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# Testing of agricultural machinery

*Tractors, machinery and implements for indoor and outdoor farm work represent the most cost-intensive production inputs for farmers and contractors and are characterised by an almost infinite application possibility. On the one hand this complicates their design and, on the other, the selection of the appropriate farm machinery is not easy because performance results come from the widest base: from industry, recognised testing institutions, specialist magazines. There are repeatedly controversial discussions over the use of the various public testing methods.*

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The wide variety of farm machinery on the market and the cost pressures on agricultural production methods mean farm managers are increasingly reliant on investment decision help which minimizes wrong-purchase risk, at least in the medium term. There's a variety of information available for the farmer and contractor to help in the reliability of strategic decisions, i. e., data from brochures, product descriptions, professional colleague experiences, test reports from the most different institutes and organisations, results of scientific investigations into questions relevant to practical farming.

### The farm as biosystem

The more they take account of working conditions on individual farms, the more appropriate are decision aids. But such aids are individually influenced by many factors: personal preferences of the farmer and workers, farm structure and orientation and, of course, soil, climate and market presence, to name but a few. Thus, each single farm represents an individual biosystem with very precise and different technology requirements depending on external conditions and specific orientation.

Farmland requirements regarding cropping equipment – dependant on soil and its water retention capability and also long-term effects of cultivation methods – remain relatively easy to define. In contrast, the physical characteristics of plant material and associated requirements in harvesting technology alter according to variety-specific characteristics, influences of weather and plant protection requirements, to such an extent that harvesting machinery can deliver excellent as well as unsatisfactory results within a single day. Thus the testing of farm machinery covers the most different data recording and measuring methods. With all test methods there is the basic conflict of aims between precision of the results and their validity. This makes interpretation more difficult so that specialists such as advisers have to revert to a broad information basis.

The relevant possibilities and methods for testing farm machinery are emphasised in *fig. 1*. Each method on its own can only deliver a part of the required information. The information from as many sources as possible must be gathered together and evaluated for the overall judgement of a machine or method. These include results and facts from

- Evaluation and calculation of specifications
- Scientifically exact measurements taken under reproducible conditions (laboratory)
- Scientifically exact measurements taken under defined conditions (field)
- General investigations and measurements
- Information from independent experts, and
- Farmer/operator experiences.

### Technical specifications

Technical specifications such as machinery measurements, working widths, separation areas or engine power allow only a general machinery recommendation or help in a preliminary selection from manufacturers' brochures and special catalogues [1]. Such information is often only precise and, above all, reliable after testing by independent specialists [2, 3]. On the face of it, analysis of such technical data appears to be an uncomplicated comparison method. The values are either simply compared with one another or arranged as relative values in comparison with a basis machine.

What does cause a problem, however, is the mostly deficient transferability of construction characteristics onto the actual performance capacity of a machine. Taken as an example here is the combine harvester. Because dimensions of the separation area and the threshing performance are positively correlated, the standard combine has had its capacity increased as far as straw walkers are concerned right up to maximum transport width. On top of this, additional separation rotors have been introduced in developing the most different threshing and separation systems which have led, within a given width of threshing channel, to different threshing and separation concaves and total separation areas [5]. Because of differing separation functions the relationship between these separation areas and the real threshing performance is small. The throughput of six combines in two test series under comparable harvesting conditions [6] was dependent neither on the total separation area nor the threshing concave area. Only the total concave area tendentially influenced the non-grain component throughput [9]. Investigati-

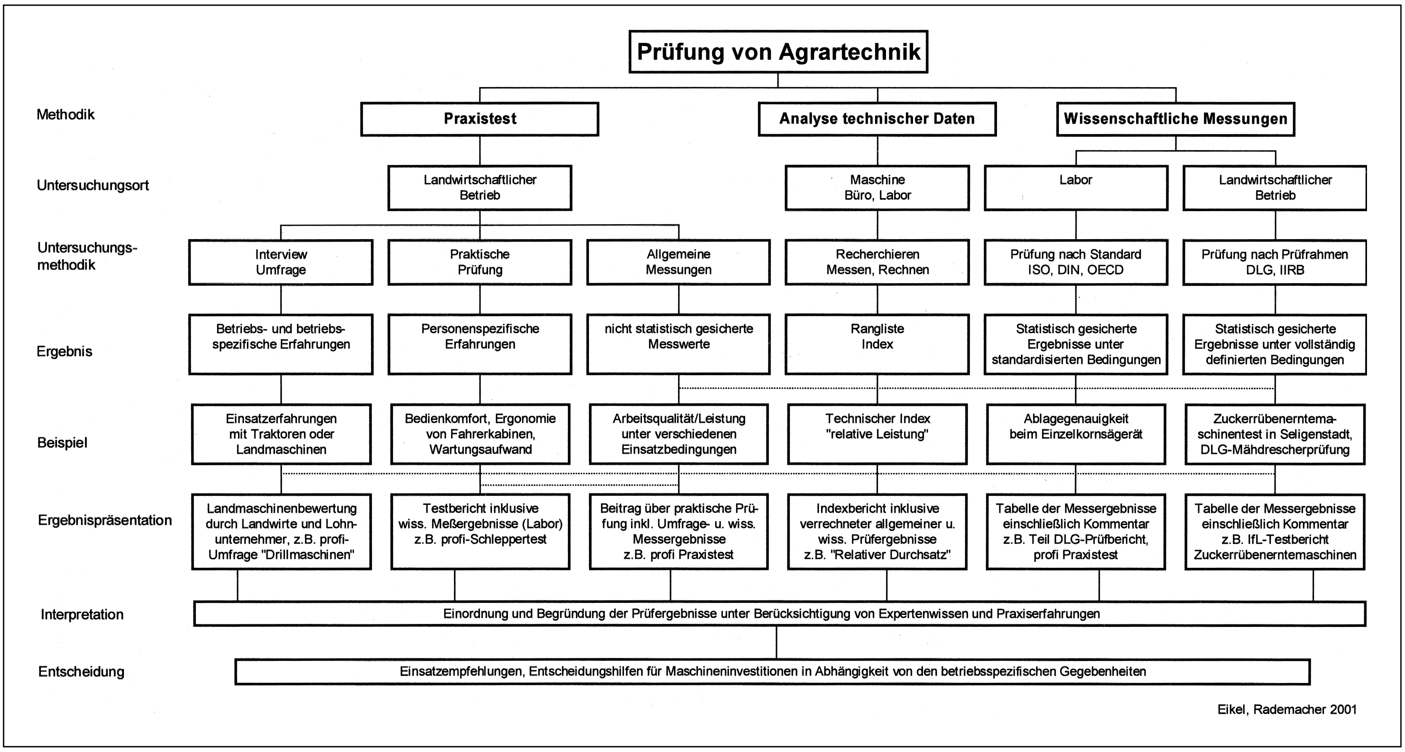


*Fig. 1: Test methods for agricultural technology - methodical procedures and forms of application*

ons with sugar beet harvesters [7] also showed a limited relationship between separation areas and soil separation.

If the separation areas of the different threshing and separation systems were supplemented with different weighting factors according to their influence on separation, the coefficient of determination of the relationship between the weighted threshing and separation areas and the actual threshing performance is increased. While it is true that the weighting factors are able to be factually explained they are not, however, verifiable through comparative test station measurements or similar trial results. The coefficient of determination of the relationships in *fig. 2* thus allows only the conclusion that threshing performance of the tested combines depends to a greater extent on the threshing and separation concave areas than on the threshing and walker areas.

Only to a certain extent do technical indices allow conclusions on performance capacity of a machine. Special features in construction, e.g. performance-increasing cutterheads or efficiency aids for straw walker separation and slope-compensation systems can only be taken into account through the use of further weighting factors, or not considered at all [8]. Thus such index values only give useful information to those interested in the construction characteristics of a farm machine, and not to the farmer or contractor.

Should the construction characteristics and their influence on work performance and quality be combined with actual performance data and interpolated for the different application conditions, the information value of the index is thus increased. An example here is the index „relative throughput“ for combines [4, 8]. Its advantages are the broad data basis and the consideration of special constructive characteristics and extreme harvest conditions. Additionally, the index method can be combined with a full cost calculation [9] so that the economic pros and cons of different machines under given harvesting conditions become clear. Disadvantageous here, however, is the difficult justifiability of the index calculation and the limited accuracy of forecasting because of the imprecisely interpolated individual values.

## Laboratory tests

Without a doubt the most precise measurement results are achieved within laboratory tests according to national or international standards such as DIN, ISO or OECD. Classical cases of these feature tests with tractors on the engine test stand or via PTO performance measuring to ascertain engine power performance specifications [10]. The test results are internationally comparable. The same applies for testing a precision drill [11]. The results concerning single seed selection and placement precision are internationally recognised and comparable.

Harvesting performance and work quality of large machines such as sugar beet harvester, combine or self-propelled silage harvester can only be tested for given parameters in the laboratory through part-investigations. A classical example of this features investigations on the threshing equipment test stand. But because the harvest material used in such cases is almost always dry, storage-quality grain, results can be used in ba-

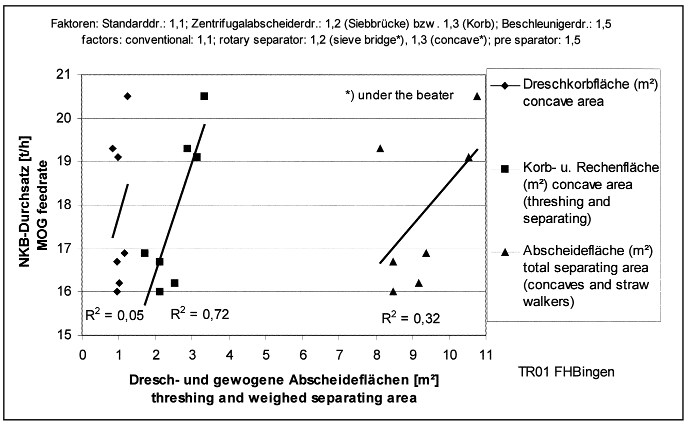


*Fig. 2: Linear relationsships between threshing and weighted separating areas and real threshing capacities [acc. to 5 ]*

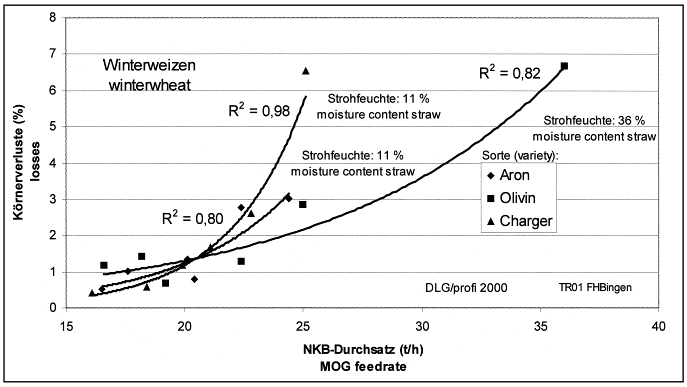


*Fig. 3: Grain loss characteristic curves of a walker combine with a centrifugal separating threshing unit in three wheat varieties with various straw moisture (acc. to [6])*

sic research, but only in the rarest of cases may be transferable into practical farming conditions. Added to this is the difficulty that a test station investigation concentrates on individual parts of the machine, e.g. the threshing mechanism and straw walkers. Pre-threshing technologies which may influence threshing and separation performance to a high degree such as cutterhead design are not considered.

### Field tests

Thus it is necessary to put the complete machine through a field test. This requires a large effort in recording the field conditions. At least 12 parameters need to be measured and declared as accompanying conditions for sugar beet field trial results, and nine for combines [6, 12, 13]. Quite apart from soil moisture content and, sometimes, leaf condition, parameters which influence work quality and harvesting performance of a harvester, e.g. morphology data and physical characteristics of a sugar beet crop, do not alter during a test. With combine harvesters the situation is entirely different. Alone the performance-influencing parameter straw moisture content and straw toughness can, depending on the heat of the sun, change to such a high degree within a single hour that a direct comparison of test values is no longer justifiable.

High coefficients of determination between grain losses and non-grain material throughput can only be established under homogenous weather and harvesting conditions. Basically the question posed here is how low the coefficient of determination of a regression can be in order to offer a reliable result. The extent of sampling and the number of results are mostly predetermined for technical recording reasons. If, within the scale of this sampling, through, for instance partial changes within the crops, there should occur so-called „widely scattered“ (untypical) values, the coefficient of determination is thus reduced. Through eliminating these scatter values the coefficient of determination of the regression can be improved. However, for result precision the results of the field tests have to be considered. Basically, in-field measurements are influenced to a much greater extent by surrounding conditions than laboratory tests and because of this it is only possible to achieve here limited coefficients of determination of regressions. An example is the grain loss performance curve recorded under differing harvest conditions shown in *fig. 3*. The 98 % coefficient of determination of the performance curve of „Charger“ can be described as excellent for field measurements. The coefficients of determination of both other performance curves – 80 and 82 % – are still very high when considered before the background of many, poorly quantifiable interactions between agricultural technology and biosystem. They indicate larger throughput-related differences in losses, i.e., different reactions of the threshing and separation equipment caused through easily shattered (Aron) or moist and tough straw (Olivin).

In broad practice, crops are characterised by a larger non-homogeneity than „selected“ test plots for a combine comparison. Thus test proceedings are only conditionally transferable onto practical farming or even onto the test farm itself. Here, the question can be asked whether test results under difficult harvesting conditions, which are rather more transferable to real conditions but are characterised by lower coefficients of determination, can represent a higher information value for the user of agricultural machinery compared with results recorded under „ideal conditions“ which contain more reliable precision. From the farmer's point of view, a trend-showing result with lower precision reliability, but better transferability onto his own working conditions, is certainly of more value than a very accurate, but not transferable, result. Thus grain loss curves recorded in dry winter wheat are worthless for the user of a combine where harvests only ever take place in moist straw conditions. Also, results of sugar beet harvester tests [14] in south German Seligenstadt are only able to be transferred onto locations with comparable ground conditions and beet morphologies and not onto north German conditions with changing types of soils and hilly fields.

### Testing in practical farming

In order to increase the information value for practical applications, precise scientific measurements are increasingly being complemented by general measurements and practical tests. Test reports then contain, alongside the special part, a general section. From the scientific point of view this means that the proportion of subjectivity is increased through non-provable data. The results of the general section help only in the interpretation and classification of the recorded results.

The question regarding the required precision of farm machinery test results can thus only be answered with a background of target group analysis. If a target group consists of farm machinery builders, precise measurements are indispensable. Only then can results be used directly for further development. Because this target group is reducing in size, the comparatively complicated investigations of farm machinery in public tests, is increasingly in question.

In that information requirement increases inline with growing investment volume, expert knowledge, i.e. farming and technology know-how in combination with practical experience, is increasingly required for the interpretation of test results to avoid purchasing mistakes. In that test results, especially regarding large machinery, are not always available, sales are increasingly being made with the help of on-farm practical demonstrations. On large farms this often means several machines of different makes being operated on the same field The decision-maker is then able to form a based judgement for the given conditions on the comparative performances after he has learned about the special technical features of the products in question. Otherwise, the farmer has to depend on advice here too.

The investment decision in association with field tests works against testing of farm machinery by experts and institutions. This is also a reason why manufacturers of large machinery tend to resist taking part in a test or comparison, because their product would in any case only be bought by the largest portion of customers after a field test. From the point of view of the manufacturer a comparison test of farm machinery appears only to make sense when the results are usable for further development of the product or for increasing market share. In that the latter is associated with risk, large machines are increasingly subjected to in-house comparative tests. A public comparison with a resulting ranking is undesirable from the marketing point of view – other than when the own-product is classed at the top. And here in particular lie hidden dangers, particularly in the case of test results which have been highly verified. The necessary calculable climate and operation conditions are given, e.g. in combine tests, as a dry period with evenly-matured grain crop Because of the system, this would mean combines constructed more for the above conditions would also be evaluated as relatively „better“. In other words, because the situation suited it, the „good weather“ combine is favoured by the test. Additionally, some tests such as those for throughput loss measurements on side slopes, are not carried out because of changing topography on test plots and the resulting too limited applicability of the results. However, manufacturers offer their machines with slope compensation systems as standard equipment in some cases- an indication of the high importance attributed to harvesting on sloping fields. Test results under these conditions have been important enough in purchasing decisions [15].

#### Practical farm questionnaires

Test results regarding work quality and performance, as well as evaluation of ease of operation and servicing, belong without doubt to the most important decision criteria for or against a farm machine. In no way may one, however, underestimate criteria such as after-sales service or machine durability. Thus, 66% of 760 combine owners in a survey gave service as a decisive purchase reason. Only after this was ranked machine throughput performance, given as a purchasing reason by „only“ 60% of the farmers [16].

But neither customer service and spare part supply through farm machinery dealers and manufacturers nor working lifetime and reliability over many years are able to be technically precisely determined. Here statements and evaluations from farmers and contractors in questionnaires are necessary. Such surveys are interesting from two points of view in the testing of agricultural equipment: assuming a sufficiently large range of interviewees, a survey taken in practical farming can very accurately reflect user satisfaction with machinery in a complete product group [16, 17]. Surveys of a smaller scale are well suited for complementing special machinery tests for verifying, adding to and generalising results [11, 18].


#### Summary

Testing of agricultural technology features very different methods because operational conditions for tractors and farm machinery are more varied than technology application areas in other economy sectors Target of the tests is the making available of decision aids for the purchase of agricultural machinery. The conflict within this aim lies in the negative correlation between the reliability of the statistical results and the validity. In future there's a need for agreement here within the working groups responsible in order to optimise the transferability of measurement and investigation methods, as well as statistical result calculations, in an as easily understood as possible form into practical farming situations. Before the background of increasing farm size and reducing numbers, this would then justify the testing facilities. For interpretation of test results and decisions regarding investment, the sum of the information – results from practical tests and on-farm surveys, analyses of technical data as well as results of scientific tests – are all of essential importance.


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