Adaptation of medicinal and aromatic plants to contemporary quality and technological demands by breeding: aims, methods and trends

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ABSTRACT: Adaptation of medicinal and aromatic plants to contemporary quality and technological demands by breeding: aims, methods and trends. Breeding has become one of the most important key factors for improvement of the MAP branch because the genotypes can be adapted to the special demands of the players in the production chain and contribute to high quality, profitable and sustainable production. The exploitation of the genetic potential of MAP is still in its initial stage. Conventional breeding methods prevail due to the high natural variability available. Nevertheless, the use of biotechnological tools and research on genes controlling the secondary metabolite formation and their transmission are in progress. Success has been achieved in the development of expense-saving selection procedures.

Key words: breeding, medicinal and aromatic plants, selection efficiency

INTRODUCTION

Medicinal and aromatic plants (MAP) take a very small cultivation area in comparison to other groups of cultivated plants. On the contrary, they comprise a huge number of used plant species with most diverse biological specifics and characteristics. Plant breeding opens the opportunity to adapt these most diverse species to the demand of their users. Considering the fact that plant breeding is a very complex field of science by itself and the objects and aims of MAP breeding vary extremely, some highlights, supplemented with a few references, were chosen to elucidate focal points of this multifaceted field. The following deliberations are made from the point of view of a Central European.

The phenotypes of plants are determined not only by environmental but also by genetic factors, which are inherited from parents by their progenies. The breeder exploits the genetic variability and tries to change the genetically controlled reaction norm of a genotype towards the aspired direction - the improvement of the average performance and of the ecological stability.

Contemporary demands on MAP cultivars

Breeding results in high performance cultivars which are indispensable for the production of high quality products in a sustainable and profitable way. But, the breeding aims differ depending on the position of the players in the production chain. The players are seed companies, farmers, trade and industry, consumers and also the general public. Some typical breeding aims are: high and stable yield, homogeneous raw material, high content of desired compounds and absence of harmful substances, resistance to biotic stress (pests and diseases), resistance to abiotic stress (climatic adaptation to the cultivation region) and high functional value and safety. MAP cultivars must be fit for the technological processes in agriculture and industry, for low input, cost saving and sustainable production and also for an effective protection of plant breeders’ rights.

Specifics of MAP breeding

Breeders of MAP cultivars are confronted with some special features. Disadvantages in comparison to the main groups of agricultural crops are that only a few results of breeding research are available - e.g. on the genetics of certain traits and on breeding methods, that MAP comprise a particularly great number of species, that often the breeding aims differ on one and the same species depending on the field of usage, that the analyses of the important constituents are particularly costly, that only limited capacities for breeding research and breeding are available for these minor crops, and that refinancing of the breeders’ expenses is insufficient due to the small saleable seed amount. But, there are also advantages: the breeder can exploit high natural variability because breeding of MAP is in its initial stage only so that a high progress is achievable already after a few selection steps. In view of these specifics and to ensure an adequate cost-value ratio, breeders have to plan very carefully which crops, breeding aims and breeding methods are to be chosen.

Recebido para publicação em agosto/2004  
Aceito para publicação em julho/2006
Utilisation of natural diversity

Sources of natural variability are accessions collected in the wild, accessions from germplasm collections - e.g. from gene banks and botanical gardens -, furthermore old primitive cultivars and landraces, and contemporary used cultivars. Introduction of a high performance population selected among a great collection of different accessions can already provide an enormous progress in adaptation of a MAP species to the demands, even without additional time-consuming and expensive breeding procedures (Stahn et al., 1997).

Generation of new variability

New variability must be created if the initial material does not provide the desired trait expression. Some common methods are addressed in the following.

Combination breeding by crossing: The aim of crossing is the combination of trait expressions of the parents (donors of certain characteristics) in common progenies. The pollen of the father parent is transferred on the stigma of an emasculated flower of the maternal parent, and the pollinated flower must be kept isolated, e.g. with a paper bag, during the period of stigma fertility. Elite plants with the aspired trait combination are selected in the following segregating generations and bred to constancy. This method is most common in MAP breeding to create new variability (Pank, 2002).

Hybrid breeding: Hybrid breeding is increasingly used for MAP because of its advantages: high performance by heterosis, high level of homogeneity, natural protection of plant breeders’ rights because unlicensed seed propagation results in worthless segregating populations. Additional expenses are necessary for development and maintenance of at least three different lines: the male sterile mother with her maintainer and a pollinator with high per se performance and good combining ability. The F₁ of the mother and the pollinator is used as cultivar. Male sterility of the mother line is necessary to guarantee controlled pollination and to save the huge expenses of emasculation (Pank, 2002).

Synthetic cultivars: Whereas hybrid cultivars exploit the good combination ability of only two distinct parent lines in the F₁ generation, synthetic populations base on several well combining parental lines. The seeds are not only produced from the F₁, as in hybrid cultivars but also from advanced generations (Lenzi et al., 2003).

Induced mutation: Also mutations of the genome induced by, e.g., radiation or mutagenic chemicals are frequently used in MAP breeding (Punia & Amkrishna, 2002).

Molecular gene transfer: Molecular gene transfer shortens the breeding procedures considerably. A lot of ongoing research also with MAP is concerned with the clarification of the biosynthetic pathway of important secondary metabolites, the identification of related enzymes, the isolation of encoding genes, and the establishment of protocols for the gene transfer. These investigations are very expensive and up to now successful breeding of transgenic cultivars with economic importance is scarcely known (Chitty et al., 2003). An obstacle in this field is the refusal of transgenic herbs by the customers on the most important MAP market in Europe.

SELECTION

If a population with an appropriate natural or artificially generated variability is available, the breeders start the improvement of the population by selection. Selection accumulates the genes in a population which control the aspired trait expressions. Selection in wild populations or landraces is the most common way in medicinal plant breeding, because most of the species are yet in the stage of wild plants with high genetic variability. Only a few selection steps provide already satisfying results.

Selection methods:

Common selection methods in MAP breeding are: mass selection, recurrent selection, pedigree breeding (selection of elite plants and testing their progenies), selection breeding in apomicts, and clonal breeding. Information on these and other selection methods can be obtained from the breeding manuals (Allard, 1999; Wricke et al., 1986). Clonal breeding has a particularly high importance for MAP because this method shortens the breeding procedures considerably. Due to the high costs of vegetative propagation mostly done by micropropagation in vitro, clonal breeding is appropriate only for high priced MAP (Hutter et al., 2001).

Improvement of selection efficiency:

The aim of selection is to achieve a high selection response with only low expense in time and money. Breeding a new cultivar with classical methods needs 10 to 15 years from first crossing up to cultivar registration. Therefore, all possibilities are to be used to shorten this period by improving the selection response. The formula \( i * h^2 * \sigma \) shows the factors affecting the selection response \( (R) \). The amount of individual plants in the initial populations should be as high as possible to improve the selection intensity \( (i) \). The heritability \( (h^2) \) can be improved by an
appropriate precision of the measurements of characteristics. The populations must excel by a high variability (σ).

Knowledge of the differing reproduction biology of the species can be used to arrange the breeding procedures most effectively which are divergent, e.g., for inbreeding species and for outbreeders. Pank et al. (2003) show how to use apomixis of Hypericum perforatum to speed up the breeding program.

The succession of generations can be accelerated e.g. by cultivation of an additional generation during winter in the glasshouse or by flower induction by vernalisation or special illumination, e.g., of an Achillea species (Zoberi et al., 2003).

Early selection on the level of young plants, calli or cell suspensions saves expenses because the cultivation period of low performance individuals is shortened. Ulrich and Pank (1996) selected Oenothera lamarckiana seedlings by analysing their cotyledones.

Effective methods for the test of resistance against pests and diseases are an indispensable prerequisite for resistance breeding (Scholz et al., 2001).

The use of doubled haploids generated from microspores speeds up the time consuming process of breeding on homogeneity (Schulte, 1998).

Traits whose expression can be measured only with high expense can be evaluated more easily by means of a strongly correlated marker: such markers are e.g. morphological and physiological, chemical (Orth et al., 2000) and molecular (Wagner et al., 2001).

Rapid analytical methods: One of the most important breeding aims is the improvement of the content of essential constituents. But, the high expenses for chemical analysis are a limiting factor. Therefore, the development of special analytical methods for MAP breeding is an indispensable prerequisite to provide a sufficient selection intensity by analysing an appropriate amount of individual plants. Analytical methods must meet the following demands: time and cost saving to allow the evaluation of as many individual plants as possible, non-destructive for keeping the investigated plant material alive for following breeding procedures, small sample quantities because single plants or parts of them are to be evaluated, direct analysis without preceding sample preparation is preferred, the precision must be reliable. A lot of expenses can be saved considering the fact that the accuracy must not comply with the high level of standard methods. For example, the rapid and non-destructive near infrared spectroscopy (Schulz et al., 1999) and the solid phase microextraction (Sartoratto, 2003) proved well in MAP breeding.

Other prospective methods for the evaluation of individual plants in selection procedures are the exploitation of computer aided image analysis, direct and indirect quality assessment by colour measurement, and tests with chemicals of high specific reactivity.

REFERENCE


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