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Associated Document
to the
General Introduction to the Examination
of Distinctness, Uniformity and Stability and the
Development of Harmonized Descriptions of New Varieties of Plants (document TG/1/3)

DOCUMENT TGP/8

"USE OF STATISTICAL PROCEDURES IN

DISTINCTNESS, UNIFORMITY AND STABILITY TESTING"

Section TGP/8.4: Types of Characteristics and Their Scale Levels

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SECTION 8.4
TYPES OF CHARACTERISTICS AND THEIR SCALE LEVELS

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8.4.1 Introduction

1. For the revision of UPOV Test Guidelines or for establishing 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 the :
   - planning of a trial,
   - recording of data,
   - determination of distinctness and uniformity and
   - description of varieties?

8.4.2 Different levels to look at a characteristic

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

Table 1: Definition of different process levels to consider characteristics

Process level	Description of the process level
1	characteristics as expressed in trial
2	data for evaluation of characteristics
3	variety description

3. From the statistical point of view the information level decreases from process level 1 to 3. Statistical analysis is only applied in level 2.

8.4.3 Types of expression of characteristics

4. 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.

5. 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 process level 1. The following types of expression of characteristics are defined in the General Introduction to the Examination of Distinctness, Uniformity and Stability and the Development of Harmonized Descriptions of New Varieties of Plants, (document TG/1/3, the "General Introduction", Chapter 4.4):

6. "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 hermaphrodite (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 order of states is not important. As a rule, the characteristics are not influenced by environment.

7. "Quantitative characteristics" are those where the expression covers the full range of variation from one extreme to the other. The expression can be recorded on a one-dimensional, continuous or discrete, linear scale. The range of expressions is divided into a number of states 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.

8. 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 the characteristic.

9. 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.

8.4.4 Types of scales of data

10. 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

11. 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

12. For description of the states of expression, see Table 6.

13. 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. A change of unit of measurement e.g. from cm into mm is only a question of precision and not a change of type of scale.

14. 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.

15. 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

16. 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.

17. 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).

18. The examples 1 and 2 (Table 6) are examples for characteristics with ratio scaled data.

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

4.1.2 Interval scale

20. 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 discretely.

21. The interval scale is lower classified than the ratio scale (Table 2). Fewer statistical procedures can be used with interval scaled data than with ratio scaled data (Chapter 7). The interval scale is theoretically the minimum scale level to calculate arithmetic mean values.

22. An example of 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

23. Qualitatively scaled 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

24. Ordinally scaled data are qualitative data of which discrete categories can be arranged in an ascending or descending order. They result from visually assessed quantitative characteristics.

Example:

Qualitative data	Example	Example number
- ordinal	Intensity of anthocyanin	3

25. For description of the states of expressions, see Table 6.

26. 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.

27. 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.

28. The ordinal scale is lower classified than the interval scale (Table 2). Less statistical procedures can be used for ordinal scale than for each of the higher classified scale data (Chapter 7).

4.2.2 Nominal scale

29. 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

30. For description of the states of expressions, see Table 6.

31. A nominal scale consists of numbers which correspond to the states of expression of the characteristic, which are referred to in the Test Guidelines as notes. Although numbers are used for designation there is no inevitable order for the expressions and so it is possible to arrange them in any order.

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

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

34. 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	Scale Level
quantitative (metric)	ratio	constant distances with absolute 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

35. From the statistical point of view a characteristic is only considered at the level of data which has been recorded, whether for analysis or for describing 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.

8.4.5 Scale levels for variety description

36. The description of varieties is based on the states of expression (notes) which are given in the Test Guidelines for the specific crop. In the case of visual assessment, usually the notes from the Test Guidelines 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.

8.4.6 Relation between types of expression of characteristics and scale levels of data

37. Records taken for the assessment of qualitative characteristics are distributed on a nominal scale, for example “Sex of plant”, “Leaf blade: variegation” (Table 6, examples 4 and 5).

38. For quantitative characteristics the scale level of data depends on the method 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 intervals between the midpoints of categories is not exactly the same.

Remark: In some cases visually assessed data on quantitative characteristics may be handled as measurements. 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 precise visually assessed quantitative characteristics the usually ordinal data may reach the level of discrete interval scaled data or of discrete ratio scaled data.

39. 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 6, examples 7 and 8).

40. In the case of using the off-type procedure for the assessment of uniformity the recorded data are nominally scaled. The records fall into two qualitative classes: plants belonging to the variety (true-types) and plants not belonging to the variety (off-types). The type of scale is the same for qualitative, quantitative and pseudo-qualitative characteristics.

41. The relation between the type of characteristics (process level 1) and the type of scale of data recorded for the assessment of distinctness and uniformity is described in table 3. A qualitative characteristic is recorded on a nominal scale for distinctness (state of expression) and for uniformity (true-types vs. off-types). Pseudo-qualitative characteristics are recorded on a combined scale for distinctness (state of expression) and on a nominal scale for uniformity (true-types vs. off-types). Quantitative characteristics are recorded on an ordinal, interval or ratio scale for the assessment of distinctness depending on the characteristic and the way of assessment. If the records are taken from single plants the same data may be used for the assessment of distinctness and uniformity. If distinctness is assessed on the basis of a

single record of a group of plants, uniformity has to be judged with the off-type procedure (nominal scale).

Table 3: Relation between type of characteristic and type of scale of assessed data

Procedure	Type of scale (level 2)	Distribution	Type of characteristic (level 1)		
			Quantitative	Pseudo-qualitative	Qualitative
Distinctness	ratio	Continuous	✔		
		Discrete	✔		
	interval	Continuous	✔		
		Discrete	✔		
	ordinal	Discrete	✔		
	combined	Discrete		✔	
	nominal	Discrete			✔
Uniformity	ratio	Continuous	✔		
		Discrete	✔		
	interval	Continuous	✔		
		Discrete	✔		
	ordinal	Discrete	✔		
	combined	Discrete	✔		
	nominal	Discrete	✔	✔	✔

8.4.7 Relation between method of observation of characteristics, scale levels of data and recommended statistical procedures

42. The scale level of data and the way of observation of characteristics are most important conditions for the application of different statistical procedures. There are four possible ways to observe characteristics (see TGP/7 "Development of Test Guidelines"):

- measurements of a group of plants or parts of plants (MG)
- measurements of a number of single plants or parts of plants (MS)
- visual assessment of a group of plants or parts of plants (VG)
- visual assessment of a number of single plants or parts of plants (VS).

43. The observation method depends primarily on the variation within and between varieties and effects the choice of the statistical method. All of the four observation methods may be relevant for the assessment of distinctness. For the assessment of uniformity observations must be done on single plants. Consequently only MS or VS are appropriate. The indication of the method of observation of characteristics in the Technical Guidelines should refer to the assessment of distinctness.

44. 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 4 and 5).

45. The relation between the expression of characteristics and the scale levels of data for the assessment of distinctness and uniformity is summarized in Table 6.

Table 4: Statistical procedures for the assessment of distinctness

Type of scale	Distribution	Observation method	Procedure[1] and further Conditions	Reference
ratio	continuous discrete	MS MG (VS) [2]	R: COY-D Normal distribution, df >=20 R: long term LSD Normal distribution, df<20 NR-P: 2 out of 3 method (LSD 1%) Normal distribution, df>=20	TGP/9.7
interval	continuous discrete			
ordinal	discrete	VG VS	R: minimum distance>=1 NR-D: threshold model	 TWC/ 14/12
Combination of ordinal or ordinal and nominal scales	discrete	VG (VS) [3]	R: state-by-state-comparison	
nominal	discrete	VG (VS) [3]	R: each state-is clearly different from the other	

1) R - recommended
NR-P - not recommended (previous method)
NR-D - not recommended (method under development)
2) see remark on page 7
3) normally VG but VS would be possible

Table 5: Statistical procedures for the assessment of uniformity

Type of scale	Distribution	observation method	Procedure[1] and Further Conditions	Reference
ratio	continuous	MS	R: COY-U Normal distribution	TGP/ 10.3.1
	discrete	MS	NR-P: 2 out of 3 method ($s^2_c<=1.6s^2_s$)) Normal distribution	
interval	continuous	VS	NR-D: LSD for untransformed percentage of off-types	
	discrete			
ordinal	discrete	VS	NR-D: threshold model	TWC/ 14/12
Combination of ordinal or ordinal and nominal scales	discrete		There is no case where uniformity is assessed on combined scaled data	
nominal	discrete	VS	R: off-type procedure for dichotomous (binary) data	TGP/ 10.3.2

1) R - recommended
NR-P - not recommended (previous method)
NR-D - not recommended (method under development)

Table 6: 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 (states of expression)	Type of scale	Unit of assess-ment	Description (states of expression)	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
					True-type Off-type	Number of plants belonging to the variety Number of off-types	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)	True-type Off-type	Number of plants belonging to the variety Number of off-types	nominally scaled qualitative data
4	Sex of plant	1 2 3 4	dioecious female dioecious male monoecious unisexual monoecious hermaphrodite	nominally scaled qualitative data	True-type Off-type	Number of plants belonging to the variety Number of off-types	nominally scaled qualitative data

Example	Name of characteristic	Distinctness			Uniformity		
		Unit of assess-ment	Description (states of expression)	Type of scale	Unit of assess-ment	Description (states of expression)	Type of scale
5	Leaf blade: variegation	1 9	absent present	nominally scaled qualitative data	True-type Off-type	Number of plants belonging to the variety Number of off-types	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
					True-type Off-type	Number of plants belonging to the variety Number of off-types	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	True-type Off-type	Number of plants belonging to the variety Number of off-types	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	True-type Off-type	Number of plants belonging to the variety Number of off-types	nominally scaled qualitative data

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