APPLICATION OF MULTI CRITERIA DEX MODEL IN HOP BREEDING

Črtomir Rozman
University of Maribor, Faculty of agriculture and life science
Pivola 11, 2311 Hoče, Slovenia
crt.rozman@um.si

Karmen Pažek
University of Maribor, Faculty of agriculture and life science
Pivola 11, 2311 Hoče, Slovenia
crt.rozman@um.si

Viljem Pavlovič
University of Maribor, Faculty of agriculture and life science
Pivola 11, 2311 Hoče, Slovenia
crt.rozman@um.si

Marko Bohanec
Jožef Stefan Institute, Department of Knowledge Technologies,
Jamova 39, 1000 Ljubljana, Slovenia
marko.bohanec@ijs.si

Martin Pavlovič
University of Maribor, Faculty of agriculture and life science
Pivola 11, 2311 Hoče, Slovenia
crt.rozman@um.si

Abstract: The planning process in agriculture often requires consideration of many conflicting criteria and participation of multiple stakeholders with conflicting interests. The multi criteria decision method DEX is therefore a viable option for decision support in farm management. This study briefly reviews The DEXi-HOP 1.0 model enables an assessment and ranking of individual hop hybrids' and hop varieties' breeding potentials. The model has 18 attributes, hierarchically grouped within four aggregated attributes: Biology, Chemistry, Morphology and Brewing value. Furthermore, utility functions in the model were defined by sets of elementary decision rules through the entire hierarchy for all aggregated attributes. Four Slovenian hop hybrids, A1/54, A2/104, A3/112, A4/122 and a reference hop variety Hallertauer Magnum with target characteristics in plant resistance and brewing value, were used for the model assessment.

Keywords: multi criteria decision making, DEXi, hop breeding

1 INTRODUCTION

Multi criteria decision analysis can be applied when the evaluation involves several variables that cannot be easily transformed into quantitative units, and the assessment process is likely to be influenced by multiple competing criteria. Such situation often emerges in agriculture and the multi criteria analysis for different kind of assessmets systems has been applied in many cases (Pavlovič et al. 2011; Žnidaršič et al. 2008; Bohanec et al. 2008; Mazetto and Bonera 2003; Griffits et al. 2008, Tiwari et al. 2009; Tojnko et al. 2011).

The most common methods like analytical hierarchical process (AHP) and multi attribute utility theory are based on quantitative assessment. For instance AHP has been used for variety assessment before (Rozman et al., 2015; Srđevićet al., 2004). On the contrary, the method DEXi (Bohanec et al. 2000) is based on discrete values of attributes and utility functions in the form of "if…then" decision rules. In particular, some methods, such as DEXi (Bohanec and Rajkovič 1990; Bohanec et al. 2000), facilitate the design of qualitative

(symbolic) decision models. In contrast to conventional quantitative (numeric) models, qualitative models use symbolic variables. These seem to be well-suited for dealing with 'soft' decision problems, that is, less-structured and less-formalized problems that involve a great deal of expert judgment and where qualitative scales can be more informative than quantitative scores. The DEXi method has already been successfully used in numerous real life decision and assessment problems such as for the estimation of tourist farm service quality (Rozman et al. 2009) or assessment of multifunctional contributions of "Streuobst" stands.

The aim of this paper is to present the applications of method DEXi in agriculture on real world agricultural decision problem, namely hop breeding.

2 ASSESSMENT OF NEW HOP CULTIVARS

The hop model (Pavlovič et al. 2011) was developed in order to assess new potential hop hybrids. Within the hop breeding research program carried out at the Slovenian Institute of Hop Research and Brewing, thousands of hop hybrids appeared to be perspective according to research objectives (Cerenak 2006). In this research the data from four different Slovenian hop hybrids A1/54, A2/104, A3/112, A4/122 were compared with a reference German variety Hallertauer Magnum, which had the desired characteristics plant resistance and brewing value. The assessment was carried out by a qualitative multi-attribute model based on the DEX methodology (Bohanec et al. 2000). We first developed the model and then applied it to assess the aforementioned perspective hybrids. The model hierarchy is shown in figure 1.

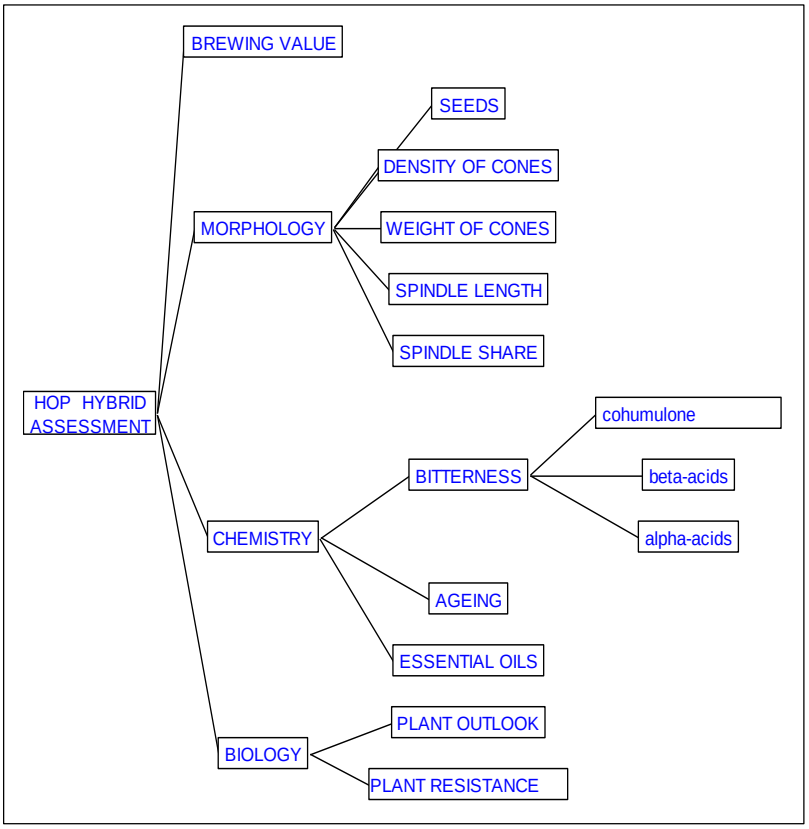


Figure 1: Hop decision model

Among over one thousand of hybrid hop plants analyzed and eliminated stepwise through a selection procedure, the four Slovenian hop hybrids such as A1/54, A2/104, A3/112, A4/122 and a reference variety Hallertauer Magnum were involved into a comparative model assessment. The hop hybrids had been selected through a hop breeding process among sets of seedlings analysed and assessed as highly forthcoming and promising new hop varieties. Numerical data of analyses and measurements of hop cones as well as beer sensory estimation were used to describe hybrids production and brewing quality parameters. They were analyzed and results were additionally discussed. The model enabled a final assessment of hybrids based on defined attributes and decision rules within defined utility functions figures 2).

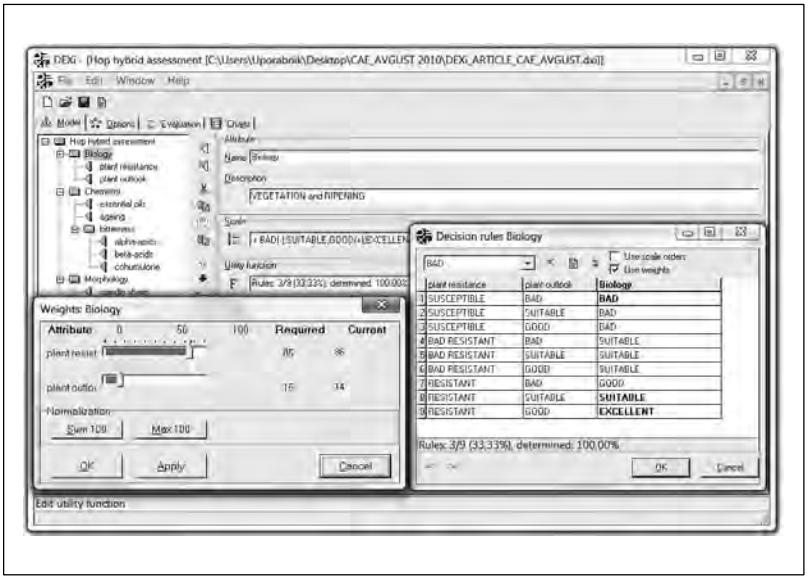
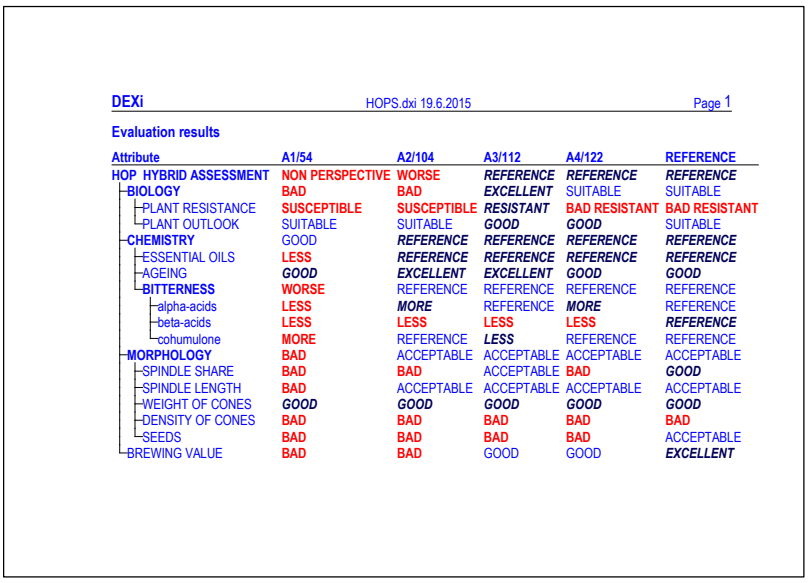


Figure 2: Determination of the DEX-HOP model utility functions for attribute *Biology*.

Based on breeding experiences and the DEXi-HOP 1.0 model results (figure 3), the overall as well as individual (aggregated and derived) attributes assessments were carried out. The results are shown on figures A3/112 and A4/122 reached the overall level of reference and were thus assessed as appropriate for further breeding. On the contrary, A1/54 and A2/104 did not meet expectations in their attributes related to the reference variety. A2/104 was in overall assessed as WORSE, while A1/54 as NON PERSPECTIVE. Therefore, they were considered as hybrids with less breeding potentials. The DEXi model was able to provide additional information on 4 hop hybrids that were initially all considered as perspective by the breeders. We were able to additionally rank them within the group of previously identified hybrids marked as perspective on the basis of breeder's assessment.



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Evaluation results

Attribute	A1/54	A2/104	A3/112	A4/122	REFERENCE
HOP HYBRID ASSESSMENT	NON PERSPECTIVE	WORSE	*REFERENCE*	*REFERENCE*	*REFERENCE*
BIOLOGY	BAD	BAD	*EXCELLENT*	SUITABLE	SUITABLE
PLANT RESISTANCE	SUSCEPTIBLE	SUSCEPTIBLE	*RESISTANT*	BAD RESISTANT	BAD RESISTANT
PLANT OUTLOOK	SUITABLE	SUITABLE	*GOOD*	*GOOD*	SUITABLE
CHEMISTRY	GOOD	*REFERENCE*	*REFERENCE*	*REFERENCE*	*REFERENCE*
ESSENTIAL OILS	LESS	*REFERENCE*	*REFERENCE*	*REFERENCE*	*REFERENCE*
AGEING	*GOOD*	*EXCELLENT*	*EXCELLENT*	*GOOD*	*GOOD*
BITTERNESS	WORSE	REFERENCE	REFERENCE	REFERENCE	REFERENCE
alpha-acids	LESS	*MORE*	REFERENCE	*MORE*	REFERENCE
beta-acids	LESS	LESS	LESS	LESS	*REFERENCE*
cohumulone	MORE	REFERENCE	*LESS*	REFERENCE	REFERENCE
MORPHOLOGY	BAD	ACCEPTABLE	ACCEPTABLE	ACCEPTABLE	ACCEPTABLE
SPINDLE SHARE	BAD	BAD	ACCEPTABLE	BAD	*GOOD*
SPINDLE LENGTH	BAD	ACCEPTABLE	ACCEPTABLE	ACCEPTABLE	ACCEPTABLE
WEIGHT OF CONES	*GOOD*	*GOOD*	*GOOD*	*GOOD*	*GOOD*
DENSITY OF CONES	BAD	BAD	BAD	BAD	BAD
SEEDS	BAD	BAD	BAD	BAD	ACCEPTABLE
BREWING VALUE	BAD	BAD	GOOD	GOOD	*EXCELLENT*

Figure 3: DEXi assessment for all four analyzed hop hybrids and the reference

Different kind of analyses can be conducted using DEXi. For instance figure 4 shows a comparison between reference hybrid (Magnum) and hybrid A1/54 that was assessed as NON PERSPECTIVE.

None of the hybrids was able to achieve the same Brewing value as reference cultivar. The chart on figure 5 shows scatter chart for the attribute Brewing value.

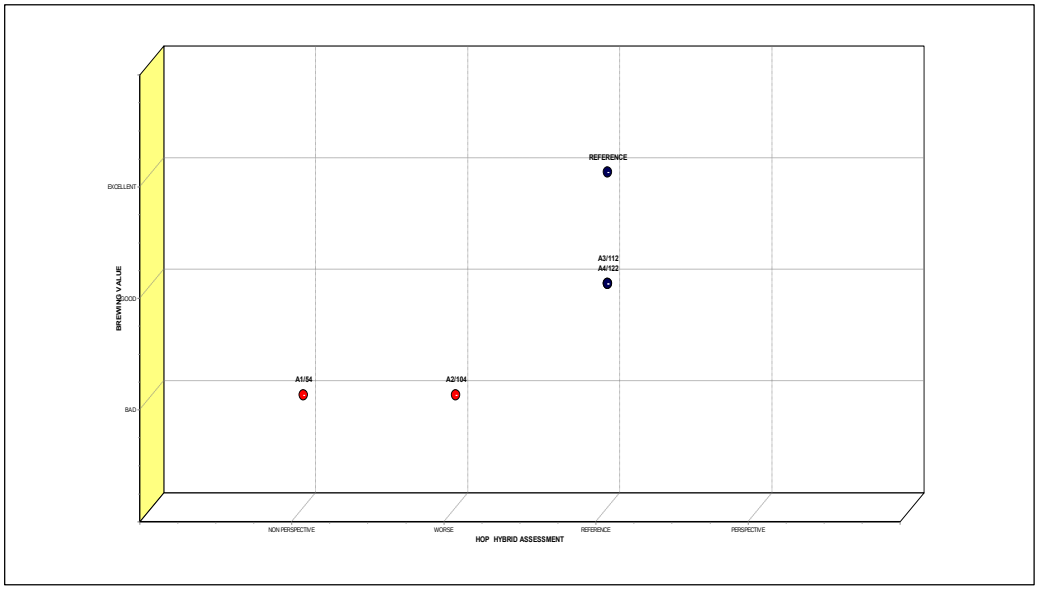

Figure 5: Scatter chart for attribute Brewing value

3 CONCLUSION

In this paper, an attempt was made to present multi-criteria method DEXI, based on qualitative attribute values and utility functions in the form of decision rules, and its possible application in the field of hop breeding.

Despite of the minor deficiencies (such as use of qualitative data only), it was found out that the approach has fulfilled most of the breeders' expectations and revealed considerable advantages in comparison with other approaches. The multi attribute model DEX-HOP 1.0 can therefore be regarded as a useful alternative tool for hop hybrids assessment. We can observe that none of the hybrids is fully equal with the reference cultivar.

This method cannot entirely replace experts, but it can be their additional tool in decision-making, since decisions based on model testing offered much faster results that validate the application of the model for further research. In future, data of new coming hybrids will be added and assessed in comparison to experts' decisions. Furthermore, also new attributes as a response to new goals in hop breeding programs will be included into the model.

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