UPOV
International Union for the Protection of New Varieties of Plants

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Technical Working Party for Vegetables

TWV/60/5 Rev.

Sixtieth Session
Pacific Grove, United States of America, May 18 to 21, 2026

Original: English
Date: May 21, 2026

ASSESSING DISTINCTNESS IN DISEASE RESISTANCE CHARACTERISTICS

Document prepared by an expert from the Netherlands (Kingdom of the)

1. Document TGP/12 “Guidance on Certain Physiological Characteristics” was developed many years ago based on understanding of disease resistances at that time. The breeding activities have not remained static in recent decades, which has created the need to revise this document.

2. Disease resistance characteristics can be classified into three types according to UPOV terminology: qualitative (QL), quantitative (QN) and pseudo-qualitative (PQ).

3. During the last TWV/59 meeting, discussion took place on how to assess distinctness for all types of resistance characteristics.

4. The purpose of this document is to clarify the assessment of distinctness for each type of resistance characteristics.

Assessment of distinctness for qualitative resistance characteristics (QL)

5. Since qualitative resistances are mostly based on a single gene, only two states of expression exist, absent and present.

6. Qualitative resistance characteristics are particularly suitable as grouping characteristics.

7. As there is a clear gap between susceptible varieties (resistance gene(s) absent) and resistant varieties (resistance gene(s) present) the difference between the two states of expression is clear in every test.

8. In this case, the assessment of distinctness between varieties with state 1 (absent) and state 9 (present) is therefore very clear. Varieties assessed in different tests, with different notes/states, can always be considered as distinct.

9. The results of the resistance test are clear and consistent, so in most cases there is no need to include a threshold control variety in a test for this type of disease.

10. However, in some cases where e.g. resistance shows incomplete penetrance, the environmental factors can influence not only the expression level between varieties but also the variation within a variety. Incomplete penetrance sometimes occurs in resistant plants, where a gene for resistance is phenotypically expressed only in a certain percentage of the population, even if all plants are genetically resistant. In these cases, a threshold control is necessary to calibrate and interpret the range of symptoms expression within a variety (e.g. *Fusarium* species).

11. Therefore, we could categorize qualitative resistance characteristics (QL) into two different subtypes:

a) qualitative resistance characteristics (QL) without threshold needed

Examples of qualitative diseases resistances (QL) with two states of expression:

12. Resistance to *Cladosporium cucumerinum* (Ccu) in cucumber (TG/61/7 Rev. 3), agreed as useful grouping characteristic

44. (+)	Resistance to *Cladosporium cucumerinum* (Ccu)	Résistance à *Cladosporium cucumerinum* (Ccu)	Resistenz gegen *Cladosporium cucumerinum* (Ccu)	Resistencia a la *Cladosporium cucumerinum* (Ccu)		
QL	absent	absente	fehlend	ausente	Cherubino, Frontera, Pepinex 69	1
	present	présente	vorhanden	presente	Corona, Marketmore 76, Sheila	9

13. Resistance to *Tomato spotted wilt virus* (TSWV) in tomato (TG/44/12), agreed as useful grouping characteristic

68.	QL VG	(+)				
	Resistance to *Tomato spotted wilt virus* - Pathotype 0 (TSWV: 0)	**Résistance au virus de la tache bronzée de la tomate - Pathotype 0 (TSWV: 0)**	**Resistenz gegen das Tomatenbronzen-fleckenvirus - Pathotyp 0 (TSWV: 0)**	**Resistencia al virus del bronceado del tomate - Raza 0 (TSWV: 0)**		
	absent	absente	fehlend	ausente	Moneymaker, Montfavet 63-5, Mountain Magic	1
	present	présente	vorhanden	presente	Bodar, Mospomor	9

b) qualitative resistance characteristics (QL) with threshold needed

14. Resistance to *Fusarium oxysporum* f. sp. *lycopersici* Race 1EU/2EU in tomato (TG/44/12), agreed as useful grouping characteristic

48.	QL VG	(+)				
	Resistance to *Fusarium oxysporum* f. sp. *lycopersici* - Race 1EU/2US (Fol: 1EU/2US)	**Résistance à *Fusarium oxysporum* f. sp. *lycopersici* - Race 1EU/2US (Fol: 1EU/2US)**	**Resistenz gegen *Fusarium oxysporum* f. sp. *lycopersici* - Pathotyp 1EU/2US (Fol: 1EU/2US)**	**Resistencia a *Fusarium oxysporum* f. sp. *lycopersici* - Raza 1EU/2US (Fol: 1EU/2US)**		
	absent	absente	fehlend	ausente	Marmande verte, Moneymaker	1
	present	présente	vorhanden	presente	Motelle	9

Assessment of distinctness for quantitative resistance characteristics (QN)

15. Quantitative resistance is mostly based on two or more genes. Therefore, there are more than two states of expression.

16. Three different subtypes of QN resistance characteristics can be distinguished:

(a) Diseases regulated by two genes, where three states of expression can be defined

(i) With a clear gap between at least two of the three states of expression

17. In this case the distribution is not completely continuous, but there is a gap between susceptible varieties and varieties with a medium or high level of resistance.

18. A threshold variety is needed in each test to define the lowest level of resistance as the border between the susceptible varieties and varieties with a level of resistance.

19. It is important to note that for this type of resistance characteristics, the aggressiveness of the test can significantly influence the behavior of the threshold(s). Therefore, the given state of expression is always in relation to the threshold variety.

20. Because of the gap, distinctness between susceptible and resistant varieties, even assessed in a different test can be based on a one note difference using the same test protocol with the same threshold variety. Additionally, statistical analysis could be used to support the decision.

21. This type of resistance characteristic is suitable as grouping characteristics between susceptible varieties and varieties with a certain level of resistance.

Example of quantitative disease resistance (QN) with three states of expression of type i.

22. Resistance to *Powdery mildew* (*Podosphaera xanthii*) (Px) in cucumber (TG/61/7 Rev. 3), agreed as useful grouping characteristic:

46. (+)	**Resistance to Powdery mildew (*Podosphaera xanthii*) (Px)**	**Résistance à l'oïdium (*Podosphaera xanthii*) (Px)**	**Resistenz gegen Echten Mehltau (*Podosphaera xanthii*) (Px)**	**Resistencia al oidio blanco (*Podosphaera xanthii*) (Px)**		
QN	susceptible	sensible	anfällig	susceptible	Corona, Ventura	1
	moderately resistant	moyennement résistant	mäßig resistent	intermedia	Flamingo	2
	highly resistant	hautement résistant	hochresistent	alta	Aramon, Bella, Cordoba	3

23. According to current wording in UPOV Test Guidelines the states of expression of this characteristic can be read as: 1/absent or very low; 2/medium; 3/high. This might be adjusted in future revision.

(ii) Without a clear gap between the three states of expression

24. In this case the distribution is completely continuous, there is no clear gap between the three states of expression.

25. Threshold varieties are needed in each test to define the border between the different levels of expression.

26. This type of resistance characteristic is not suitable as grouping characteristic. Varieties can only be considered distinct having been subject to side-by-side comparison and described with different notes in the same trial. Additionally, statistical analysis could be used to support the decision.

Example of quantitative disease resistance (QN) with three states of expression of type ii

27. Resistance to *Cucumber green mottle mosaic virus* (CGMMV) in cucumber (pending revision)

Proposed addition of new Characteristic 52 "Resistance to *Cucumber green mottle mosaic virus* (CGMMV)" at the end of the Table Of Characteristics

		English	français	Deutsch	español	Example Varieties Exemples Beispielssorten Variedades ejemplo	Note/ Nota
52. **(+)**	**VS**	**Resistance to *Cucumber green mottle mosaic virus* (CGMMV)**	**Resistance au *Cucumber green mottle mosaic virus* (CGMMV)**	**Resistenz gegen *Cucumber green mottle mosaic virus* (CGMMV)**	**Resistencia a *Cucumber green mottle mosaic virus* (CGMMV)**		
QN		absent or very low				Topspin	1
		medium				Bonaire, Bluesbrother	2
		high					3

28. In case of CGMMV, there is currently no example or control variety for state of expression 3 (high), as it does not exist yet.

(b) Diseases regulated by multiple genes, where nine states of expression can be defined

29. In this case the distribution is completely continuous, there is no clear gap between the nine states of expression.

30. Distinctness is based on the same criteria as for morphological QN characteristics, which means that in general varieties with 2 notes difference can be considered as distinct.

31. This type of resistance characteristic is in general not suitable as grouping characteristic.

Example of quantitative diseases resistances (QN) with nine states of expression:

32. Resistance to *Colletotrichum trifolii* in luzerne (TG/6/5):

19. **(+)**	**VS** **C**	**Resistance to *Colletotrichum trifolii***	**Résistance à *Colletotrichum trifolii***	**Resistenz gegen *Colletotrichum trifolii***	**Resistencia al *Colletotrichum trifolii***		
QN		very low	très faible	sehr gering	muy baja	Saranac	1
		low	faible	gering	baja	Venus	3
		medium	moyenne	mittel	media		5
		high	élevée	hoch	alta	Saranac AR	7
		very high	très élevée	sehr hoch	muy alta	Arc	9

Assessment of distinctness for Pseudo-qualitative resistance characteristics (PQ)

33. Pseudo-qualitative resistances are based on at least two genes and are discontinuously expressed in more than one dimension. This type of resistance results in different phenotypes/types of symptoms, which can be considered as the two dimensions.

34. Distinctness is based on the same criteria as for morphological PQ characteristics, which means that in general varieties with 1 note difference can be considered as distinct, even if assessed in a different test.

Example of pseudo-qualitative diseases resistances (PQ) with three states of expression:

35. Resistance to *Bean Common Mosaic Virus* (BCMNV) in French bean (TG/12/9 Rev. 2), agreed as useful grouping characteristic:

50. **(*)** **(+)**	**VS/** **VG**	**Resistance to *Bean common mosaic necrosis virus* (BCMNV)**	**Résistance au *Bean common mosaic necrosis virus* (BCMNV)**	**Resistenz gegen *Bean common mosaic necrosis virus* (BCMNV)**	**Resistencia al *Bean common mosaic necrosis virus* (BCMNV)**		
PQ		absent	absente	fehlend	ausente	Dufrix, Flandria	1
		present with necrosis	présente avec nécroses	vorhanden mit Nekrose	presente con necrosis	Booster, Odessa	2
		present without symptoms	présente sans symptômes	vorhanden ohne Symptome	presente sin síntomas	Bizet	3

36. Resistance to BCMNV in beans is controlled by a complex genetic system involving one dominant gene (I) and several recessive genes (bc series).

Overview of all types of resistance characteristics:

Types of resistance characteristics	Subtypes	States of expression	Description	Abbreviation	Suitable for grouping
QL	a	1/9	qualitative resistance characteristics (QL) without threshold needed	QL(a)	yes
	b	1/9	qualitative resistance characteristics (QL) with threshold needed	QL(b)	yes
QN	a(i)	1/2/3/ or 1/2-3	quantitative resistance characteristics (QN) with gap	QN (a i)	yes
	a(ii)	1-2-3	quantitative resistance characteristics (QN) without gap	QN (a ii)	no
	b	1 to 9	quantitative resistance characteristics (QN)	QN (b)	yes,same as QN morph. char. with difference of at least 2 notes
PQ		1/2/3	pseudo-qualitative diseases resistances (PQ)	PQ	yes

37. The Annex to this document contains a presentation on “Assessing distinctness in disease resistance characteristics”.

[Annex follows]

Purpose and context

- **Why an update**

Modern breeding (genetics, molecular tools, complex mechanisms) now produces new insights not fully covered in TGP/12

- **What is being clarified**

Resistance characteristics can be classified as QL, QN, or PQ characteristics

However, unlike morphological characteristics, due to the interaction between the pathogen and the plants, resistance characteristics require an additional step of interpreting symptoms before a note can be given.

- Provide **practical rules for assessing distinctness** by the different resistance types: when threshold control varieties are needed and when grouping use is reliable.

Reminder

- Expression of morphological characteristics is influenced by:
  - Plant x environment
- Expression of resistance characteristics: **much more complex**
  - Plant x environment
  - Plant x pathogen (e.g. degree of penetrance)
  - Pathogen x environment

This difference requires a **different approach** (repeatability, genetical background…)

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Reminder

- Observations in classes versus interpretation into UPOV notes
- 1 class ≠ 1 note
- The plants of a single variety will be distributed across the “observation” classes, and this distribution will differ in every test.
- In contrast to a morphological characteristic such as plant height, in a resistance test the classes are assigned to all plants of all samples in the test.
- Based on the (threshold) control varieties included in the test, and depending on the severity of the test, the interpretation will be carried out and the appropriate UPOV notes will be assigned.

Symptoms caused by the pathogen → observations in classes

translation step

Resistance characteristic (property of the variety) → UPOV notes

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Assessment of distinctness for qualitative resistance characteristics (QL)

- **Genetical background:**

QL characteristics are mostly controlled by a single major gene

- **How it behaves**

With sufficient pathogen pressure, a consistent gap separates susceptible (no gene) and resistant (gene present) varieties, states 1 and 9 are always distinct, even across years.

- **Matters for DUS**

QL traits are robust grouping characteristics

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Subtypes of qualitative resistance characteristics (QL)

a) Clear-cut, no threshold needed

Fully penetrant gene

Example:

Tomato spotted wilt virus (TSWV) in tomato

Susceptible variety

clear symtoms

resistance absent = note 1

Resistant variety

no symptoms

resistance present = note 9

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Subtypes of qualitative resistance characteristics (QL)

b) No clear-cut, threshold needed

Some “qualitative” resistances show incomplete penetrance: plants carry the gene, yet only a proportion expresses resistance, influenced by temperature, inoculum pressure, and plant stage.

Therefore, symptom presence/absence alone is insufficient; a **threshold variety** is essential for the calibration of the translation from observation scale into the UPOV note

Example*: Fusarium oxysporum* f. sp. *lycopersici* race 1EU/2EU in tomato

Susceptible control (Moneymaker)

clear symtoms

resistance absent = note 1

Treshold resistant control (Agostino)

Few plants with light symptoms

resistance present = note 9

Resistant control (Tradiro)

no symptoms

resistance present = note 9

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With the use of validated threshold, these characteristics remain a valid grouping characteristic

Assessment of distinctness for quantitative resistance characteristics (QN)

- **Genetical background:**

Polygenic control (2 or more genes) produces partial, additive effects; expression is multi-level rather than binary.

- **How it behaves**

Scoring requires relative resistance levels, strongly influenced by disease pressure, environment, and genes interactions

- **Matters for DUS**

Use threshold varieties (and sometimes statistics) to standardize comparisons and support decisions.

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Subtypes of quantitative resistance characteristics (QN)

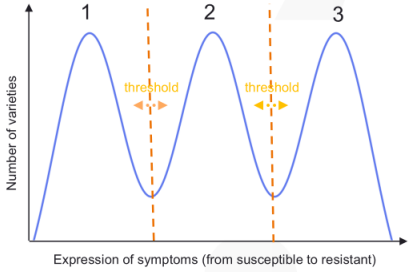
a) Quantitative resistance showing three states of expression

i. <u>with</u> a clear gap between at least two of the three states of expression

- States are interpreted relative to the threshold variety under the same protocol and test aggressiveness
- Suitable as grouping

Example: *Powdery mildew* (*Podosphaera xanthii*) (Px) in cucumber

46. (+)	**46.**	**VG/VS**	**Resistance to Powdery mildew (*Podosphaera xanthii*) (Px)**	
QN		susceptible	Corona, Ventura	1
		moderately resistant	Flamingo	2
G		highly resistant	Aramon, Bella, Cordoba	3



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Subtypes of quantitative resistance characteristics (QN)

ii. <u>Without</u> a clear gap between the three states of expression

- Threshold varieties must be included in each test
- Statistical support may be needed
- Not suitable as grouping
- Distinctness based only on side-by-side comparison

Example: *Cucumber green mottle mosaic virus* (CGMMV) in cucumber (pending revision)

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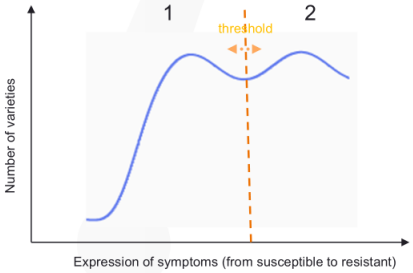
QN	absent or very low				Topspin	1
	medium				Bonaire, Bluesbrother	<u>2</u>
	high					<u>3</u>



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Subtypes of quantitative resistance characteristics (QN)

b) Quantitative resistance showing nine states of expression

- Polygenic resistance shows a fully continuous distribution across nine notes, aligned with quantitative morphology assessment.
- Distinctness typically requires a minimum difference of **two notes**; side-by-side trial comparison remains essential.
- In general, not suitable for grouping

Example: *Colletotrichum trifolii* in luzerne

19. (+)	VS C	Resistance to *Colletotrichum trifolii*	Résistance à *Colletotrichum trifolii*	Resistenz gegen *Colletotrichum trifolii*	Resistencia al *Colletotrichum trifolii*		
QN		very low	très faible	sehr gering	muy baja	Saranac	1
		low	faible	gering	baja	Venus	3
		medium	moyenne	mittel	media		5
		high	élevée	hoch	alta	Saranac AR	7
		very high	très élevée	sehr hoch	muy alta	Arc	9

Rating:

Resistance is assessed as percentage of seedlings surviving 10 to 14 days after inoculation.

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Assessment of distinctness for Pseudo-qualitative resistance characteristics (PQ)

Example: *Bean Common Mosaic Virus* (BCMNV) in French bean

Determined by a complex genetic system that relies on interaction between a dominant gene and several recessive genes

2 different symptoms, virus and necrosis (->PQ)

- Suitable as grouping

50. (*) (+)	VS/ VG	Resistance to *Bean common mosaic necrosis virus* (BCMNV)	Résistance au *Bean common mosaic necrosis virus* (BCMNV)	Resistenz gegen *Bean common mosaic necrosis virus* (BCMNV)	Resistencia al *Bean common mosaic necrosis virus* (BCMNV)		
PQ		absent	absente	fehlend	ausente	Dufrix, Flandria	1
		present with necrosis	présente avec nécroses	vorhanden mit Nekrose	presente con necrosis	Booster, Odessa	2
		present without symptoms	présente sans symptômes	vorhanden ohne Symptome	presente sin síntomas	Bizet	3

Susceptible control (Dufrix)

clear symtoms

resistance absent = note 1

Resistant control with necrosis (Booster)

No symptoms

resistance present = note 2

Resistant control without necrosis (Bizet)

No symptoms

resistance present = note 2

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Overview of all types of resistance characteristics

Types of resistance characteristics	Subtypes	States of expression	Description	Abbreviation	Suitable for grouping
QL	a	1/9	qualitative resistance characteristics (QL) **without threshold** needed	QL(a)	yes
	b	1/9	qualitative resistance characteristics (QL) **with threshold** needed	QL(b)	yes
QN	a(i)	1/2/3 or 1/ 2-3	quantitative resistance characteristics (QN) **with gap**	QN (a i)	yes
	a(ii)	1-2-3	quantitative resistance characteristics (QN) **without gap**	QN (a ii)	no
	b	1 to 9	quantitative resistance characteristics (QN)	QN (b)	yes,same as QN morph. char. with difference of at least 2 notes
PQ		1/2/3	pseudo-qualitative diseases resistances (PQ)	PQ	yes

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[End of Annex and of document]