E

TWC/19/10
ORIGINAL: English
DATE: May 17, 2001

UPOV

INTERNATIONAL UNION FOR THE PROTECTION OF NEW VARIETIES OF PLANTS

GENEVA

TECHNICAL WORKING PARTY ON AUTOMATION AND COMPUTER PROGRAMS

Nineteenth Session
Prague, June 4 to 7, 2001

TYPES OF CHARACTERISTICS AND THEIR SCALE LEVELS

Document prepared by experts from Germany

TYPES OF CHARACTERISTICS AND THEIR SCALE LEVELS

Uwe Meyer and Beate Rücker
Bundessortenamt, Hannover, Germany

1. Introduction

For the revision of UPOV Test Guidelines or for the establishing of new ones, and in order to understand the relations between the different steps of work of the crop experts during the DUS test, it is necessary to have an answer to the following questions:

1. What is a characteristic ?
2. What is a scale level of a characteristic ?
3. What is the influence of the scale level on :
   - planning of trial,
   - recording of data,
   - determination of distinctness and uniformity and
   - description of varieties ?

2. Different levels to look at a characteristic

Characteristics can be considered in different levels of view (Table 1). The characteristics as expressed in the trial (type of expression) are considered as view level 1. The data taken from the trial for the assessment of distinctness, uniformity and stability are defined as view level 2. These data are transformed into states of expression for the purpose of variety description. The variety description is view level 3.

Table 1: Definition of different view levels to consider characteristics

View level	Description of the view level	Potential for statistical analysis
1	characteristics as expressed in trial	high
2	data for evaluation of characteristics	medium
3	variety description	low

From the statistical point of view the information level decreases from view level 1 to 3.

3. Types of expression of characteristics

In the 1991 Act of the UPOV Convention the term characteristics is used for the aspects of a variety which result from the expression of a given genotype or combination of genotypes and by which a variety can be defined.

Characteristics can be classified according to their types of expression or in other words according to their observed variation within the species. The consideration of the type of expression of characteristics corresponds with view point 1. The following types of expression are defined in the General Introduction (TC/37/9(a)):

[*The final wording for the definitions will be taken from the adopted Document!*]

"Qualitative characteristics" are those that are expressed in discontinuous states (e.g. sex of plant: dioecious female (1), dioecious male (2), monoecious unisexual (3), monoecious hermaphroite (4)). These states are self-explanatory and independently meaningful. All states are necessary to describe the full range of the characteristic, and every form of expression can be described by a single state. The states do not necessarily have any logical order. As a rule the characteristics are not influenced by environment.

"Quantitative characteristics" are those whose expressions can be recorded on a one-dimensional, linear scale and which show continuous variation from one extreme to the other. The range of expressions is divided into a number of states of expression for the purpose of description (e.g. length of stem: very short (1), short (3), medium (5), long (7), very long (9)). The division seeks to provide, as far as practical, an even distribution across the scale. The Test Guidelines do not specify the difference needed for distinctness. The states of expression should, however, be meaningful for DUS assessment.

In the case of "pseudo-qualitative characteristics" the range of expression is at least partly continuous, but varies in more than one dimension (e.g. shape: ovate (1), elliptic (2), circular (3), obovate (4)) and cannot be adequately described by just defining two ends of a linear range. In a similar way to qualitative (discontinuous) characteristics – hence the term "pseudo-qualitative" – each individual state of expression needs to be identified to adequately describe the range of characteristic.

The given classification of characteristics is based on the observations made by the crop expert, on what he can see in the tests and on his general experience in the specific crop. This classification is appropriate to give general recommendations for the definition of states of expression in the Technical Guidelines and to develop general rules for the assessment of distinctness, uniformity and stability.

4. Types of scales of data

The possibility to use specific procedures for the assessment of distinctness, uniformity and stability depends on the scale level of the data which are recorded for a characteristic. The scale level of data depends on the type of expression of the characteristic and on the way of recording this expression. The type of scale may be quantitative or qualitative.

4.1 Quantitatively scaled data

Quantitative data are all data which are recorded by measuring or counting. Weighing is a special form of measuring. Quantitative data can have a continuous or a discrete distribution. Continuous data result from measurements. They can take every value out of the defined range. Discrete quantitative data result from counting.

Examples:

Quantitative data	Example	Example number
- continuous	Plant length in cm.	1
- discrete	Number of stamens	2

For description of the states of expression, see Table 5.

The continuous quantitative data for the characteristic "Plant length" are measured on a continuous scale with defined units of assessment. It depends only on the costs and the necessity to get any value in cm or in mm. Changing of measure e.g. from cm into mm is only a question of precision and not a change of scale.

The discrete quantitative data of the characteristic "Number of stamens " are assessed by counting (1, 2, 3, 4, and so on). The distances between the neighbouring units of assessment are constant and for this example equal to 1. There are no real values between two neighbouring units but it is allowed to compute an average which is between those units.

In biometrical terminology, quantitative scales are also designated as metric scales. A synonym for metric scale is cardinal scale. Quantitative scales can be subdivided into ratio scales and interval scales.

4.1.1 Ratio scale

A Ratio scale is a quantitative scale with a defined absolute zero point. There is always a constant distance (different from zero) between two adjacent expressions. Ratio scaled data may be continuous or discrete.

The ratio scale is the highest classification of the scales (Table 2). That means that ratio scaled data include the highest information about the characteristic and it is possible to use many statistical procedures (Chapter 7).

The examples 1 and 2 (Table 5) are examples for characteristics with ratio scaled data.

The definition of an absolute zero point makes it possible to define additional constant ratios. This is also a requirement for the construction of index numbers (e.g. ratio length to width). An index is the combination of at least two characteristics. In UPOV terms this special case is defined as combined characteristic.

4.1.2 Interval scale

An Interval scale is a quantitative scale without a defined absolute zero point. There is always a constant distance (different from zero) between two adjacent expressions. Interval scaled data may be distributed continuously or discrete.

The interval scale is higher classified than the ordinal scale but lower than the ratio scale (Table 2). That means that it is possible to use more statistical procedures. In comparison to ratio scaled data with interval scaled data less statistical procedures can be used

(Chapter 7). The interval scale is theoretically the minimum scale level to calculate arithmetic mean values.

An example for a characteristic with continuous interval scaled data is the relative measurement "Temperature in °C". It is probably impossible to find an example for this kind of scale in the Technical Guidelines. But there are examples for characteristics with discrete interval scaled data in many guidelines (e.g. time of beginning of flowering as date, see example 6).

4.2 Qualitatively scaled data

Qualitatively data are data which can be arranged in discrete qualitative different categories. Usually they result from visual assessment. Subgroups of qualitative scales are ordinal and nominal scales.

4.2.1 Ordinal scale

Ordinally scaled data are qualitative data whose discrete categories can be brought in an ascending or descending order. They result from visually assessed quantitative characteristics.

Example:

Qualitative data	Example	Example number
- ordinal	Intensity of anthocyan	3

For description of the states of expressions, see Table 5.

An ordinal scale consists of numbers which correspond to the states of expression of the characteristic (notes). The expressions vary from one extreme to the other and thus they have a clear logical order. It is not possible to change this order, but it is not important which numbers are used to denote the categories.

The distances between the discrete categories of an ordinal scale are not exactly known and not necessarily equal. Therefore, an ordinal scale does not fulfil the condition to calculate arithmetic mean values, which is the equality of intervals throughout the scale.

The ordinal scale is higher classified than the nominal scale but lower than the interval scale (Table 2). It is possible to use more statistical procedures than for nominal scaled data but less than for interval scaled data (Chapter 7).

4.2.2 Nominal scale

Nominal scaled qualitative data are qualitative data without any logical order of the discrete categories.

Examples:

Qualitative data	Example	Example number
- nominal	Sex of plant	4
- nominal with two states	Leaf blade: variegation	5

For description of the states of expressions, see Table 5.

A nominal scale consists of numbers which correspond to the states of expression of the characteristic (notes). Although numbers are used for designation there is no inevitable order for the expressions and so it is possible to bring them in any arrangement.

Characteristics with only two categories (alternative characteristic) are a special form of nominal scales.

The nominal scale is the lowest classification of the scales (Table 2). Only few statistical procedures are applicable for evaluations (Chapter 7).

The different types of scales are summarised in the following Table.

Table 2: Types of scales and scale levels

Type of scale		Description	Distribution	Data recording by	Scale Level
quantitative (metric)	ratio	constant distances with exact zero point	Continuous	Absolute Measurements	High
			Discrete	Counting	
	interval	constant distances without exact zero point	Continuous	Relative measurements	↑
			Discrete	Date	
qualitative with underlying quantitative variable	ordinal	Ordered expressions with varying distances	Discrete	Visually assessed notes	↑
qualitative	nominal	No order, no distances	Discrete	Visually assessed notes	Low

From the statistical point of view a characteristic is only considered on the level of data which have been recorded to analyse and to describe the expression of the characteristic. Therefore, characteristics with quantitative data are denoted as quantitative characteristics and characteristics with ordinal and nominal scaled data as qualitative characteristics.

5. Scale levels for variety description

The description of varieties is based on the states of expression (notes) which are given in the Technical Guidelines for the specific crop. In case of visual assessment, usually the notes from the guideline are used for recording the characteristic as well as for the assessment of DUS. As outlined in chapter 4, the notes are distributed on a nominal or ordinal scale. For measured or counted characteristics, DUS assessment is based on the recorded values and the recorded values are transformed into states of expression only for the purpose of variety description. The scale changes from a quantitative to qualitative (ordinal) one.

6. Relation between types of expression of characteristics and scale levels of data

Records taken for the assessment of qualitative characteristics are distributed on a nominal scale, for example "Sex of plant", "Leaf blade: variegation" (Table 5, examples 4 and 5).

For quantitative characteristics the scale level of data depends on the way of assessment. They can be recorded on a quantitative or ordinal scale. For example, "Length of plant" is usually recorded by measurements resulting in ratio scaled continuous quantitative data. Under specific circumstances, visual assessment on a 1 to 9 scale may be appropriate. In this case, the recorded data are qualitatively scaled (ordinal scale) because the size of categories is not exactly the same.

Remark: In some cases visually assessed data of quantitative characteristics may be handled as quantitative data. The possibility to apply statistical methods for quantitative data depends on the precision of the assessment and the robustness of the statistical procedures. In case of very precisely visually assessed quantitative characteristics the usually ordinal data may reach the level of discrete interval scaled data or of discrete ratio scaled data.

A pseudo-qualitative type of expression is caused by a characteristic which varies in more than one dimension. The different dimensions are combined in one scale. At least one dimension is quantitatively expressed. The other dimensions may be qualitatively expressed or quantitatively expressed. The scale as a whole has to be considered as a nominal scale (e.g. "Shape", "Flower color"; Table 5, examples 7 and 8).

7. Relation between scale levels and recommended statistical procedures

The scale level of data is one of the most important conditions for the application of different statistical procedures. Well-known statistical procedures can be recommended for the assessment of distinctness and uniformity considering the scale level and some further conditions like degree of freedom or unimodality (Tables 3 and 4).

The relation between the expression of characteristics and the scale levels of data for the assessment of distinctness and uniformity is summarized in Table 5.

Table 3: Recommended statistical procedures for the assessment of distinctness

Type of scale	Distribution	Further conditions			
		Normal distribution df<20	Normal distribution df>=20	Unimodality	Other
ratio	continuous	long term LSD	COY-D or 2 out of 3 method (LSD 1%)		
	discrete				
interval	continuous				
	discrete				
ordinal	discrete	minimum distance>=1		threshold model *)	
Combination of ordinal or ordinal and nominal scales	discrete	state by state comparison			
nominal	discrete	minimum distance=1			

*) Procedure under development (not yet recommended)

Table 4: Recommended statistical procedures for the assessment of uniformity

Type of scale	Distribution	Further conditions		
		Normal distribution	Unimodality	Other
ratio	continuous	COY-U or 2 out of 3 method ($s^2_c \leq 1.6 s^2_s$)		LSD for untransformed percentage of off-types
	discrete			
interval	continuous			
	discrete			
ordinal	discrete		threshold model *)	
nominal	discrete	Off-type procedure for alternative (binary) data		

*) Procedure under development (not yet recommended)

Table 5: Relation between expression of characteristics and scale levels of data for the assessment of distinctness and uniformity

Example	Name of characteristic	Distinctness			Uniformity		
		Unit of assess-ment	Description	Type of scale	Unit of assess-ment	Description	Type of scale
1	Length of plant	cm	assessment in cm without digits after decimal point	ratio scaled continuous quantitative data	cm	assessment in cm without digits after decimal point	ratio scaled continuous quantitative data
					Cat1 Cat2	Number of plants belonging to the variety Number of offtypes	nominally scaled qualitative data
2	Number of stamens	counts	1, 2, 3, ... , 40,41, ...	ratio scaled discrete quantitative data	counts	1, 2, 3, ... , 40,41, ...	ratio scaled discrete quantitative data
3	Intensity of anthocyanin	1 2 3 4 5 6 7 8 9	very low very low to low low low to medium medium medium to high high high to very high very high	ordinally scaled qualitative data (with an underlying quantitative variable)	Cat1 Cat2	Number of plants belonging to the variety Number of offtypes	nominally scaled qualitative data
4	Sex of plant	1 2 3 4	dioecious female dioecious male monoecious unisexual monecious hermaphroite	nominally scaled qualitative data	Cat1 Cat2	Number of plants belonging to the variety Number of offtypes	nominally scaled qualitative data

Example	Name of characteristic	Distinctness			Uniformity		
		Unit of assess-ment	Description	Type of scale	Unit of assess-ment	Description	Type of scale
5	Leaf blade: variegation	1 9	absent present	nominally scaled qualitative data	Cat1 Cat2	Number of plants belonging to the variety Number of offtypes	nominally scaled qualitative data
6	Time of beginning of flowering	date	e.g. May 21, 51st day from April 1	interval scaled discrete quantitative data	date	e.g. May 21, 51st day from April 1	interval scaled discrete quantitative data
					Cat1 Cat2	Number of plants belonging to the variety Number of offtypes	nominally scaled qualitative data
7	Shape	1 2 3 4 5 6 7	deltate ovate elliptic obovate obdeltate circular oblate	combination of ordinal and nominal scaled discrete qualitative data	Cat1 Cat2	Number of plants belonging to the variety Number of offtypes	nominally scaled qualitative data
8	Flower color	1 2 3 4 5 6 7 8 9 10	dark red medium red light red white light blue medium blue dark blue red violet violet blue violet	combination of ordinal and nominal scaled discrete qualitative data	Cat1 Cat2	Number of plants belonging to the variety Number of offtypes	nominally scaled qualitative data

[End of document]