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Experiences with descriptors for characterization of medicinal and aromatic plants

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Abstract

Well-defined descriptors are an indispensable tool for management, maintenance and utilization of plant genetic resources. The International Plant Genetic Resources Institute (IPGRI), the International Union for the Protection of New Varieties of Plants (UPOV) and national authorities have published descriptor lists for a great variety of agricultural and horticultural crops, but only for a few species belonging to the group of medicinal and aromatic plants (MAP). Forty years of experiences with the use of descriptors in MAP mainly in the field of breeding research are communicated to support forthcoming efforts in elaborating new descriptors lists. The deliberations focus on some specifics of these minor crops, classifying the descriptors to the following groups: object, experimental data, sample specification, characteristics—growth, development, flower and reproduction biology, cytological traits, molecular traits, biotic and abiotic stress susceptibility, yield, quality differentiated in morphology-dependent quality traits, constituents, sensory quality, and impurities. MAP-specific descriptors are exemplified and the principles of important determination methods are explained. Most of the general available UPOV and IPGRI descriptors are applicable also for MAP.

Keywords: analysis; breeding; development; growth; quality; sample specification; stress; yield

Introduction

Before starting a research project, researchers must elucidate which plants they are going to investigate under which experimental conditions, by which characteristics the plant material should be defined, how to arrange the data in a database and by which method the data shall be mathematically processed to derive the aspired conclusions. All these procedures need the definition of appropriate variables right from the start of the investigations.

The variables must meet the following requirements:

- appropriate description of the object and the experimental conditions;
- adequate precision level to expose differences of the essential characteristics;
- suitable for evaluation by statistical procedures and practicable for secondary interpretation;
- as low as possible expenses of time and money needed for the ascertainment of the variables.

There are a lot of possible descriptors available compiled by different international (International Plant Genetic Resources Institute, IPGRI; International Union for the Protection of New Varieties of Plants, UPOV) and national (e.g. Federal Office of Plant Varieties Germany) institutions. Which of the numerous variables shall be used depends on the aim of the research and on economic aspects of the specific investigation.

The aim of this paper is to pass on experiences of the use of descriptors for medicinal and aromatic plants

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(MAP) basing on 40 years of experiences and focusing on characteristics important for plant breeders. It is not intended to list all possible descriptors and to add further descriptor lists for distinguished species to the already available compilations, but rather to communicate experiences with descriptors which proved as important according to our own long-term experiences focusing on specifics of these minor crops and explaining them by some selected examples. The principles of the examples delineated for a certain species can be adopted to other species and can be helpful for the consideration by experts who are going to plan experiments with more or less similar fields of activity.

The descriptors treated in the following were used in own experiments with MAP in Germany in the period 1965–2004. They are restricted to a selection of MAP species typical for Central Europe and they take into consideration mainly the point of view of the plant breeder.

The experiments were accomplished mainly on the experimental field and only in some cases in the glasshouse. Descriptors similar to descriptors of the main crops are indicated more in general and not explained in detail. The interested reader can adopt the numerous already-available lists of descriptors and use the given scales (UPOV, 2002, 2004; Bundessortenamt, 2004; IPGRI, 2004). Only descriptors very specific for these minor crops are delineated more in detail and exemplified in some cases.

The order of the treatment of the descriptor groups follows the chronology of the data collection in the experiments.

The characteristics can be measured or visually observed. According to the UPOV definition *qualitative characteristics* are those that are expressed in discontinuous states (e.g. dioecious female, dioecious male), *quantitative characteristics* are those where the expression covers the full range of variation from one extreme to the other (e.g. the growth height in cm). 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. *Combined characteristics* are the combination of some traits, e.g. the ratio length to width of leaves (UPOV, 2002).

Object

The following specifications are necessary for adequate identification of the object of the investigations.

Genotype: genus, species, subtaxon (e.g. annual or biennial type of caraway—*Carum carvi* L.), cultivar, breeder's line. The history of origins and the characteristics of the genotype, known to date, should be documented in the experimental plan.

Mode of population establishment: by sowing or planting plantlets—e.g. valerian (*Valeriana officinalis* L.) can be sown directly to the field or pre-cultivated plantlets can be planted.

Evaluated year of growth: for example, 1, 2, 3 … Thyme is sown in the first year and remains on the field a second and third year.

Pollination: e.g. open pollination, isolation, caged with insect pollination. The information about the mode of pollination is needed for heredity investigations.

Experimental data

General data: designation of the experiment (e.g. experiment no. 48), year of the experiment (e.g. 2004), location (e.g. the city), cultivation place (e.g. glasshouse or experimental field), experimental design (e.g. Fisher block, Latin rectangle), number of the variant (e.g. 08), number of the block and the column (e.g. a and II).

Soil characteristics and climate data.

Size of the plot: in total and the harvested area, m^2.

Cultivation method: seeding or planting technique, date of planting or sowing, rate, depth, distance of rows and of the plants within the row (in case of planting or singling). Provided sufficient seeds are available, seeding with singling after emergence proved good, in experiments with individual plant evaluation, to adapt the experiment to practice conditions and to save the expense of plantlet pre-cultivation.

Cultivation measures: fertilization: products, doses, method of application, developmental stage of the crop at application time. Plant protection products used against which pathogen, doses, date of application, developmental stage of the crop and the pathogen at application time. Controlled pollination: isolation techniques, pollen transfer by hand or insects. Manual or mechanized hoeing, irrigation.

Harvest: equipment, developmental stage of the crop at harvest because of considerable changes of the content and composition of important constituents of some species during ontogenesis.

Dehydration: the conservation of MAP is in general accomplished by dehydration. Besides the equipment, the drying temperature and the period of dehydration (dates) should be documented. This information is needed because the drying conditions can influence the expression of some important characteristics. For example, the highest acceptable air temperature to prevent essential oil losses is 45°C.

Additional data for experiments in the glasshouse: description of cultivation conditions (cultivation

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substrate, regime of temperature, illumination and watering regime).

Sample specification

An exact description of the material from which the sample is derived is needed. The date of sampling should be indicated.

Plants: mixture of plants of a plot or individual plants. The sample must be identifiable by the number of the plot or of the individual plant. The samples are often marked by an additional identifier by the laboratory which accomplishes the analysis.

Plant organs: the entire plant or part of the plant: e.g. flowers, seeds, herb, leaves, stalks. The harvested part of, for example, St John's wort (*Hypericum perforatum* L.) is the so-called 'flower horizon', that means the upper flower-bearing section of the sprout.

In some cases the ramification level of umbels should be noted (e.g. caraway and fennel—*Foeniculum vulgare* Mill.): p = primary, s = secondary, t = tertiary umbel, m = mixture of umbels.

Pre-sampling: it is necessary to take preliminary samples, e.g. when the selection in the frame of a breeding programme must be accomplished up to a certain deadline for biological reasons and results of chemical analysis must be completed in time. In case of fennel, late ripening in autumn, the analysis must be accomplished in a short space of time between harvest and the occurrence of frost, because the roots of the selected elite plants have to be dug out for further breeding procedures before the frost damages them. The fennel umbels mature subsequently according to the ramification level. To extend the period available for the chemical analysis between harvest and frost, ripe secondary umbels are picked as pre-samples, although not all umbels of the plant are ripe in total. For clear identification, separate numbers have to be provided for the pre-sample and the yield of the residual plant. Another pre-sampling is needed to facilitate family selection with subsequent selection of the best individuals within only the best families. A certain portion of the plot must be reserved for preliminary sampling. After the investigation of the preliminary samples, the best populations can be selected for the evaluation of all individual plants.

Characteristics

In the following, the characteristics are arranged according to the chronology of the evaluation. There are primary traits and secondary traits—the latter calculated secondarily from primary traits.

Growth

Morphology traits characterize the changes of the dimension and the weight of plants. Traits characterizing growth are assessed in the course of the vegetation period to support primarily the yield assessment which is evaluated at the end of the cultivation period. They are needed as additional information because the exact yield determination is often affected by technical deficiencies. Table 1 presents some well-proven morphological descriptors.

Development

Development is the succession of different stages from germination to seed maturity. Phenological phases are better calculated by using emergence as starting point instead of sowing, because the period between sowing and emergence is often predominantly influenced by weather conditions (Table 2).

Flower and reproduction biology

The evaluation of the polymorphy of the flower and reproduction biology is important for genotype characterization and breeding purposes.

Male sterility is widely used for the controlled pollination of hybrid varieties. The following key proved to be good for characterization of the male fertility level of the flowers of thyme (*Thymus vulgaris* L.), marjoram (*Origanum majorana* L.) (Langbehn *et al.*, 2001; Mewes and Pank, 2005) and fennel: xx = no anthers, 00 = degenerated anthers only, 11 = normal anthers only, x0 = xx + 00, 01 = 00 + 11, x01 = xx + 00 + 11. The floral sex ratio is calculated secondarily from the share of hermaphrodite and staminate flowers. Also the colour and shape of the anthers of, for example, thyme can vary: v = violet, w = white, y = yellow and b = brown; r = round (normal), s = shrivelled, d = only a dot deep in the perianth. The level of apomixis or sexuality of St John's wort has high importance for plant breeders. The mode of reproduction of individual plants is deduced by flow cytometry of the DNA content of the cell nuclei of the embryo and the endosperm of their seeds. Flow cytometry of filtered nuclei makes it possible to determine their ploidy levels and to assign the plants to different reproductive pathways (Pank *et al.*, 2003a).

Cytological traits

The ploidy level and the chromosome number are important traits for the characterization of genotypes. The ploidy level can be determined most efficiently by

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Table 1. Morphological descriptors

Trait	Method of assessment	Unit/key
Foliage coverage[a]	Visually	% covering the ground
Growth vigour	Visually	Scores
Growth type	Visually	Scores, e.g. 9 = prostrate, 5 = semi-erect, 1 = erect
Growth height[b]	Yardstick, individual plants	cm
Stand height[c]	Yardstick, the entire stand	cm
Plant bush diameter	Yardstick, maximum, medium, minimum	cm
Bush volume[d]	Secondarily calculated	cm^3
Ramification	Visually	Scores, e.g. 9 = very strong, 5 = medium, 1 = no branches
Leaves: length, width, circumference	Computer-aided image analysis	mm
Leaves: area	Computer-aided image analysis	mm^2
Leaves: shape	Visually	Scores, e.g. 9 = broad, 5 = medium, 1 = narrow
Leaves: size	Visually	Scores, e.g. 9 = big, 5 = medium, 1 = small
Leaf-index	Secondarily calculated: length/width	
Leaf-index	Secondarily calculated: area/circumference	
Quantity of plants[e]	Counting	Number per m^2
Lodging tendency	Visually	Scores
Shattering tendency of seeds[f]	Manually, visually, by measuring tools	
Under limit of flower horizon[g]	Yardstick	Distance (cm) between the ground and the first flowers at the stem
Flower horizon[g]	Secondarily calculated	Difference (cm) of growth height and under limit of flower horizon
Stubble height	Yardstick	cm
Vitality[h]	Visually	Scores, e.g. 9 = very vital, 5 = medium vital, 1 = dying off
Rooting[h]	Visually	Scores
Regeneration ability[i]	Visually	Scores

[a] Foliage coverage: imagine a projection lamp above the plant stand and assess the shadow on the ground caused by the cover of vegetation.
[b] Growth height: distance between the ground and the top of the individual plant. This definition is valid also in case of lodging when the stem of the plant is permanently displaced from its upright position.
[c] Stand height: distance between the ground and the upper horizon of the entire stand. Put the yardstick into the stand, move your eyes to the position of the upper horizon of the stand, and read the stand height from the yardstick neglecting some individual plants overtopping the vast majority of the plants.
[d] Bush volume: a morphological marker for the prediction of the yield. Calculated by the formula (maximum bush diameter)^2 × growth height × π.
[e] Quantity of plants (or also missing plants per plot, plant density plants per m^2): the number of plants can be counted at different periods, e.g. after planting or emergence, after allotment of the standing area by singling, after harvest counting the stubbles or digging out and counting the roots (fennel, caraway) or after overwintering.
[f] Shattering tendency: may cause losses when the seeds drop to the ground prior to harvest due to high shattering tendency (e.g. caraway, coriander—*Coriandrum sativum* L., fennel). The power needed to rip off e.g. ripe fruits can be assessed manually or by a special measuring device (Pank, 2000). Another reason for seed losses by high shattering tendency is the opening or disintegration of the seed coat before harvesting (e.g. poppy—*Papaver somniferum* L., evening primrose—*Oenothera* sp.). The shattering tendency can be assessed by the percentage of seeds dropped out and lying on the soil. The cultivars should have a low shattering tendency to make the harvest by combine harvesters possible in an adequate maturity stage.
[g] For example, chamomile (*Chamomilla recutita* (L.) Rausch.) and St John's wort.
[h] For example, cuttings for vegetative propagation during the rooting period.
[i] For example, peppermint (*Mentha* × *piperita* L.) regrowth after the first cut or second cut.

Table 2. Descriptors characterizing plant development

Trait	Method	Unit/key
Emergence	Visual	Date, when 50% seeds are emerged
Period up to emergence	Secondarily calculated	Date/number of days between sowing and emergence
First year bolting tendency	Counting	% bolting plants (e.g. *Digitalis lanata*)
Flower buds	Visually	Date
Start of flowering	Visually	Date, when five flowers of the individual plant are open, or when 10% of the plants on a plot have started flowering
Period up to start of blooming	Secondarily calculated	Days between planting/emergence to start of flowering
Full bloom	Visually	Date
Period up to full bloom	Secondarily calculated	Days between planting/emergence to full flowering
Level of ripeness	Visually	%, ratio of ripe plant organs at harvest
Stage of seed/fruit ripeness		Green, milky wax, brown, death ripe
Ripeness		Date
Period up to ripeness	Secondarily calculated	Days between planting/emergence to harvest ripeness
Harvest		Date

flow cytometry (Givan, 1993). Chromosome counting by microscopy is more time consuming. For example, Pank *et al.* (1999) reported on the chromosome determination of peppermint.

Molecular traits

Different methods for the fragmentation of plant DNA or plant enzymes are used widely for the characterization of genotypes. These methods are independent of the influence of external factors. Klocke *et al.* (2002) showed, for example, clear differences between individual plants of marjoram by means of randomly amplified polymorphic DNA (RAPD) assays.

Biotic stress susceptibility

MAP are attacked by pests and diseases like other crops. The origin and the degree of infestation have to be evaluated to provide evidence of plant protection measures or of resistance breeding. The simplest method is the visual assessment of the damage caused by the pathogen. Infestation scores should be arranged logarithmically for better detection of small differences of plants only attacked a little (Bundessortenamt, 1995): 9 = very high, >67.5–100%; 8 = high to very high, >35–67.5%; 7 = high, >25–35%; 6 = intermediate to high, >15–25%; 5 = intermediate, >10–15%; 4 = low to intermediate, >5–10%; 3 = low, >2.5–5%; 2 = very low to low, >0–2.5%; 1 = no visible sign of infestation, 0%. Taubenrauch *et al.* (2001) used computer-aided image analysis to calculate the percentage of the leaf surface of fennel infested by *Mycosphaerella anethi*. Methods of the evaluation of pathogen infestation are also communicated by Scholze *et al.* (2001) for St John's wort attacked by the wilt disease *Colletotrichum* cf. *gloeosporioides*.

Abiotic stress susceptibility

Some Mediterranean species (balm—*Melissa officinalis* L., oregano—*Origanum vulgaris* L., thyme, sage—*Salvia officinalis* L., fennel) cultivated in Central Europe are frequently damaged by frost. Winter killing can be calculated as the ratio of the plants which died during the winter (the difference between the number of plants in the past autumn and early spring). The reaction to drought is most effectively assessed by the yield.

Yield

Yield is one of the most important characteristics. The evaluated yield component and its condition (water content) must be indicated. An adequate precision of weighing needs at least three numbers above null, e.g. 12.2 kg or 0.0546 g.

Examples of yield components are: roots—valerian; herb—peppermint; stems and leaves as fractions of the herb—balm; flowers—chamomile; fruits—caraway; number of seeds per individual plants—e.g. for breeding purposes; flower horizon—St John's wort; tops of sprouts—sage; constituents—essential oil.

The yield of the pre-sample and the yield of the residual plant must be identified separately to allow the yield determination of the total plant by addition of the weight of both samples.

Levels of the moisture content of the plant material are, for example, fresh, air dry (storage at room temperature, e.g. in the laboratory), standardized to a standard moisture content of, for example, 11% for peppermint leaves, 8% for fennel fruits, 12% for valerian roots and chamomile flowers by calculation according to the *European Pharmacopoeia* (PhEur; EDQM, 2002), or oven-dry matter.

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The harvest dates of the pre-sample and of the residual material of a plant must be recorded.

The yield can also be assessed visually when harvesting and weighing are impossible, e.g. by the following scores: 9 = very high, 7 = high, 5 = medium, 3 = poor, 1 = no yield.

The essential oil yield is calculated by multiplication of the following factors: essential oil content (% v/w) × oven-dry material × specific gravity of the essential oil (average values according to Gildemeister, 1966), e.g. fennel = 0.971, peppermint = 0.928, chamomile = 0.937, valerian = 0.960.

Quality

The demand on quality depends on the field of usage. For example, quality parameters for medicinal drugs are defined by the pharmacopoeia or by specific standards of the pharmaceutical industry. The results of the investigation of quality characteristics depend on the determination method. Therefore, the standards indicate not only the quality parameter but also the concerning determination methods. These methods are often costly and time consuming. A lot of expense can be saved considering the fact that, for example, for breeding purposes the precision must be reliable but the accuracy does not have to comply with the high level of standard methods. Therefore, some examples of expense-saving methods are delineated in the following, besides the quality characteristics itself. The date of the analysis and the moisture content of the evaluated material should be recorded.

Quality traits conditional on morphology

The following quality traits depend on the expression of morphological characteristics.

Thousand seed weight

Visually assessed by, for example, the following scores: 9 = very big, 7 = big, 5 = medium, 3 = small, 1 = very small. It has proved an advantage to prepare example samples of each score before starting the evaluation.

Counting at least 100 seeds per sample provides more exact results (g/1000 seeds). In the cases of, for example, caraway, coriander and fennel, it must be considered that these species have schizocarps and that each single fruit must be counted according to the methods of the International Seed Testing Association (ISTA). Seed counting can be facilitated by special devices and by image analysis (Franke *et al.*, 1996).

Rate of plant organs

In most cases only certain plant organs are the important yield components. All growing and processing measures should improve their rate. The share of the important plant parts is quoted absolutely, in grams, or as rate, as a percentage of the evaluated material. For example, the leaf–flower fraction is the most important yield component of most herbal drugs. The share of the leaf–flower fraction of some herbal drugs has, according to longtime experience, the following average percentage: peppermint and balm 50%, sage 60%, marjoram 46%, thyme 37%, summer savory (*Satureja hortensis* L.) 25%, parsley (*Petroselinum crispum* (Mill.) Nym. ex Aw Hill) 55%.

The separation of stems and leaves of dried samples can be accomplished manually (to save time on this tedious work, the top 5 cm of the sprout can be assigned to the leaf–flower fraction all in all if the stem is only small in this section, e.g. peppermint, balm), the dry herb can be rubbed through a sieve or it can be chopped by machine and thereafter separated by an air separator (broad-leafed, e.g. peppermint, balm, sage) or the fractioning can be accomplished by a laboratory-scale thrasher with subsequent separation by sieves, trieurs and air separators (small-leafed, e.g. marjoram, summer savory, thyme).

A high flower horizon rate of the herb is required in the case of St John's wort.

Rate of seed fractions

The rate of seed fractions is an important quality trait, for example, in the case of fennel, where small seeds (fraction 1–2 mm) are required for the tea bag-filling machines. The different fractions are quoted as percentage of the total sample weight. The seed samples are separated by sieve machines (Pank *et al.* 2003b).

Foreign matter

The rate of undesirable matter in the used plant fraction must be limited to an acceptable amount; for example, the funicles adherent on the fruits of caraway. The ratio is calculated as percentage by separation of 100 complete schizocarps (two adherent single fruits) into fractions with and without adherent funicles.

Constituents

Dry matter content

Dry matter content is the substance of plant material remaining after oven drying at 105°C to a constant weight. Facing the variable moisture content, all data

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should be related to the dry matter content to make real comparisons possible. The water content determination by distillation of a mixture of toluol and the drug according to PhEur 4.00/2.02.13.00 (EDQM, 2002) is very time consuming. Satisfactory results can be achieved with less expense by (i) assumption of an empirically derived dry matter content after at least a two-week storage period of acclimatization of dried drug samples in the laboratory at room temperature (e.g. summer savory and marjoram leaves 91%, caraway and fennel fruits 92%), (ii) the determination of the drying losses at 105°C in a drying oven to a constant weight. The weight of the evaporated essential oil should be added to the oven-dry matter if the essential oil content of the drug exceeds 2% (Luckner, 1966, for specific gravity of essential oils see the chapter 'Yield').

Content of essential oil and its components

The essential oil content of the plant material is quoted as % v/w and related to dry matter (e.g. valerian 0.5–2.1%, peppermint leaves 0.5–4%, caraway 3–7%, chamomile 0.3–3%, according to PhEur). The analytical reference method of PhEur is hydrodistillation. Cleaning of the PhEur apparatus after each analysis is complicated and easier to accomplish by an apparatus according to DIN 10 228 (1995).

The unit of the content of individual compounds of the essential oil is % v/v. Most of them are determined, up to standard, by gas chromatography, but thin layer chromatography (TLC) and near-infrared spectroscopy (NIRS) are also used.

The methods of the analysis must be indicated (distillation, extraction, TLC, NIRS) because the method influences the result.

NIRS proved very good for the evaluation of a lot of important constituents in a great variety of species. The samples are put in a cuvette and exposed to a wolfram light source. After calibration, the content of the substance is calculated from the reflected infrared spectra. NIRS meets in particular the plant breeders' demands: it is non-destructive, highly productive and reliable (Schulz *et al.*, 2001) (Table 3).

Important compounds of the essential oil are, for example, carvone of caraway, matricine and α-bisabolole of chamomile, menthol and menthone of peppermint.

Other important constituents

Some examples for other important constituents of MAP are, for example, *Digitalis lanata*—total glycoside content, c-glycosides; poppy—morphine in the capsule and crude protein and crude fat in seeds; evening primrose—the total content and the spectrum of fatty acids, e.g. γ-linolenic acid; St John's wort—content of hypericine and hyperforine. The analytical methods are different, highly specific and often expensive (HPLC). TLC facilitates the determination of many constituents (Reich and Blatter, 2002).

Sensory quality

Colour

Colour is an important quality trait of many herbs. For example, a light green colour of the drug of parsley, dill (*Anethum graveolens* L.) and marjoram is required as well as dark brown caraway fruits. Colour is also applicable for genotype differentiation, e.g. the occurrence of anthocyane on caraway fruits in the milky wax stage,

Table 3. Coefficients of determination of the regression between the essential oil content or its components determined by hydrodistillation and NIRS

	Oil components				
	Essential oil	Carvone	Anethole	Fenchone	Estragole
Caraway fruits					
1998	0.9317	0.8905			
1999	0.9471	0.7367			
2000	0.9762	0.9315			
2001	0.9472	0.8449			
2002	0.9796	0.8490			
2003	0.9571	0.9224			
Fennel fruits					
1998	0.9624		0.9773	0.9946	0.8142
1999	0.9266		0.9866	0.9921	0.9862
2000	0.9785		0.9866	0.9896	0.9934
2001	0.9484		0.9635	0.9844	0.9752
2002	0.9611		0.9613	0.9898	0.9853
2003	0.9697		0.9432	0.9853	0.9248

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on stems of St John's wort or on the stipulae of the lateral branches of fennel and the colour of flowers, e.g. of thyme and summer savory spanning from white to violet.

Colour can easily be measured by a spectrophotometer according to the CIELAB-System. The device measures the following colour coordinates: 0 L* = white to 100 L* = black; −a* = green to +a* = red; −b* = blue to +b* = yellow (Pank *et al.*, 2000).

Colour assessment can be done also visually. The use of colour scales is recommended.

Smell

One of the most important characters is olfactory characteristics, in particular in the case of drugs for cosmetic preparations and spices. Olfactory tests can be accomplished only by trained panels. Hoberg *et al.* (1997) delineated the principles of sensorial evaluation. The following scores can be used, for example, for the characterization of the smell of marjoram: 5 = typical, pure, fully aromatic, spicy; 4 = typical, pure, aromatic, spicy; 3 = still typical, not completely pure, slightly aromatic, not so spicy; 2 = hardly typical, impure, hardly aromatic, not spicy; 1 = not typical, strange, 0 = spoilt (Novak *et al.*, 2002).

Taste

Taste has the first priority for spices but it is important also for medicinal herbs. Testing the taste requires also well-trained panels. For the evaluation of, for example, marjoram, the following scores can be used: 5 = typical, pure, fully aromatic, mild bitter note, spicy; 4 = typical, pure, aromatic, mild bitter note, spicy; 3 = still typical, not completely pure, slightly aromatic, bitter note somewhat dominating, not so spicy, slightly hay-like; 2 = hardly typical, impure, hardly aromatic, strong bitter note, not spicy, hay-like; 1 = not typical, strange, 0 = spoilt (Novak *et al.*, 2002).

Impurities

Residues of plant protection products, heavy metals (Cd, Pb, Hg), microbiological contamination and aflatoxines are examples of impurities in MAP (Steinhoff, 2002). They are primarily affected by the production technology but, for example, heavy metal accumulation can be also subjected to genetic control (Schneider *et al.*, 2002). Other examples of the impact of genotypes are: the morphology of valerian roots—ratio of hairy roots to thick roots—influences the result of soil removal by washing procedures and therewith the content of mineral impurities which are determined by the ash content not soluble in hydrochloric acid; the portion of undesirable plant matter—e.g. stems in the flower drug of chamomile—varies depending on the different fitness of the genotypes for combine harvesting.

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