fully mature seed. (Source: Plant Research International)

Chlorophyll Fluorescence of Germinating Seeds

A second development with CF of seeds is not just to measure the seed as a whole and obtain one figure, which is already quite informative, but to get values from over the entire surface of a seed: that is to say create a fluorescent image. Ideally this should again occur in an automated way and with large numbers of seeds at a time.

A set-up was created with high resolution cameras and special filtering producing the images in Fig. 4. It represents one pepper seed in a time sequence of 48 hours.

Fig. 4 Chlorophyll Fluorescence of Germinating Pepper Seed showing Differential de novo Synthesis of Chlorophyll in a Seed Embryo. (Source: Plant Research International)

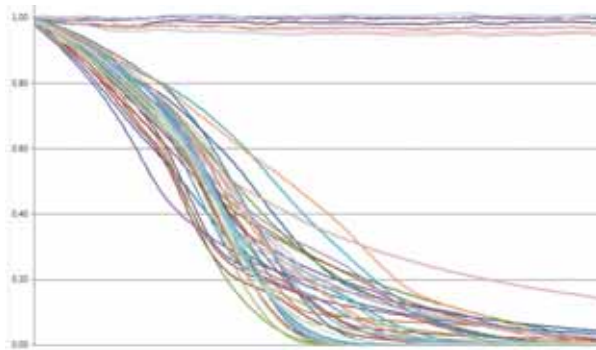
New technological developments make new applications possible. In dry and fully mature seeds the level of chlorophyll is relatively low, as we have seen; as soon as seeds start to imbibe, de novo synthesis of chlorophyll takes place. In this pepper seed the strongest signals come from the elongating hypocotyl and root base, followed by the cotyledons. This technology can, apart from being used for research purposes, also be developed into automated seed germination tests. CF provides ultra-clean images of seeds without background, which are ideal for image analysis.

Q2 Technology

A totally different approach is given by measuring gases. The first example is the use of oxygen consumption by seeds as parameters for seed viability and vigor.

Seeds, and certainly germinating seeds, breathe, although plants at this stage use oxygen rather than produce it. The Q2 technology uses the wells of ELISA plates in which seeds are placed individually. The cells are covered with a specially coated foil, which if excited with a laser, produces fluorescence. This fluorescence is influenced by oxygen and results in a measure of the oxygen content of the cell. The process is fully automated and many plates can be followed at the same time.

Fig. 5 Curves showing Oxygen Depletion of 96 Seeds (Source: Astec Global)

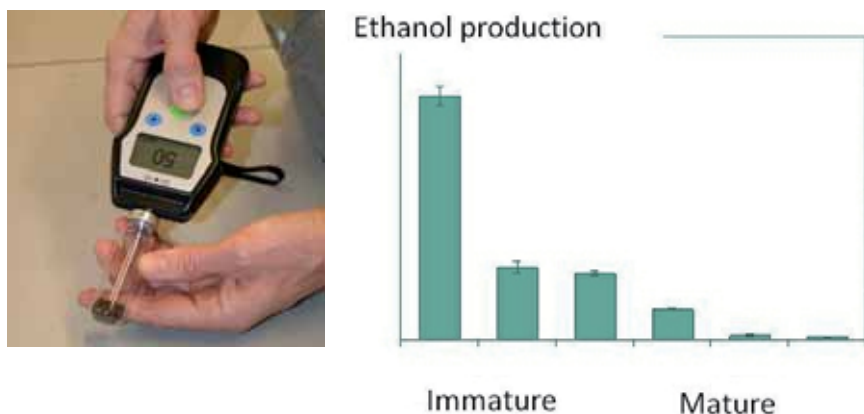


Seeds normally completely exhaust the oxygen present in the cell in a time span of 48 hours, resulting in S-shaped curves as shown in Fig. 5. The upper curves, however, where the oxygen hardly decreases are filled with dead seeds. Intermediate values are obtained when seeds are of low vigor. Curve-fitting algorithms of the various shapes of the curves allow extraction of a number of solid parameters per seed, and thus a prediction of, for instance, vigor, field performance and total germination.

Ethanol Assay

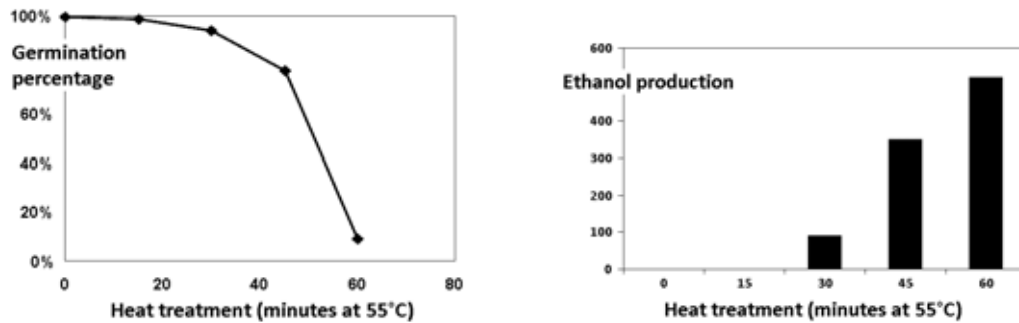
Another gas-based technology uses the production of ethanol vapor by seeds (Fig. 6). This very new technology is based on the fact that when seeds deteriorate they disintegrate slowly under the production of ethanol. The measurements are made with a slightly modified breathalyzer, as is normally used by traffic police. Measuring ethanol in a test tube in which the seeds have been put for some time, shows clear differences between different quality groups. In the right-hand graph you can see that the more immature the seeds, the more ethanol they exhale, indicating seed deterioration and lack of vigor. This increased production of ethanol in less mature and immature seeds is explained by damage to the mitochondrial system, possibly due to reduced membrane integrity and subsequent oxidative stress, resulting in a blockage of the Krebs cycle and subsequent production of acetaldehyde and ethanol.

Fig. 6 Using a Breathalyzer to measure Ethanol Production by Seeds. Immature and Less Mature Seeds produce more Ethanol than Fully Mature Seeds (Source: Plant Research International)



The ethanol assay can be used to monitor and optimize seed treatments. We have experimented with the hot water treatment of cabbage seeds; an important tool for environmentally safe sanitation of seeds (Fig. 7). In the left graph we see a rapid decline in quality during the heat treatment. From the outside the deterioration of the seed cannot be seen, so one knows only after it is too late. Ethanol measurements of tiny quantities of seed can be used to optimize this. In the graph on the right we see that ethanol appears at the moment that the germination starts to decline after 30 minutes. So with a little shorter treatment one is at the safe side.

Fig. 7 Germination Decline during Heat Treatment (left) and Ethanol Production of the Same (right)
(Source: Plant Research International)



The ethanol assay also proved to be a good marker for deterioration during seed storage. As soon as the germination speed of cabbage seeds decreased, the production of ethanol markedly increased. In this way the assay can be used as a monitoring tool and helps to decide what to do with the lot.

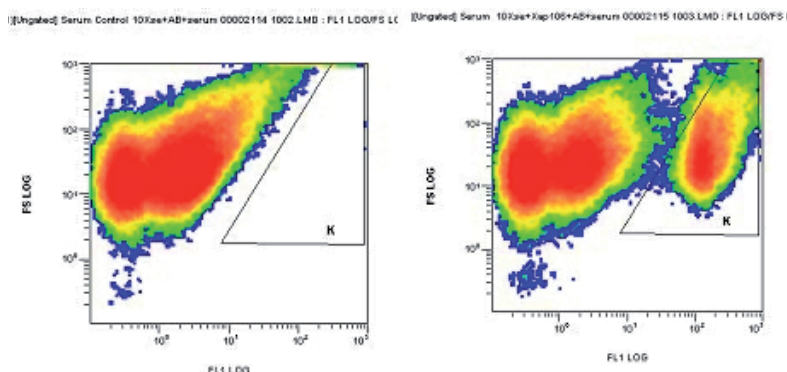
Molecular Technologies

We will now briefly touch upon some technologies used for the detection of pathogens. Several are based on immunofluorescence, like the well-known and widely used ELISA method. Modern versions of this principle have been developed to speed up the process and also to enable the measuring of various pathogens at the same time: i.e. multiplexing.

Flow Cytometry

To enhance detection of seed-borne viruses and bacteria, flow cytometry (FCM)-based techniques were developed. (Fig. 8). FCM enables multiparameter analysis and quantification of particles, such as bacterial cells and fungal spores. Particles are analysed on the basis of size, granularity and emission of fluorescence, if particles are autofluorescent or have been stained with a fluorescent probe. We developed FCM immuno-detection procedures for *Xanthomonas axonopodis* pv. *phaseoli*, *X. campestris* pv. *campestris* and *Clavibacter michiganensis* subsp. *michiganensis* in seed extracts.

Fig. 8 Flow Cytometric Analysis of Seed Extracts of Beans showing Presence of *Xanthomonas axonopodis*
(Source: Plant Research International)



Luminex® MAPS

We also explored the potential of the Luminex® MAPS technology for multiplex detection of seed-borne viruses and bacteria. This technology is based on the use of antibody coated paramagnetic microspheres (immunobeads), internally stained with fluorochromes. These beads act more or less as microscopic ELISA-wells. We developed an assay for the detection of several viral pathogens including lettuce mosaic virus and pepino mosaic virus. The assay was performed in 96 wells microplates and

could be completed within 60 min. The detection level for bacteria and viruses was similar to that of a DAS-ELISA. The assay can be extended to a multiplex assay of up to 100 different pathogens.

Fig. 9 Luminex® Apparatus for High-Speed throughput Analysis using Immunobeads (Source: Luminex Corporation)

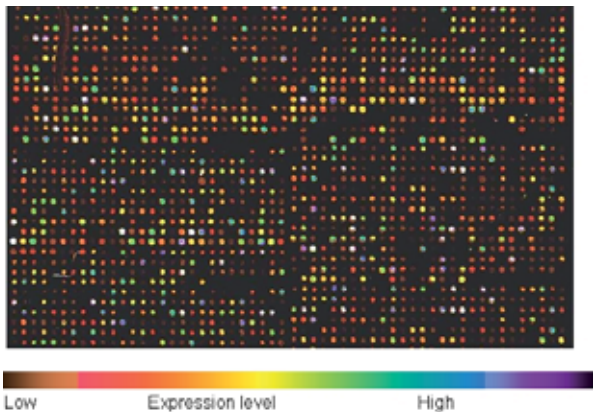


Genomics

Other molecular approaches are based on DNA, proteins or metabolites.

A very powerful tool that looks at gene expression is the cDNA micro-array platform with 1536 spots on one slide. It shows the genes' activities at a certain phase of development, in a certain organ (leaf, root, flower parts, etc.) or of a particular developmental phase such as during seed maturation, germination, priming treatments, etc. Results include the identification of a subgroup of genes that are up-regulated during osmopriming and germination and are down-regulated again during drying. These can be used to fine-tune the priming and re-drying process.

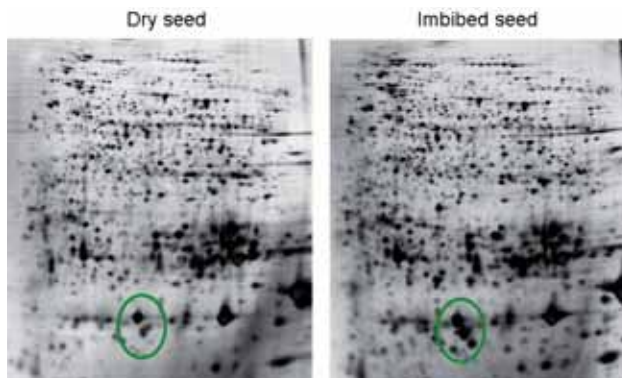
Fig. 10 Gene Expression in cDNA Array with 1536 Spots in one Operation. (Source Soeda et al. 2005)



The technology can be used to create QTL-maps, which in turn are very useful for plant breeding and crop improvement.

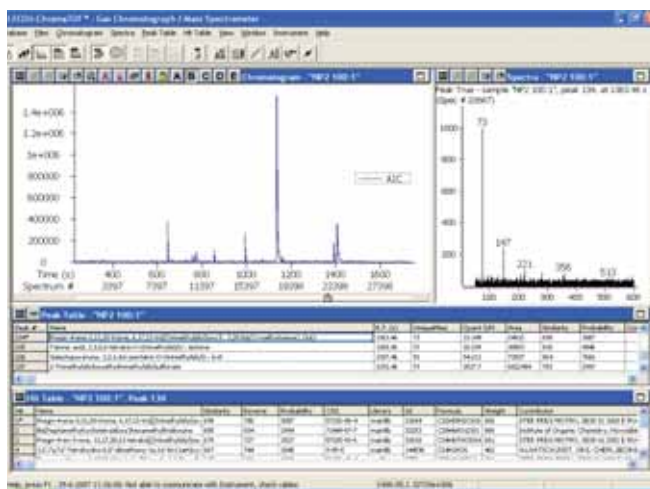
Proteomics

Proteomics is the large-scale study of proteins, particularly their structure and function. Fig. 9 shows an example of a total stain of all proteins present in two seed extracts: on the left a dry seed on the right an imbibed seed. In the second slide we see the de novo synthesis of a protein which apparently plays a role in the initiation of the metabolism. In this way the up-and-down regulation of proteins can be studied to help us unravel complex developmental processes such as germination and to detect protein markers for seed vigor and priming.

Fig. 11 Protein Profiles of Dry and Imbided Arabidopsis Seed (Source: Gallardo et al. 2001)

Metabolomics

Finally we have metabolomics or the study of the final metabolites in a cell, metabolic mapping giving a snapshot of all cell constituents of a certain cell type at a certain moment in time, just like proteomics. The technology is quite different, however. In the old days we would use thin-layer chromatography; presently we have high throughput gas chromatographers - mass spectrometer combinations (GC-MS), producing up to 500 spectra per second. With this technology the role of seed oligosaccharides and anti-oxidants have been studied in relation to desiccation tolerance and seed longevity. Presently we are performing non-targeted metabolomics, so using the whole spectrum of metabolites in our research for private companies.

Fig. 12 GC-S Analysis of Seed Metabolics. (Source: Plant Research International)

Seed Enhancement

At the turn of the previous century experiments with the application of electricity to improve seeds had already been done. Charles Mercier (1919) reports on successful experiments and practical application of electro-chemical treatment on seeds: cereal and vegetable seeds. He talks about experiments using electrical currents through water baths enriched with electrolytes. This resulted in more vigorous growth and higher yields. It was in fact a combination of priming and electric treatment. The costs of such treatments were rather high in the early days of electricity.

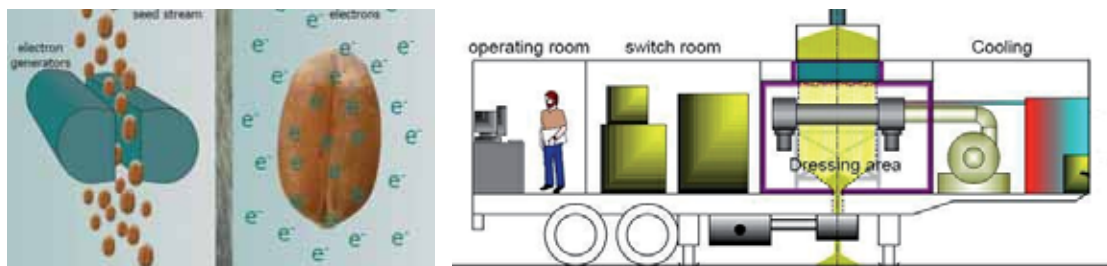
Priming of Grass Seed

A lot can be said about priming, but time is limited and I would like to mention one development which I found striking. Priming is common practice in many crops, especially vegetables, but in grasses it is relatively new. Grass is a rather bulky product; it is chaffy and for a long time one did not want to engage in wet treatments: the costs were also prohibitive. In recent years one started to use priming to speed up the germination of smooth-stalked meadowgrass, *Poa pratensis*, which is a notoriously slow germinator, in order to increase its chances of survival in sods grown from mixtures with faster-germinating species like *Lolium perenne*. *Poa pratensis* is essential because of its property to make stolons, resulting in stronger turf. PreGerm®-treated seeds germinate 5 to 7 days faster than untreated seeds and result in about twice as much presence in the turf.

Electrification

A modern version of the application of electricity on dry seeds has been developed in Germany (e-ventus™) and is based on seeds falling through a field with electrons, resulting in killing off most bacteria and fungi (Fig. 13). This is an environmentally safe method with no chemicals involved. It is now available as a movable unit in a truck with a capacity of up to 30t/h.

Fig. 13 Treatment of Seed with Electrons. Principle (left), Practice (right) (Source: Schmidt-Seeger)



Concluding

ISTA established the Advanced Technologies Committee a few years ago and is following these developments closely, trying to share them with our colleagues as soon as they are fit for seed testing or seed improvement purposes.

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DISCUSSION

ISMAHANE ELOUAFI: Ismahane Elouafi from the Canadian Food Inspection Agency. I wanted to just ask you a question about the flow cytometry. You showed the Luminex 100, that is the flow cytometry if I understood you well. So it's microbeads and is it based on hybrid? I just want to understand this a bit more. So I know it is a flow cytometry and you were talking about the Luminex 100 that uses microbeads, so I just want to know a bit more how you detect the different viruses. Do you have to have previous knowledge of the virus or the pathogen to use the machine?

JOOST VAN DER BURG: I hope I understood your question well, and you should rather ask my colleagues about this, but the microbeads are in fact a sort of medium to put your antigens and antibodies, like in ELISA. So it is not the well itself, but it is on a small ball, and this ball itself also shows fluorescence. And then depending on the normal technology that you use for ELISA, using different probes with different colours, different fluorescent colours, you can sort these beads.

ISMAHANE ELOUAFI: OK, thank you. It is different packaging of ELISA techniques?

JOOST VAN DER BURG: Different what?

ISMAHANE ELOUAFI: Packaging. It is just a different way to make multiple ELISA system, yes, OK, I thought it is a different thing. Thank you.

MAINTAINING CAPACITY IN SEED TECHNOLOGY AND SEED TESTING

Mr. J.G. HAMPTON*

Summary

The seed industry of the 21st century has a continuing need for seed technologists and seed analysts. However, there is a world-wide shortage of skilled people available to enter the industry. This shortage will increase as the drivers and leaders of today, the baby boomers, begin to retire. Attracting vibrant, energetic, passionate, motivated, creative and able young people from the Y Generation will be vital for the survival of the seed industry. Increasingly, governmental support for the seed industry and seed quality assurance is being withdrawn. The private sector must take an increasing responsibility for the long-term future of their own industry. The current situation is discussed and some options for the future are presented.

Introduction

Seed technology embraces breeding, evaluation and release, production and processing, storage, testing and certification of seeds (Feistritzer, 1975). It therefore encompasses aspects of agricultural practices which date back thousands of years. For example, prehistoric man knew and realised the importance of seed storage (Chin, 1991); the writings of Theophrastus (311-287 BC) cover seed germination, dormancy, viability and longevity (Evanari, 1984). However, it was not until the 19th century that national and then international seed trading developed, and the need to test for seed quality became evident (Hampton, 2002). Unscrupulous business practices and/or lack of knowledge by those involved in the marketing of seed in 19th century Europe and the Americas led to the first seed laws (e.g. the Adulterated Seed Act, 1869, UK) and the development of what Copeland and McDonald (1975) called "the art and science of seed testing". In 1869, Professor Nobbe published his Statute concerning the testing of agricultural seeds (Steiner and Kruse, 2007) and he established the world's first seed testing laboratory in Germany.

We have come a long way in the ensuing 140 years. Today the global seed market is around 37 billion US dollars, with seed traded internationally worth just over 6 billion US dollars (Bruins, 2008). This market has almost tripled over the last three decades (Le Buanec, 2007). Key drivers of this increase include the evolution of multinational seed companies, the increased availability of F1 hybrids, protection of intellectual property, an increasing use of counter-season production and the development of GM crops. Five companies now represent around 30% of the global seed market (Le Buanec, 2007).

In US dollar values, seed exports are dominated by The Netherlands, the US and France, and seed imports by the US and France (Bruins, 2008). Outside Europe and The Americas, only New Zealand, Japan, China, Australia, Thailand and South Africa make the list of the top 29 seed exporting nations, and Japan, China, South Africa and Australia the list of the top 29 importing nations (Bruins, 2008). This information is a reminder that the world's agriculture is still divided into "commercial and subsistence sectors" (Dominguez et al., 2001), and that there may be different needs between the developing and the developed economies. However, one need, the availability of quality seed, is common to both sectors.

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Capacity in Seed Technology

The seed industry of the 21st century, both in the developed and developing economies, has a continuing need for seed technologists. The New Zealand Grain and Seed Trade Association has noted that “the seed industry is short of skilled people” (Gerard, 2008). Positions within the industry recently advertised have included:

- ▶ plant breeders
- ▶ marketing assistants
- ▶ research technicians
- ▶ territory sales managers
- ▶ grain and seed representatives
- ▶ crop and pasture agronomists
- ▶ seed analysts

According to the ISF, this lack of skilled people is a global phenomenon (Bruins, pers. comm. 2009), both for the “old technologies” such as agronomy, and, in this “omics” era, the “new technologies” made available through advances in plant biotechnology. The seed industry requires tertiary qualified people with science degrees, preferably with an agricultural focus. Our industry offers wide career paths and the opportunity to specialise in research, production, management, marketing, sales, policy analysis, regulatory, finance and logistics (Gerard, 2008). So what is the problem? Why, with attractive career opportunities are there problems with obtaining suitably qualified candidates in the seed industry?

Tertiary Opportunities

At first glance, the answer may be that tertiary students cannot obtain the necessary seed technology skills. After all, the internationally known seed technology programs during the 1980s at Mississippi State University, US (Prof. James Delouche and colleagues), Massey University, New Zealand (Prof. Murray Hill and colleagues) and Edinburgh University, UK (Dr Mike Turner and colleagues) have either ceased to operate or have been significantly reduced in scale. However, as demonstrated in Table 1, tertiary training in seed technology at postgraduate diploma, masters and doctoral levels is still available around the world.

Table 1 Examples of Universities offering Postgraduate Qualifications in Seed Technology¹

<i>Region</i>	<i>Country</i>	<i>University</i>
South America	Brazil	Universidade Federal de Pelotas
North America	US	Ohio State University
Australasia	New Zealand	Lincoln University
Asia	India	Bangalore University
Europe	Netherlands	Wageningen University

Lack of Students?

Is it difficult to attract students? The answer to this question will differ among countries, and between the developing and developed economies. In the former there appears to be keen interest in acquiring a postgraduate qualification in seed technology, if my own experience is mirrored by that of my peers. For several years now I have received over 50 emails per year from prospective postgraduate students from countries in Asia, Africa, the Middle East and South America wanting to undertake a Masters or PhD with me in seed technology. The majority have an undergraduate academic record which would give them admission to postgraduate study at my university. The problem is that only very rarely does an enquiry come in without the words “please arrange a scholarship for me so that I can become your student”! This I cannot do.

In the developed world there is increasingly a different situation which is much broader than seed technology – a problem with attracting students into agriculture or related areas. With increasingly

¹ This list is indicative only; within each region there are other universities which offer postgraduate qualifications in seed technology.

urbanised populations, where the knowledge of agriculture is limited to the “fact” that milk comes from a bottle and chicken from a plastic tray at the supermarket, a career in the land-based industries is not seen as an attractive option. In a speech to secondary school careers advisors in 2008, New Zealand’s then Minister of Agriculture, the Hon. Jim Anderton stated “in the past three years, as a proportion of New Zealand’s total graduates, those in the agriculture/agribusiness areas comprised only 0.01% (c.f. 25% in the society and culture category, and 8% in the creative and performing arts). The Minister went on to say “these percentages are somewhat back to front, because we need many, many more people to meet the demand from the primary industries”. New Zealand is not alone with this problem; similar situations exist in Australia (K. Boyce, pers. comm., 2009) and Europe and North America (M. Bruins, pers. comm., 2009).

Generation Y

In the agricultural world of today, the drivers and leaders have been the baby boomers (born between 1946 and 1964), who are now starting to retire. The average age of farmers, scientists and agricultural industry personnel is approaching 50 years in many countries, and it would seem that Generation X-ers (born between 1965 and 1979) tended to view a career in agriculture as unattractive. As the baby boomers retire, attracting vibrant, energetic, passionate, motivated, creative and able young people as replacements will be vital for agriculture, including the seed industry. Members of the Y Generation (born between 1980 and 1995) fit this description – by their own admission (Rowarth and Goldblatt, 2006).

Much has been written about the Y generation (e.g. Sheahan, 2005; Heath, 2006). Some characteristics (Rowarth and Morris, 2008) of them are:

- ▶ preferred style of leadership – collaboration with management is expected;
- ▶ value of experience – irrelevant as the world is changing so fast;
- ▶ autonomy – questions, questions, questions;
- ▶ feedback – needed constantly and immediately;
- ▶ rewards – money talks;
- ▶ training – still in exam driven mentality;
- ▶ work hours – as long as needed (or until they get bored);
- ▶ work/life balance – busy lives; need a lot of “me” time;
- ▶ loyalty – already working out their exit strategy;
- ▶ meaning of money – just something that allows them to maintain their lifestyle.

Note that these characteristics were compiled before the current world financial crisis; 2009’s reality may result in some changes, particularly the rapidity with which they expect to change employment!

It may appear that I have digressed too far from my topic of today, but for the seed industry, it will be members of Generation Y who replace the baby boomers. While it is easy to over-generalise, it is significant that the Generation Y-ers want personal career development, and are used to the concept of a mentor (Rowarth and Goldblatt, 2006).

Capacity in Seed Testing

In 1974 when I began my career in seed technology at what was then the New Zealand Official Seed Testing Station, 86 seed analysts were employed in the laboratories. “Seed analyst” was an occupational class within the public service and therefore had its own salary scale. Each year up to 20 school leavers were taken on, and after three years of practical and theory training (including passing examinations), became qualified as seed analysts. Although the New Zealand seed industry of that time was considerably smaller than that of today, taxpayer dollars paid for all seed testing and as a result, each seed lot was tested approximately every three months!

Times change; within ISTA's membership today there are:

1. Seed testing laboratories which remain part of a government organisation and receive varying amounts of taxpayer support (e.g. much of Eastern Europe).
2. Laboratories which are still designated as "governmental" but receive no taxpayer support and must be financially self-sustaining (e.g. Denmark, Netherlands).
3. Private independent laboratories operating as a commercial business (e.g. Australia, US).
4. Seed company laboratories testing proprietary seed lots (e.g. Denmark, Hungary).

The days of any laboratory employing large numbers of seed analysts have also largely disappeared. In a 2009 survey of ISTA member laboratories:

- ▶ The mean number of analysts employed per laboratory was 11.4, with a range from 1 to 26.
- ▶ Only 9% of the laboratories employed more than 20 seed analysts
- ▶ 19% of the laboratories employed five staff or less
- ▶ For 54% of the laboratories, up to half of their analysts were employed on a part-time basis.

Factors effecting this change include:

1. A reduction in seed lot numbers for testing, either because of changed seed production practices (e.g. fewer, larger fields), or increases in seed lot size following changes to the ISTA Rules (e.g. from 20t to 30t for cereals).
2. Commercial reality following loss of taxpayer funding. A requirement to be either cost neutral or make a profit on the year's activities means that staff numbers are examined critically. The seed-testing business is "lumpy" in that the greatest demand for testing normally occurs in the five months following harvest; the use of part-timers during this period can be cost-effective.
3. Competition for the seed-testing business has reduced demand for services for laboratories which might have previously enjoyed a monopoly.

Seed Analysts

The international trading of seed relies on the skills of the seed analyst. Seed industry confidence in the accuracy of the seed lot quality information presented on an ISTA International Seed Analysis Certificate derives from the fact that the certificate was issued by a laboratory accredited to do so by ISTA. The gaining of that accreditation, and the laboratory's ability to retain that accreditation, ultimately depend on the expertise of the seed analysts employed.

A seed analyst requires a basic knowledge of seed biology and seed physiology, must be able to identify seeds of several 100 crop and weed species, distinguish between normal and abnormal seedlings, understand the importance of seed sampling and accurately conduct seed quality tests. Some specialise in a small number of agricultural or tree/shrub species, while others deal annually with many agricultural, horticultural and amenity species. Some only test temperate species, others mainly subtropical and tropical species, while yet others test species from within all these groups. A seed analyst is therefore required to be a highly trained specialist.

Are there currently sufficient qualified seed analysts to meet demand? In the only recent survey which asked that specific question, the response from North America (Anon, 2006) was that AOSA/SCST members considered there was a shortage of seed analysts. In Australia and Asia, recent seed analyst vacancies have been difficult to fill (K. Hill, pers. comm., 2009); note that while there is usually a reasonable number of applicants, few if any have any seed testing experience. The situation is also similar in Europe, where most applicants have little or no previous seed testing experience (J. Léchappe, pers. comm. 2009). In the 2009 ISTA survey already referred to, only 16% of the seed analysts currently employed by ISTA member laboratories had previous seed testing experience prior to that employment.

In the North American survey, respondents suggested the following reasons for the shortage of seed analysts (Anon, 2006):

- ▶ lack of training opportunities;
- ▶ amount of training needed to become a certified/registered seed analyst;
- ▶ low salaries do not reflect the amount of training required to become qualified;
- ▶ lack of emphasis by school careers' advisors for agricultural careers.

The lack of training opportunities is also a feature for Australasia, Asia, Africa and South America, but is currently less so in Europe. In the majority of ISTA's member countries, the training that is provided is "in-house", meaning that trained analysts do the training. For a large laboratory, work schedules can be more easily organised to provide time for training, but in small laboratories, time required for training can significantly reduce throughput, as a qualified analyst is removed from seed analysis work.

While currently most laboratories have trained staff it is of concern that in many of them, particularly government laboratories, the majority of these staff are either baby boomers or early generation X-ers. They will retire within the next 15 years. In some countries the same applies for the part-time staff who are employed at peak demand times. There are very few of the Y Generation employed as seed analysts, partly because they do not see a career path in seed testing, but also because, at least until this year, there have been more attractive salary packages available elsewhere.

Will new seed-testing methods reduce the need for seed analysts? For some seed quality attributes such as cultivar purity, seed health and the presence or absence of specified traits, there are already highly accurate and rapid testing methods available, but not yet in common use primarily because of cost. New approaches for the "bread and butter" of seed testing, purity and germination, have been proposed, and ISTA has a New Technologies Committee charged with evaluating the potential of these methods for routine use in seed testing. While it is possible that methods may be found which reduce the time required to obtain results, it is unlikely that they will ever fully replace the need for skilled seed analysts.

Maintaining Capacity in the Seed Industry

The seed industry will need to find ways to not only maintain the present capacity in seed technology and seed testing, but to increase that capacity. Generation Y-ers must be attracted into the industry.

Seed Technologists

Convincing young people that there are interesting and rewarding career opportunities in agriculture, and specifically the seed industry, is not an easy task, and the approaches necessary may differ among countries. In countries such as Brazil, China, India and Iran which have seed technology departments at one or more universities, graduates are available to fill positions in the seed industry. In developing economies where there appears to be a great interest among young people, providing scholarships for individuals to pursue a tertiary qualification in seed technology is an option. Traditional sources of such funding, for example Western government overseas assistance programs, have either ceased or substantially diminished, as "seeds" have been downgraded in priority or removed completely from target areas. In the 1980s, the Western governments provided scholarships for students from Africa, Asia and the Pacific to come to a university in the US, UK or New Zealand and study seed technology (Hill and Coolbear, 2005); today funding is no longer available for this purpose. It is now time for the regional seed associations in Asia/Pacific and Africa, in conjunction with FAO to assess priorities and organise scholarship funding from whatever sources are available (with the important proviso that students must return home after graduating and work in the local seed industry!).

In the developed economies, some large seed companies (e.g. Monsanto in the US) do provide scholarship funding to universities, but this alone may not be enough. Generation Y-ers are familiar with mentoring (Rowarth and Goldblatt, 2006). Consideration should be given to identifying promising recruits early and while providing fees bursaries/scholarships, also provide vacation and academically credit-bearing internships as a way of gaining work experience and eventually a position with the company. The New Zealand dairy industry has adopted this approach with some success; from the first

year, selected university students are supported financially, mentored, provided with vacation employment and know where they will be employed and at what salary after they have completed their degree.

While this approach has much to commend it, there is still a problem in that it only captures young people who have already decided on a career in primary industry (as indicated by the degree for which they have enrolled). It is not directly targeting those who have not previously considered there could be a career in the primary industries for them. As Rowarth and Morris (2007) observed, "Meeting the needs of the future requires proactive management by industry and education providers together. It needs to be directed by creative and exciting vision for the future, and inform them that there is more to these industries than just 'farming'. It must create a new perception of what a future in the primary industry has to offer". For the seed industry, this is a challenge which can best be collectively met by ISF, the regional seed associations and national seed organisations. The seed industry is ultimately dependent on the maintenance of the technologies which currently serve them and the development of new technologies. The private sector must take responsibility for its own future by adding investment in people to the investments already made for infrastructure and research and development.

Seed Analysts

Attracting young people into a career in seed testing and retaining them is probably more difficult than attracting them into a career in seed technology, primarily because the career options for the former are not as attractive as for the latter. Increasingly seed analysis is regarded as a basically unskilled job, and training on the job is not attractive. Additionally, a seed-testing business does not generally have the capacity to offer salaries for qualified staff as high as those that could be obtained in other occupations after the same time of training (i.e. up to three years). In most countries, seed analysts are not highly educated, but interestingly there are some laboratories in Asia and Africa where prospective seed analysts must hold a BSc/BAgrSc or higher degree before they can gain employment.

It is evident that many laboratories will require new staff within the next decade; the smaller laboratories in particular would like to employ trained staff, but increasingly this is not an option. For them, having to train beginners is difficult because of the time away from seed testing required. Other laboratories may continue to meet their needs by providing in-house training.

One method to attract new seed analysts and allow them to develop and meet career aspirations may be to introduce some form of international seed analyst training, based on the ISTA Rules for Seed Testing, with a program that culminates in an end-point (e.g. a Certificate or Diploma in Seed Testing) that is recognised internationally and would allow the holder to move among laboratories within a country or between countries. The latter is already occurring; seed analysts from an ISTA laboratory in the Netherlands travel to an ISTA laboratory in New Zealand and assist with testing at the peak of the season, and vice-versa (while innovative, it is successful only because the seed-testing peaks occur at different times of the year, and staff from both laboratories are willing to work in another country for several months each year – it does not address the long-term shortage of seed analysts).

Another method may be to make the job of a seed analyst more attractive, because the work involves a lot of routine tasks. Seed analyst job satisfaction is generally greater in a small laboratory than in a larger laboratory, because in the former, the analyst is likely to be conducting different tests on different species, while in the latter, the analyst may be conducting the same test five days a week. As noted by Dr Anne Bülow-Olslen, who as an auditor has visited seed laboratories all around the world: "In my opinion, making the job of an analyst attractive must be based on a varied job (not just barley purity tests from morning to evening), and ideally access to modern technology rather than only manual tests".

As already mentioned, ISTA is currently working with its member laboratories to address their needs for seed analyst training. Whether this alone will be sufficient to attract new seed analysts into the industry is doubtful.

Conclusion

Since the 1980s in the developed world there has been a gradual shift in responsibility for seed industry and seed quality assurance matters, moving from direct government support to increased private inputs. This is likely to continue elsewhere in the world. It is time now for the private sector to take responsibility for their own long-term survival; continuing to rely on governments may cease to be an option.

What will happen if the last highly skilled seed analyst goes the way of the dodo? A seed quality test result is only as good as the analyst. Will crops fail and people die of famine because the seed sown was not tested accurately? Will quarantine weeds rapidly multiply in a new country because their seeds were not recognised during a purity test? Will a seed-borne disease reduce yields and quality because the pathogen was not detected in the seed lot? "Over-the-top" scenarios, or are they?

Like other primary industry sectors, the seed industry is already experiencing difficulties in attracting Generation Y-ers to replace the retiring baby boomers. Motivators for Generation Y employees have been identified as culture, team, management style, flexibility, conditions and salary (Sheahan, 2005). The challenge for the seed industry is to create a workplace environment that acts as a magnet for talent. The message to young people must be that the seed industry offers a vibrant career with a myriad of opportunities. The time to begin is now.

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DISCUSSION

FRANÇOIS BURGAUD: François Burgaud from French Seed Organisation. Two small remarks. First, you have no possibility to do that because of time, but we always have to think that when we are talking about developing countries, there is, as you know, a very different situation in Asia, Africa and Latin America. The second thing, to talk about Africa, my feeling and my experience is that what we miss more is not post-graduate persons in seed business, but - if I may say that - undergraduate persons. You know, people who are going only to college, but in the college who have some specialisation, and not only for laboratories, but it is also the case for the production of seeds and everything about seeds. And it is one of the main problems, to have this type of education, organised by the governments. It was when we had the privatization in Morocco for example it was really the biggest problem to find that type of persons. The second thing is more general and we will discuss that, I think, this afternoon. I think the idea of accreditation of private laboratories of ISTA is a good idea to have more flexibility with the national responsibilities of governments, if we go also on this way on OECD. Until it is not possible to have OECD accreditation of the seed company alone, without government, I think it is impossible to use fully the ISTA accreditation. And finally, you can't think that a regional association will do a lot of work to implement that in the situation of today. The main problem of a regional association in developing countries is to find ways to encourage production of seeds. And until you have production of seeds, you don't really need somebody very good to analyse anything.

JOHN HAMPTON: Thank you for your comments. I fully agree about the need to have skilled people in all aspects of the industry, and if I could just give the example of the Massey University Seed Center at which I was working. In 10 years we had nearly 900 people through that center, with training from short courses though to post-graduate qualifications. The original idea always was going to be that these were the people who were going to be training the trainers. We surveyed people who had returned home to find out five years later where they were working. Nearly 60% were not involved with seeds whatsoever. And as Michael already referred, I think that is being one of the big problems; that people who did have the training and gained the skills - and these were not all seed analysts, these were production, the whole game of seed technology - simply moved off to other areas.

ORLANDO DE PONTI: I found it a very interesting presentation, thank you. Especially because you are right, and that is an overall problem of the seed industry, that we are facing the retirement of the baby boomers and this situation is taken very seriously by the companies, because of course they need competent people as successors. In one of your slides, you called on ISF to take collective responsibility. I think there is a different perspective what we have. We all are very much aware of the problem and it is taken very seriously by national seed associations. The big national seed associations all have programmes on training and in the end I think it is the individual responsibility of the individual companies; but they have joint programmes quite often in a particular country. The first important point is, as you mentioned, you have to bring those people into the company. Because as soon as you are in a company and want to make a career, the companies are very interested to give them all kinds of trainings. And it is in-company training but quite often it is a combination with government or semi-government organizations. Just to give the example for seed analysts in the Netherlands; that is a joint programme, it is very well covered by Naktuinbouw. And the companies are very happy to bring their good people to those trainings and of course the companies will pay for the training. So, again, it is working together in order to build the capacity, to maintain the capacity. The problem is, the most important problem is to attract the attention for the industry. You say, it is a vibrant industry and of course I agree it is a very vibrant industry, but the problem is to raise the interest of the school kids to take up a career in agriculture. Because, whether we like it or not, agriculture is not sexy - that's the problem. They move to other fields of career etc, and again we take our responsibility. We have all kind of programmes and we have spent a lot of budgets to attract them to our industry. And they can become a plant breeder, a seed analyst, a seed sales person, whatever. But this is just taken extremely seriously, but I can also tell you it is not easy. It is more about psychology than about genetics.

GENERAL DISCUSSION

KATALIN ERTSEY: I would like first to return to the other question raised at the beginning by the European Union representative which was regarding the seed moisture content and also the correlation between the moisture content and the seed quality and how to handle it. And I would like to ask Alison to answer this question. And of course after that the floor is yours for free discussion.

ALISON POWELL: I think the suggestion was that there could be a linear relationship between a reduction in seed moisture content and improved germination and vigour. I don't think you can say that. Seed moisture content is important in terms of influencing the response of the seed to subsequent storage, and there it is true that in orthodox seeds, the reduction in seed moisture content will improve the storage potential. So you compare the storage of a high-moisture content and a low-moisture content seed after a period of time – yes, below-moisture content seed will have higher germination and vigour, but that is only after a storage period. If you were to take two seed lots grown in the same area, reduce the moisture content at harvest of one much lower than another, I doubt there would be any difference in germination and vigour at that time. It might be, if there is a very big difference in moisture content, that the high-moisture content seed would germinate a little faster, but that would just be on the basis of it having a higher moisture at the beginning of the germination phase, rather than its intrinsic germination or vigour capacity. So I think the main effect of moisture content on seed quality is through its influence on storage potential.

JOHN HAMPTON: If I could just add to that comment on this, the other side of the coin, where seed moisture content in fact gets too low, and you are likely to be in a situation fulfilled saying where there is plenty of moisture you are likely to get imbibition damage because of the very rapid uptake of water, and so that again would in fact decrease performance, even though potentially it was a high vigour seed lot.

EUNICE OMBACHI: Thank you. My name is Eunice Ombachi from Kenya. I would just like to know whether there is a really serious effect on the method of drying seed after harvesting and maybe does it matter what the speed is and the time of drying, and what is the long-term effect on the quality of seed?

ALISON POWELL: I think the speed of drying and its effect on quality will largely depend on the initial moisture content of the seed, because if you are starting to dry a seed with very high moisture content and you dry that rapidly, that could be damaging. And of course very high temperatures during drying, particularly when the seed starts at a high moisture content will be damaging to the seed.

ROBERT GUEI: My name is Robert Guei from FAO. I would have two comments. One is a general comment, and then the other one will be to address some of the concerns that were raised during Larinde's presentation. The first one is: there is one aspect, which for me was not really dealt with during the presentations and for me is important maybe will be addressed later on. When we look at the title of the Conference, it is "Responding to the Challenges of a Changing World", and one of the global challenges that we are facing today is climate change. Some people don't believe in that, others do, but the fact is that today in West Africa, floods are happening there today which have destroyed most of the seed capitals have not happened before for a long time. In East Africa there is draught. We trust that it is developing fast. Yesterday in the news they were talking about hurricanes or tornados in Southern, let's say Latin, America, which was not there before, with very, very bad effects. So the problem is, there was a presentation on breeding and although breeding actually contributes to climate change adaptation, in most of the developing countries where the seed sector or the seed system does not exist or is not efficient, it is difficult under these conditions for farmers to have access to the good varieties that the breeding would actually come with. So for us, investing, encouraging policymakers to invest in the seed system development enabling policies for the private sector, IP issues that we talk about, those things actually I am quoting for the private sector to operate in these countries, so that we can have an efficient seed system to contribute rapidly to having access to these

good varieties. And I think this is important. It is so important that also at the beginning of the Conference paper they say that this event is aimed at policymakers and government officials. So for us, FAO, what we get out of this, what we have to take to these policymakers will be to appraise them to invest and unless this Conference actually appraise that, it will be difficult for us to do. So my suggestion is that this should be actually recognised by the Conference.

The second issue is the QDS issue, the question that was asked or the concern about QDS. And I would like to say, to add to Larinde's response, that QDS is only a minimum standard for countries that don't have any other standard in place. It is not used actually in Europe, because European they have standards in place, but in some African countries where the seed system is strong or really where they have standards, they are not required to use QDS. So it is only in countries where such standards do not exist, and it has actually been very helpful for some of the crops in those countries where no standard exists. Thank you, Madam Chair.

KATALIN ERTSEY: Thank you for these remarks and I hope our Conference can also add some things to solve these problems. Mr. Le Buanec, please.

BERNARD LE BUANEC: Thank you Madam Chair. Le Buanec, Bernard, Organising Committee. First reaction on what Mr. Guei said; of course we will have the conclusions of the Conference tomorrow evening, so we will be able to check what we are going to say tomorrow evening, but it won't be far from what is said now I guess. I would like to come back to the question from our colleague this morning on insurance. And that is a very tricky issue. And you say, Madam Chair, that of course it is easier to have an insurance when you have quality assurance, and I agree. But then insurance, who do you want to insure? The farmer, if he has bad seed; the seed producer, the seed seller, the seed company in general? If it is the farmer it is always difficult, because when there was a problem in the field, the farmer first of all always says: "we have bad seeds". But then we have to show that it is really the case. So you need experts to be sure that it is bad seed or not. Then you have to know if you have standards and then of course if it is fraud, it is clear, according to the country it can be a criminal act, but that's a legal issue, that is not a question of insurance - it's a legal issue with penalties. And then you have errors and omissions and here you have a lot of insurance systems that have been put in place by insurance companies. So it is a very tricky issue and if ISTA wants to embark on it, I would really encourage them to be extremely careful and take a lot of lawyers to help them. Thank you, Madam Chair.

FRANCISCO MITI: Thank you. My name is Francisco Miti from the Seed Control and Certification Institute in Zambia. I have two questions. One to Larinde and the other to van der Burg. Larinde in his presentation he said national system for limited generation of seed production. I really did not understand what he meant and wanted more clarification on this. The presentation of van der Burg was quite exciting and particularly the area of ethanol production by seed that is deteriorating. From Ms. Powell's presentation this morning we know that germination can be high when vigour in fact is low, meaning that seed deterioration has already started when in fact the seeds have good germination. It means at this stage that ethanol production should have also started being generated, because the seeds are deteriorating, according to van der Burg. I see this test to be very useful especially in the area of measuring vigour, levels of vigour, seed vigour. Probably I missed some statistics, but if he has I wanted some statistics about the correlation of ethanol production to vigour. Are they positive, is it a strong correlation which people can depend on so that they can interchange and use it for vigour determination? Thank you.

MICHAEL LARINDE: Thank you, Madam Chair. Basically I am talking of a seed certification system, because in seed certification you limit the generation; you go from one generation to another till you get to certified seed, and it could be classical seed certification or, in this case, Quality Declared Seed. Thank you.

JOOST VAN DER BURG: Thank you for the question, Mr. Miti. Ethanol production is a very new item for us at least, and my colleague Steven Groot can give you all the details, so I will be happy to provide you with his e-mail address. So far we have been experimenting with Brassica seeds only, so it is only available for that species until now and I made the graphs a little bit nicer, but the sketches were there underneath but I cannot show them right now. I will be happy to provide you with them later on.

ALISON POWELL: As I know well that ethanol has been related to vigour for many years. It was related to vigour first of all in India, in Calcutta by Professor Bhasu (?) and he himself actually developed some vigour tests. This new method obviously offers a lot of potential for rapid detection of differences in seed vigour, but like the colleague from Zambia I am also looking forward to see the correlations between the evolution of ethanol and either field emergence or storage potential of seed lots. Only where assessments are related to an outcome of vigour, do they really test seed vigour. So I am looking forward to seeing that data.

OBONGO NYACHAE: Thank you. I wish to clarify the situation of seed in East Africa. A lot of work has been going on in harmonising regulations, seed rules and laws in 10 countries in Eastern and Central Africa. And several of these have actually developed legislation that supports a formal seed system. And some of the countries have even applied in order to be accredited by ISTA, by OECD in order to have these systems supported by their own governments. SADC, the Southern African Development Coordination, also has a programme, I think you will hear it later in the afternoon, where a lot of effort has been made to try and bring people out of these informal, perpetual system of poverty. So I am really making an appeal. Robert, you did explain that the Quality Declared Seed Systems are in the countries which do not have capacity. That is OK. Where those countries have moved a step and have legal mechanisms for the development of the seed sector in their countries, my appeal is to put money in the systems that are existing that support finally a more sustainable seed system. I have in mind a country like Uganda. Ten years ago they did not have such a system. Now they have more than 20 companies that have invested in the development of seed. That is true of several countries I could quote here. So in such countries it is very important that they get supported, the private sector gets supported, to be able to pick up seed development, including the so-called orphan crops.

VICTORIA HENSON-APOLLONIO: Thank you. I am Victoria Henson-Apollonio, I work with CG Systems, I head up the Central Advisory Service on Intellectual Property. I found this morning's presentations very, very fascinating, because I think it is really important for our CG stakeholders, our poor farmers, resource-poor farmers, that they have quality seed that they plant. And I am curious; you know yesterday we heard a lot about patent protection and PVP, but I am wondering about translating all of the work that you all have been talking about this morning into something that the customer can recognise, the farmer can recognise, as being seed that is quality seed. So I wanted to sort of raise the flag a little bit about trademarks, but I am curious what is the thinking of ISTA about making farmers aware that they can trust this seed. I hear a lot of programmes that are on the other side in terms of developing quality seed, but I do not hear anything about the side of the farmer or the customer in terms of knowing about what this means to them.

KATALIN ERTSEY: I would like to answer very short. I think the work of ISTA and all that we have done is only a tool to achieve the goal of using quality seeds. We have 74 member states and I think so the ISTA member states, inside the country and the ISTA members inside the country, they have the task to do it. And me personally and I think all our colleagues try to do it in their countries' interest to keep this message to the farmers and the growers.

KATALIN ERTSEY (SESSION SUMMERY): I think that this session has demonstrated that seed is the first determinant of future plant development, and the quality of the seed used is the starting point and one of the most important factors for successful plant production. The first presentation underlined the different testing methods that are available to help to fulfill the requirements of farmers and growers. The determination of seed quality parameters, of course, needs broad knowledge on taxonomy, botany, seed physiology, biology, seed processing and also some legal knowledge, and demands intensive scientific study or work.

In the second presentation, our speaker analysed the correlation between quality of seed used for cultivation and agricultural yield, and supported the establishment of a quality assurance system and certification schemes as a good means to achieve good seed quality.

And I think the outcome of the third presentation was the same: the evolution of seed testing. It is clear from this presentation that secure seed supply systems are needed all over the world with uniform application of methods for seed sampling and testing and that we require well-equipped laboratories with pertinent quality assurance systems and staff with the necessary knowledge and skills. I think the ISTA Rules and the ISTA Quality Assurance System can fulfill these requirements.

From the FAO presentation, for me, it seems that there are huge security problems in the world, and also seed security problems too. I think we have to be aware of this. And also underline that in many countries quality seed is simply not available to poor farmers, either because they cannot afford it or because they do not have ready access to supply.

From the fifth presentation our speaker assured us that there is permanent progress and development to evaluate seed technology and use of it for better seed quality determination and these technical procedures are based on the latest scientific research.

And now I come back to the presentation about the necessity for the seed analyst. We realised that there is a lack of highly educated seed analysts because of significant cuts in scientific research activities and programmes over the last decades, with reduced possibilities for young academics: and also the use of scientific knowledge as a competitive advantage for companies and the need to make money out of scientific knowledge, the huge transparency and scientific exchange of the latest research results. The uncompetitive salaries for seed analysts in developed countries make the career in seed quality control unattractive for young people. Governments as well as the private sector need to give increasing attention to this development to prevent it having a negative effect on the overall seed sector. And now I would like to close our session only with one sentence: High quality seeds are the basic requirements for productive agriculture.

Session 4. Conclusion, presented by the Chairperson **The importance of quality seed in agriculture**

- ▶ The session demonstrated the importance of seed quality for crop productivity and agricultural production. It has underlined, that a lack of information on seed quality could result in crop failures and has the potential to threaten food security for whole countries
- ▶ The determination of seed quality parameters requires a broad knowledge of plant and seed physiology, taxonomy and botany and requires intensive scientific studies and research
- ▶ The application of seed quality evaluations requires a detailed knowledge regarding seed production, seed marketing, seed regulations and the seed sector
- ▶ Since 1924 the International Seed Testing Association (ISTA) has been the impartial and objective platform where leading seed technologists and researchers have come together to discuss relevant scientific progress and make the necessary definitions regarding seed quality and how to measure it
- ▶ Currently in developing countries there is not an adequate seed quality assurance infrastructure with respect to seed testing and this is required to increase crop productivity and provide enhanced food security in these countries
- ▶ The evolution of seed quality determination has not reached an end point and there are interesting developments in the pipeline that take account of the changing needs of the market. These will make tests and their applications more relevant, effective, robust, quicker and cheaper
- ▶ Significant cuts in scientific research and education has reduced the possibility for young academics to acquire the necessary seed technology skills
- ▶ In the seed technology area transparency in and scientific exchange of the latest research results remain of crucial importance for continued progress
- ▶ Uncompetitive salaries for seed analysts in developed countries make a career in seed quality control unattractive for young people.