Scotland's Rural College

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Analysis of cereal trials to evaluate market and non-market benefits of new varieties and their traits

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Introduction

The public good role of agriculture is increasingly emphasised in discourse on sector sustainability, and most OECD countries are now locked into a range of commitments on climate, change mitigation, soil and water quality improvement and biodiversity conservation. In this context, the development of new varieties will increasingly face the challenge of demonstrating financial benefits while contributing to the management of good and bad external impacts.

Characterisation and evaluation of cereal varieties for both market and environmental values would be a significant step towards developing new sustainability criteria for the variety testing system and for reducing the reliance on high inputs (AEBC 2005; FOSSE 2001). At present, successful varieties are characterised by high yields in response to fertilisers, fungicides and plant growth regulators and without competition from weeds. EU Directives require testing for value for cultivation and use (VCU) as part of National Listing (NL), based on yield, resistance to harmful organisms and quality characteristics, which are primarily market-led drivers. UK farming would benefit from varieties (and their traits) giving quantifiable environmental benefits as well as high market value, and although EU Directives do not preclude additional criteria, the NL testing system is almost entirely funded by applicants (i.e. plant breeders), and consequently assessment of traits with possible environmental benefits is limited to disease resistance.

The stated objective of improving the public good benefits of new varieties suggests the need to improve our understanding of traits conferring such benefits and how they could be incorporated in VCU testing. Examples are plant traits of general value to lower inputs e.g. yield without fungicide and with more importance placed on disease resistance ratings (FOSSE, 2001), high weed suppression characteristics (Watson et al. 2006; Mason and Spaner, 2006), early crop vigour (Bertholdsson 2005; Richards and Lukacs 2002; Rebetzke and Richards 1999) and widening of sowing dates to offset weed, pest and disease build-up (FOSSE, 2001).

Traits to consider in future cereal trials

Future evaluation should include integration of data from trials undertaken across different input levels to broaden the range of selection criteria and genotype *x* environment interactions under test. This needs to take into account the likelihood that the yield gap between genotypes becomes less as inputs are reduced (Sinebo et al. 2002) and that good performance at low inputs is not always precluded or predicted by testing at high inputs or *vice versa* (Abeledo et al. 2003; Hasegawa 2003; Sinebo et al. 2002). For the key issues of disease control, weed competition and more efficient nitrogen use, genotypes will require a 'character set' of traits to suit reduced fungicides, herbicides and nitrogen fertiliser. These traits need to be

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highlighted for positive and/or negative interactions within the character set for each genotype. This may include possible trade-off and optimizations to suit different purposes on farm.

The value of a genotype depends on its combination of traits. New varieties are normally defined according to their *market* value (dependent on yield, quality, profit margin); but they can also be rated in terms of their social value, which is notionally determined by the net value of financial return plus/minus the value of positive and negative external impacts. These impacts arise for example from the reduction of fungicide, herbicide and fertiliser use. This approach extends to an externality quotient or 'footprint' of each genotype. Direct and indirect inputs and outputs will include economic value, energy balance, nitrogen budgets and waste. This type of evaluation would allow the industry and testing authorities to estimate the marginal effects of any explanatory variable (i.e. traits) on the value of the genotype. New plant breeding targets such as competitiveness and increased vigour, along with improved disease resistance ratings, would provide opportunities for cost savings and reduced inputs on-farm. A market and non-market evaluation will also enable plant breeders and the variety selection and testing systems to understand the context within which genetic improvement takes place and the potential mechanism for prioritising further trait development. Governments are bound by a range of environmental and rural policy objectives, some of which are evolving through time. For example, policy targets are set out in the UK Government Sustainable Development Strategy, as well as more specific targets such as compliance with the Water Framework Directive and the Emissions Ceiling Directive. The wider aspiration of farming making a positive net contribution to the environment leads us to consider how new varieties might be assessed for their contribution to the wider policy drivers, indicated above.

Approaches for designing and analysing future cereal trials

The use of both market and non-market drivers within VCU testing, as well as in NL and national Recommended List (RL) trials, would require: (1) experimental designs with appropriate variety and environmental controls to differentiate genotype responses across different trials series and growing systems: including low-input and organic field trials to put material under the severest test (e.g. Hoad et al. 2006) and (2) methods to assess market and non-market value: including cost-benefit analysis of aggregate returns to the costs of selecting new varieties and their subsequent adoption, and hedonic pricing (assigning value to characteristics of goods) to value individual traits.

The response of genotypes (and their traits) to crop inputs or management factors is central to assessing their market and non-market benefits at both the development and testing stages. Seasonal and site differences mean that the environmental component in genotype *x* environment analysis is highly variable: this can make analysis of management effects difficult. A new approach would be to clarify both 'environmental' and 'management' factors across broader ranges within the trial design. Systematic trial development using specific environments and well defined management options would enable the 'environmental' component (in genotype *x* environment) to be sub-divided into management *x* environmental components. Thus providing more reliable outputs for the analysis of cost-effectiveness of new genotypes in delivering socio-economic benefits.

Economic analyses should include comparison of the relative costs and benefits of new genotypes and their trait combinations with alternative methods. These could include other research avenues or policy levers such as market-based instruments, for achieving specified objective outcomes. Thus demonstrating the extent to which the introduction of new varieties may contribute to the delivery of environmental benefits. Hedonic valuation (Evenson et al.1988; Gollin and Evenson 1988) may be useful in valuing the wider environmental benefits of plant traits. In its simplest form, one such procedure is described by:

$$V_{ij} = F(T_{1ij}, T_{2ij}, ..., T_{nij}, Z_{ij})$$

where V_{ij} is some measure of the economic value of a variety *i* in location *j*. T_{1ij}, T_{2ij}, ..., T_{nij} are indexes of traits *1*, *2*, ..., *n* of the variety in location *j*. Z_{ij} is a further measure of economic or ecological factors or benefits associated with variety *i*.

For any given research priority or policy objective (e.g. mitigation or adaptation to climate change, protection of biodiversity or reduce pollution and waste) we can determine whether there is an alternative method of delivering the output equivalent to that delivered by the new genotype/s. In most cases, the relative options are unlikely to be delivering on exactly the same benefits and so a cost-effectiveness comparison can be complex. However, it is possible to conduct an "incremental cost effectiveness analysis" to compare additional variety or trait benefits to the current best, or currently implemented intervention, for achieving specific outcomes. New varieties may offer a cost-effective option to address specific policy objectives with the advantage that benefits of genetic improvement are permanent and cumulative. Even if the present value of the costs of alternatives (e.g. changes in crop rotations or policy-led reduced inputs) can be low, a genetic approach is still favoured providing assumptions about levels of adoption by farmers and end users hold.

Present value costs of adopting new genotypes can be assessed by comparing values of the genotype and alternative approaches with the expected future benefits derived from the genotype and alternative options in delivering the desired objective e.g. reducing fertiliser or pesticide inputs.

PVg = Present value of new genotype/s
PVc = present value of the alternative strategy
Qg = quantity of improvement or benefit under new genotype option (within a time frame)
Qc = quantity of improvement or benefit under alternative strategy

An incremental cost-effectiveness ratio can be considered as:

$$\frac{PV_g - PV_c}{Q_g - Q_c}$$

by substituting various options for the costs and benefits of the alternatives to introducing the new genotype/s. The use of this comparison is in terms of comparing the unit cost of incremental benefits delivered by the genotype/s. In some cases we may be only interested in the strategy that delivers a greater quantity of social or environmental or market benefit. If this numerator is negative, then there is an incremental saving from not introducing the new genotype/s, unless the specified alternative strategy delivers less benefit over a different and specified time period. The net present value (*NPV*) can be derived by a discounting procedure. The following equation summarizes the procedure:

$$NPV = \sum_{t} \sum_{i} \frac{B_{it} - C_{it}}{(1+r)^{t}}$$

where NPV is the net present benefit, B is a measure of monetary benefits (element *i* at time *t*), C represents the monetary cost, and r is the discount rate. When all the market and non-market costs and benefits of a new genotype are measured in monetary terms, the aggregation is simple: the discounted value of the total costs over time is subtracted from the total benefits also discounted over time. Positive *NPV* (i.e. benefits exceed the costs) indicates that the new variety is superior to the current best or 'do nothing' situation in terms of overall value. If the *NPV* is negative (i.e. the costs are larger than the benefits), then the new variety would not be expected to have significant benefit, unless there were other strong non-monetized benefits to consider.

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