Adaptation of evaluation criteria to changing agriculture practice in maize and their impact on variety registration

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Abstract

In the past 50 years, great progress has been made in improving plant yield, harvest security, disease resistance and crop quality. Although high fertilizer input, pesticide availability, better varieties and adapted crop husbandry have made this progress possible, intensive agriculture has important drawbacks. Growing crops such as silage and corn maize cause unwanted side effects in several European countries, such as N- and P- losses to ground water, loss of biodiversity, smaller rotations, higher disease pressure, lower soil fertility and worsened soil structure. In the future, breeders will have to ameliorate these negative effects while maintaining high productivity. The question arises, “Are the currently cultivated crops such as maize (in most cases, a restricted variety assortment) adapted for future agriculture, or do we need other crops or other types of varieties?”
This presentation will address the different aspects of future variety testing for maize (silage and grain) and which parameters have to be judged in light of intensive ecological agriculture.
In particular the paper describes i) the European regulation concerning variety testing ii) value for cultivation and use iii) current evaluation criteria for silage and grain yield in Belgium, and iv) introduction of new criteria such as to give a more precise evaluation of maize performance and approved in variety testing. The evaluation criteria should be balanced between parameters for yield, harvest security (resistance to lodging and stalk rot), disease resistance and quality. The choice of the standard varieties also greatly determines the level needed for admission.

Keywords: maize, variety testing, agricultural practice, criteria

Introduction

In the past 50 years, great progress has been made in improving plant yield, harvest security, disease resistance and crop quality. High fertilizer input, pesticide availability, better varieties and adapted crop husbandry have made this progress possible. However, intensive agriculture has important drawbacks. Cultivation of crops such as silage and corn maize cause unwanted side effects in several European countries, such as N- and P- losses to ground water, loss of biodiversity, smaller rotations, higher disease pressure, lower soil fertility and worsened soil structure. In the future, breeders will have to ameliorate these negative aspects while maintaining high productivity. Climatic change can also strongly affect a variety’s performance. Future agriculture will need to become sustainable, economically, ecologically and socially.

The challenge for future agriculture will be to obtain high production levels for different crops while meeting the restrictions imposed by governments (regional, national and EU). A high production level is necessary to maintain the cost-effectiveness at farm level. All of this translates into intensive ecological agriculture. High soil fertility and good soil structure will also become very important in such agricultural practices.

This presentation will cover the different aspects of future variety testing for maize (silage and grain) as well as the parameters requiring judgment for use in intensive ecological agriculture. Important questions include: “Are the currently cultivated crops such as maize (with in most cases a restricted variety assortment) adapted for this new evolution? Do we need other crops or other types of varieties? What role can variety testing play?”

European regulations concerning variety testing

In the European Union, a new variety of an agricultural crop must submit to official trials for DUS (Distinctness, Uniformity, Stability) and VCU (Value for Cultivation and Use) before commercialization. The guidelines for those tests are summarized in European Directive 70/457/EC (1970), revised in 2002 (2002/53/EC). The aim of the VCU research should be to predict the agronomical and technological value of a new variety in a reliable way in comparison with standard varieties. This would ensure that only the most valuable varieties would be presented to the market.

Each EU member state must comply with EU legislation concerning plant varieties and seeds.

The conditions for accepting the varieties of ag-

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ricultural plant species that may be marketed in the EU to the Common Catalogue (Council Directive 2002/53/EC, 2002) are set forth in Council Directive (CD) 2002/53/EC, a revised version of Directive 70/457/EC (on the common catalogue of varieties of agricultural plant species). This directive does not apply to varieties whose seed or propagating material is intended for export to non-EU countries.

CD 2002/53/EC, Article 7 describes the characteristics to be covered at a minimum by the examination as well as the minimum conditions for examining certain varieties of agricultural plant species. CD 2003/90/EC (Council Directive 2003/90/EG, 2003) gives general advice about creating implementation measures for these examinations.

A variety is accepted onto the National List of a EU member state only if (1) it is first determined to be distinct, uniform, and stable (DUS) and (2) if the value for cultivation and use (VCU) determination shows a clear improvement on varieties already on the National List, or if it has some special characteristic that compensates for any inferior performance in some other aspect. The variety's denomination must also be approved (BS, 28/10/2008, 2008).

The objectives of the European Union seed legislation are: (a) to improve agricultural productivity, (b) to ensure food security in the EU, (c) to improve the competitiveness of the related sectors and (d) to contribute to the harmonisation of the legislation at EU level, which will lead to more open markets.

Value for Cultivation and Use (VCU)

Directive 2002/53/EC, Article 4 defines the criteria for a variety's value for cultivation and use (VCU). According to that directive, a variety must first be compared to other varieties accepted in a National List and its qualities, taken as a whole, must be examined. The variety will be regarded as satisfactory if those qualities offer (at least in any given region) a clear improvement for either cultivation, usefulness of the crop, or usefulness of any products derived from the crops. Where superior characteristics are shown, inferior characteristics may be disregarded.

Variety research lies between agricultural practice and breeding (Figure 1). The evaluation criteria are based on the most important characteristics for agricultural practice, and can push the breeding companies in a certain direction. On the basis of criteria for release of new varieties, variety research can contribute to more sustainable conventional agriculture and/or organic agriculture, anticipate new situations, or be a step ahead of new quality criteria.

Two aspects of the VCU procedure are very important: 1) testing conditions that simulate agricultural practice and 2) testing for genetic differences between varieties. VCU criteria must reflect agricultural practice and test the varieties under the same exploitation as in practice. For example if maize is grown in different agricultural regions of Belgium, thus the variety testing (2 to 3 years of testing) must also take place in various locations.

The aim of variety testing should be to evaluate the genetic differences between the varieties and not the seed treatment or crop husbandry method used, e.g., fertilization, herbicide treatment. For this reason, the testing process has several requirements. The most important are: 1) delivery of untreated seeds of all varieties and treatment with the same product(s); 2) sowing at higher density (+ 10%) and thinning out to the same plant density; 3) harvest of all the varieties at the same date (reference variety) and 4) application of the same fertilization and herbicide treatments.

Based on these principles, the protocol for VCU testing is then worked out.

Breeding ←→ Variety Research ←→ Agricultural practice

Breeding:
-New hybrids
-Registration and commercialization

Variety Research:
-Comparison with standard varieties
-Release of best varieties
-Criteria : most important agricultural characteristics
-Descriptive and recommended list

Agricultural practice:
-Knowledge of new varieties compared to registered varieties
- Cultivation techniques adapted to the demands of society (environmental problems, quality demands)

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Crop Husbandry and Quality Research

Figure 1 - Interaction between variety research, breeding and agricultural practice

Table 1 - Index system for silage maize (for each earliness group)

Characteristic	Rating scale	Coefficient
Yield of total dry matter (kg/ha)	% (relative figure in comparison with the 4 standards)	+ 1,0
Sensitivity for lodging	% lodged plants	< 5 + 0.3 x x = average % of standard
Digestibility (% on dry matter)	% (real figure)	+ 1,5

Current evaluation criteria for silage and corn maize in Belgium

The evaluation criteria require an equilibrium between parameters for yield, harvest security (resistance to lodging and stalk rot), disease resistance and quality. At the beginning of the testing period the criteria and the potential standard varieties are fixed and do not change during the testing period. Each year new varieties are introduced for the trials; the standard varieties can then change and be used to test the new variety. These are in general the best admitted varieties, which raises the bar for each new variety tested.

Belgium uses an index system based on the most important quantitative and qualitative characteristics (Anonymous, 2010). The coefficients for the parameters in the index are based on correlations. For silage maize, new varieties are compared to six standards for the various earliness groups, of which the best four are chosen for the final judging based on their characteristics as a whole. For corn maize new varieties are compared to eight standards, of which the best four, are chosen for the final judging based on their characteristics as a whole (Tables 1 and 2). For harvest security parameters (resistance to lodging and stalk rot), new varieties are compared to the average of all standard varieties. The formula used is based on the acceptable level of lodging and/or stalk rot in practice.

In addition, other characteristics (mostly morphological, i.e., early vigour, flowering date, plant and ear insertion height) are judged but they are not incorporated into the index.

Introduction of new criteria

In the near future, farmers will be confronted with changing exploitation conditions. This will affect the farm's cost-effectiveness. How can variety testing affect this process? Based on the criteria and the level for registration, variety testing can determine the type of varieties that will be registered on the national and European catalogues and thus become commercialized. Due to demands for reduced loss of nutrients and pesticides to soil water, farmers will soon need varieties with a high production level in spite of reduced input of fertilizers and pesticides.

Variety research must have a birds-eye view of all aspects of maize culture (now and in the future). A combination of the needs of farmers and the society shall have be translated into criteria for registration. The final goal must be early ripening varieties with a high production level. After early harvest of maize, a covering crop can be sown that will have a high probability of good germination and good soil covering before and during winter. A well-established catch crop is positive for the environment and the soil structure.

In addition to the current criteria (Tables 1 and 2) other parameters will need to be evaluated and some of them incorporated into the index for registration.

Possible new criteria could include the following:

Table 2 - Index system for grain maize

Characteristic	Rating scale	Coefficient
Yield of grains (kg/ha)	% (relative figure in comparison with the 4 standards)	+ 1,0
Earliness (% humidity in the grains)	% (real figure)	- 3,0
Sensitivity for lodging	% lodged plants	< 5 + 0.3 x x = average % of standard
Sensitivity for stalk rot	% plants with stalk rot	< 5 + 0.3 x x = average % of standard

field emergence, early vigour, cold tolerance, nutrient efficiency, drought tolerance, disease resistance (other than already included in the criteria), earliness in combination with a high production level, N-content at harvest, total plant mass remaining and biogas production (only for maize), quality (cell wall digestibility - only for silage). The effect of these possible new criteria on the type of registration has to be studied during several years. Not all of them will have to incorporated in the index system; most can serve as additional information for specific conditions of exploitation.

A maize cultivation depends on good field emergence, even under cold and wet (or very dry) climatic conditions in early spring. This parameter can be predicted in the laboratory by a severe cold test (7 days in the dark at 10°C, followed by 4 days at 25°C in the light) (Van Waes J, 1995). Possible parameters for judgment can be the rapidity of field emergence (in days), regularity of field emergence (scale 1-9) and the total percentage of field emergence.

Early sowing makes it possible to prolong the growing period and thus increase the production level. However, in light soils, cold (and frost) temperatures in spring can be fatal for young plants. Studies executed by Lootens et al (2004) show clear differences between maize varieties for cold tolerance Possible parameters can be chlorophyll production and pigment contents of young seedlings in a growth chamber at low temperatures (just above 0°C). In most cases this parameter is also correlated with early vigour; it can be evaluated in a scale from 1-9 (where 1 is low and 9 is high).

Restricting fertilizer input can greatly affect the production level and ranking order of maize varieties (Van Waes et al, 2002) Visual evaluation of differences to determine nutrient deficiency (N, P, K and others) can be very useful to determine which varieties have the best nutrient efficiency. Breeders can of course select plants that thrive under low input conditions.

A good drought tolerance is important to have varieties adapted for growing under dry climatic conditions, especially during the flowering period. This parameter can be evaluated by visual scoring of the rolling of the leaves during drought and grain filling.

Besides Fusarium and *Ustilago maydis*, other diseases on leaves and in the soil can reduce the plant productivity. A disease index for root and leaf development can very helpful to determine the most tolerant varieties. In the new criteria for maize evaluation, “Helminthosporium (leaf disease)” is scored in a scale 1-5. Inghelbrecht et al (2011) have developed a screening test for Rhizoctonia.

In most cases there is still a negative correlation between earliness and yield production. However, ecological maize culture will require early varieties. In the criteria a bonus for earliness could become a bonus in the new criteria.

To restrict the losses of nitrogen (and phosphorous) to ground water it is important to maximize the export of minerals such as N (kg/ha). The N-export is the product the percentage of N. of the harvested plants and the dry matter yield (kg/ha). Measurement of both parameters at harvest can give important information about the differences between varieties. In terms of the N-content and the N-export this variation is up 30% (1.0 – 1.3 % N) and 40% (N-export from 220 to 320 kg/ha) (Anonymous, 2010) respectively.

Other possible parameters are cell wall digestibility for measuring the quality of silage maize and the yield of remaining plant material for biogas production in grain maize.

In conclusion, many new parameters can be judged. A simulation of their incorporation into the index for registration would require studying their effect over 2 to 36 years. Such lengthy testing would evaluate the effect of these criteria on the type of varieties that pass the index. International co-operation could be very valuable here. It is possible that only a few of these criteria would be incorporated into the index, but they could nonetheless yield important additional information about specific exploitations and soil conditions.

What role could GMOs play in this process? Agriculture may face some very drastic situations in the near future (e.g., very restricted nutrient supply, extreme dry climatic conditions, frost in spring after emergence). Therefore, the availability of varieties adapted to such conditions can be very useful. In some cases, GMO technology can be an effective tool to quickly create varieties adapted for such conditions.

Evolution of varieties

The evolution of maize varieties for the future has to reflect at least four scenarios:

1) Continued progress in breeding. Breeding has continually improved over the past years (Table 3). Based on the hypothesis that this progress will continue due to new combinations of lines with a better heterozygotis effect, the area required for production may be significantly reduced. In the VCU trials, the level for registration climbs a bit each year Van Waes and Van Bockstaele (2008), Van Waes et al (2010), Pannecoucque et al (2011). This results in a restricted percentage of new varieties with a higher potential (yield and other characteristics) in the catalogue. Maintenance of this regime of registration during several years, under the assumption that the best varieties are continuously incorporated in the agricultural plan can quickly result in the realisation of the same production (silage or grains) on less surface area. Another assumption in this model maintains the staple at the same level for the next 10 years.

Table 4 contains a model for silage maize. In 2008, silage maize was cultivated in Belgium on 176,000 ha. The new varieties have a higher potential around 1.1% in yield; for 2009, the same production can be

Table 3 - Evolution of silage and corn maize varieties in Belgium during the period 1993 – 2010 (basis: five best silage and grain maize varieties of the recommended list (Van Waes et al, 1993, 2010).

Silage maize		Grain maize	
Total dry matter yield	↑ 1.1 % /year (rel.)	Grain yield	↑ 2.8 % /year (rel.)
Total digestible organic dry matter yield	↑ 1.2 % /year (rel.)	Dry matter content of the grains	↑0.4 % /year (rel.)
Dry matter content of the total plant	↑ 0.8 % /year (rel.)	Resistance to lodging (scale 1-9)	↑ from 7.0 till 8.2
Resistance to lodging (scale 1-9)	↑ from 6.9 till 8.5	Resistance to stalk rot (scale 1-9)	↑ from 7.2 till 8.4
Resistance to stalk rot (scale 1-9)	↑ from 7.0 till 8.9		

realised on 174,085 ha. Maintaining this level during 10 years can result in a decrease of the surface for silage by about 19,150 ha. The vacant surface can be used for the cultivation of other crops, which indirectly results in eventually higher income for the farmers (Van Waes, 2009).

2) Better understanding of the correlation between agronomical parameters. Breaking this negative correlation, of which some examples already exist, offers the possibility of maintaining a high production level even under a shorter growing season. The latter can be obligatory in the framework of the environmental policy (sowing catch crop after a maize culture and the necessity for a good soil covering before and during the winter).

Table 4 - Evolution of the potential of varieties in relation to the needed surface for cultivation - Case silage maize in Belgium (Van Waes, 2009)

2008	
Total ha of silage maize	176,000
Production of 1 ha	15,000 kg (dry matter)
Total dry matter production on 176,000 ha	2.64 billion kg (dry matter)
2009	
Increase in yield (basis: average of 5 best varieties)	+1.1% = 165 kg (dry matter)
Potential kg dry matter of 1 ha in 2009	15,000 x 1,011 = 15,165 kg
Number of necessary ha for production of 2,400 billion kg dry matter	2.64 billion kg : 15,165 kg = 174,085 ha
Reduction in surface 2009 compared to 2008	1,915 ha

3) Introduction of stress tolerance (i.e. cold, drought) to counter possible negative effects on yield. How to do this is another question; perhaps a combination of conventional and biotechnological breeding.

4) Maize in other rotations and as main or secondary crop. This can lead to possible compensation of the negative effects of monoculture (less disease and weed pressure, better soil structure). Another possibility can be valorisation of all the biomass during the growing season (maize as main crop followed by a covering crop), which can finally lead to a higher income.

Conclusions

In the past 50 years, great progress has been made in plant yield, harvest security, disease resistance, and crop quality. But cultivation of crops such as silage and grain maize cause unwanted side effects in several European countries. In the future, farmers will have to ameliorate these unwanted effects while maintaining high productivity.

Variety research, especially the VCU test, lies between agricultural practice and breeding. The evaluation criteria are based on the most important characteristics for agricultural practice; they can push the breeding companies in a certain direction. On the basis of criteria for release of new varieties, variety research can contribute to a more intensive ecological agriculture and anticipate new situations.

For more than 40 years, variety research has been regulated at the European level via council directives concerning plant varieties and seeds. These directives stipulate that the Value for Cultivation and Use (VCU) must be tested for new crop varieties before commercialization.

The evaluation criteria require an equilibrium between parameters for yield, harvest security (resistance to lodging and stalk rot), disease resistance and quality.

In the future, farmers will be confronted with changing exploitation conditions which will affect cost-effectiveness of growing a crop. How can variety testing contribute to this process? The criteria and the level for registration variety testing can determine the type of varieties that will be registered in the national and European catalogue and thus commercialized.

In addition, to the current criteria it will be necessary to evaluate other parameters and to incorporate some of them in the index for registration. The focus can be direct on cold tolerance, nutrient efficiency, and drought tolerance.

The evolution of maize varieties for the future has to reflect at least four scenarios. In the past new maize varieties only stayed at the top for three to four years. Will this evolution continue in the future, given the changing agricultural practice? Regardless, choosing the right variety in the future will still be an important factor for the cost-effectiveness of maize cultivation.

Varieties with a higher production level also reduce the amount of land necessary for the same production. The vacant surface can be used for the cultivation of other crops, such as energy crops, which do not compete with food and forage crops and can thus increase the farmers' income.

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