



HAL
open science

Assessment of the visual quality of ornamental plants: comparison of three methodologies in the case of the rosebush

Pierre Santagostini, Sabine Demotes-Mainard, Lydie Huché-Thélier, Nathalie Leduc, Jessica Bertheloot, Vincent Guérin, Julie Bourbeillon, Soulayman Sakr, Rachid Boumaza

► **To cite this version:**

Pierre Santagostini, Sabine Demotes-Mainard, Lydie Huché-Thélier, Nathalie Leduc, Jessica Bertheloot, et al.. Assessment of the visual quality of ornamental plants: comparison of three methodologies in the case of the rosebush. *Scientia Horticulturae*, 2014, 168, pp.17-26. <10.1016/j.scienta.2014.01.011>. <hal-00940893>

HAL Id: hal-00940893

<https://institut-agro-rennes-angers.hal.science/hal-00940893v1>

Submitted on 3 Feb 2014

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



HAL Authorization

1 Assessment of the visual quality of ornamental plants: comparison of three
2 methodologies in the case of the rosebush

3

4 P. Santagostini ^a, S. Demotes-Mainard ^b, L. Huché-Thélier ^b, N. Leduc ^c, J. Bertheloot ^b, V.
5 Guérin ^b, J. Bourbeillon ^d, S. Sakr ^d and R. Boumaza ^{d,*}

6

7 ^a Agrocampus Ouest, F-49045 Angers cedex, France

8 ^b INRA, UMR1345 IRHS (Institut de Recherche en Horticulture et Semences), SFR 4207
9 QUASAV, F-49071 Beaucouzé, France

10 ^c Université d'Angers, UMR1345 IRHS, SFR 4207 QUASAV, PRES L'UNAM, F-49045
11 Angers, France

12 ^d Agrocampus Ouest, UMR1345 IRHS, SFR 4207 QUASAV, F-49045 Angers, France

13 * Corresponding author: Rachid Boumaza, Agrocampus Ouest, 2 rue A. Le Nôtre, F-49045
14 Angers cedex, France

15

16 E-mail addresses

17 pierre.santagostini@agrocampus-ouest.fr

18 sabine.demotes@angers.inra.fr

19 lydie.thelier@angers.inra.fr

20 nathalie.leduc@univ-angers.fr

21 jessica.bertheloot@angers.inra.fr

22 vincent.guerin@angers.inra.fr

23 julie.bourbeillon@agrocampus-ouest.fr

24 soulaiman.sakr@agrocampus-ouest.fr

25 rachid.boumaza@agrocampus-ouest.fr

26

27 ABSTRACT

28 The quality of ornamental plants can be appraised with several types of criteria: tolerance
29 to biotic and abiotic stresses, development potentialities and aesthetics. This last criterion,
30 aesthetic quality, is specific to ornamental plants and objective measurements are required.
31 Three methodologies for measuring aesthetic quality have been proposed. The first involves
32 classical measurements of morphological features, such as flower number and diameter or leaf
33 size. The second is based on sensory methods recently adapted to ornamental plants. The
34 third, used by the International Union for the Protection of New Varieties of Plants (UPOV)
35 for distinctness, uniformity and stability (DUS) tests, is based on morphological
36 characteristics calibrated on specific reference varieties. The aim of this work was to compare
37 these three methodologies for assessing some flowering and foliage characteristics of
38 rosebushes. Six plants from 10 rose varieties identified by UPOV as reference varieties were
39 cultivated for two years in a greenhouse and outdoors in Angers, France. They were measured
40 and photographed weekly during flowering. Photographs of the plants in full bloom were
41 submitted to a panel of judges for sensory assessment. The results of the three assessment
42 methodologies were compared. Sensory and morphometric measurements were highly
43 correlated and sensory measurements confirmed UPOV scales, whereas some morphometric
44 measures diverged slightly from UPOV scales. We discuss the advantages, disadvantages and
45 complementarity of these three methodologies.

46

47 Keywords

48 UPOV; rose; aesthetic quality; sensory analysis; floribundity.

49

50 Abbreviations

51 UPOV: International Union for the Protection of New Varieties of Plants

52

53 1 Introduction

54

55 Quality is defined by the ISO 8402-1986 standard as “the totality of features and
56 characteristics of a product or service that bears its ability to satisfy stated or implied needs”.
57 The quality of plants can be appraised with several types of criteria: tolerance to biotic and
58 abiotic stresses, development potential and aesthetics, a criterion specific to ornamental plants
59 (Habib et al., 1997; Dijkshoorn-Dekker, 2002; Heuvelink et al., 2004, Giorgioni, 2007). The
60 measurement of aesthetic quality is necessary for objective studies, such as modelling or
61 assessing the effects of various treatments. However, as pointed out by Boumaza et al. (2009),
62 the multiple possibilities make it difficult to measure.

63 The characteristics of aesthetic quality to be taken into account depend on the type of
64 ornamental plant considered: trees, shrubs, bushes or cut flowers. However, some of these
65 characteristics may be common to several plant categories. We focus here on the rosebush, a
66 model plant in ornamental horticulture, considering only visual aspects and ignoring all
67 considerations relating to scent. Furthermore, we do not aim to characterise the visual quality
68 of all the aerial parts of the plant. Indeed, this aspect has been dealt with in previous studies
69 based on the use of tools and methods from the domain of sensory analysis (Boumaza et al.,
70 2010, Huché-Thélier et al., 2011) or architecture analysis (Morel et al., 2009, Crespel et al.,
71 2013). Instead, we focus on the partial evaluation of flowers and leaves, two of the principal
72 determinants of the visual quality of the rosebush.

73 Floribundity is defined as “the capacity of a plant to produce abundant flowers at high
74 density on each of its branches” (<http://fr.wiktionary.org/>, 10/11/2012). However, should we

75 take into account the number of flowers at peak flowering or throughout the year? In its
76 guidelines, UPOV specifies that all observations should be made when the plant is in full
77 flower (UPOV, 2010). Hereafter, we refer to this measurement as the peak floribundity index.
78 The longitudinal floribundity index is the variation of the floribundity index during a season.
79 Another related question concerns the stage at which flowers should be counted. Should we
80 count all flowers, regardless of their stage of development (buds, opened, withered, rose hips)
81 or only fully opened flowers? If we focus on the vitality of the plant, it would be tempting to
82 consider all the flowers. However, if we are more concerned about visual quality, we may
83 wish to restrict the flower count to opened flowers – that is, flowers with visible petals – and
84 rosehips. Indeed, these two types of organ are brightly coloured and stand out from the foliage
85 of the rosebush, which is usually green once the leaves have fully emerged. The peak
86 floribundity index reported here takes into account all flowers but not the rosehips, whereas
87 the longitudinal floribundity index takes only open flowers into account. We characterised
88 floribundity by three types of methods or methodologies: the morphometric methodology, the
89 sensory methodology and the UPOV methodology. The flower and leaf dimensions were
90 characterised by the morphometric and UPOV methodologies.

91 The morphometric methodology is classically used in agronomy. It includes all methods
92 based on counting, such as flower, leaf or axis counts, methods based on the measurement of
93 dimensions, such as the diameters and heights of flowers, the lengths and widths of leaflets
94 and stem length, and methods based on image analysis.

95 The sensory methodology involves the methods and tools initially used in sensory
96 analysis. These methods were originally developed in the agro-food industry and have since
97 been extended to other domains. They have recently been adapted for the objective
98 characterisation of the visual quality of ornamental plants, as perceived by the human eye,
99 which can be considered as a measurement instrument in this context (Boumazza et al., 2009).

100 These methods require the choice of appropriate descriptors, the constitution of a jury of
101 about 15 judges and the evaluation of each descriptor for each product. Two applications
102 (Boumaza et al., 2010; Huché-Thélier et al., 2011) have demonstrated the relevance of such
103 methods to ornamental horticulture, a sector in which visual quality is an important
104 component of the commercial value of the products.

105 The UPOV methodology is based on the DUS (distinctness, uniformity and stability)
106 requirements laid down by UPOV in 1990 for the examination of cultivars or varieties for the
107 acquisition of plant breeders' rights. This method is based on scoring rosebushes on a scale of
108 1 to 9 for characters identified as useful for distinguishing between varieties or for evaluating
109 the uniformity and stability of a variety. Scores of 1, 3, 5, 7 and 9 correspond to examples of
110 varieties that will be referred hereafter as reference varieties (Table 1). The most important
111 feature of this method is that the relative behaviour of the reference varieties is identical in all
112 environments. In some ways, this renders this approach almost international. In this study, we
113 also considered the relevance of this approach, although this was not the principal objective.

114 The reference varieties studied here were those used between 1990 and 2010. The
115 recommendations for the DUS examination were subsequently modified in 2010 (UPOV,
116 2010). This modification led to changes in the reference varieties for the two characters
117 considered. However, this does not undermine the importance of this work, which was begun
118 in 2008 and focuses on a key question: Is it possible to decrease the costs of rosebush
119 evaluation when using a sensory method, and if so, how? Indeed, if the requirements for the
120 reproducibility and repeatability of measurements are to be respected, the sensory method is
121 more expensive than morphometric analyses. Furthermore, neither of these two methods has
122 the almost international nature of the UPOV method.

123 The aim of this study was, therefore, to compare these three methodologies. We evaluated
124 floribundity, and the flower and leaf dimensions of UPOV reference roses, and then compared

125 the results obtained and considered the advantages and disadvantages of each methodology.
126 For validation of some of the findings of these comparisons, we also considered the data
127 obtained for rosebushes by Boumaza et al. (2010), referred to hereafter as supplementary
128 data.

129

130 2 Materials and Methods

131

132 2.1. Plant material and growing conditions

133 Ten rosebush varieties, listed in Table 1, were cultivated at Angers, France (latitude:
134 47° 30' N; longitude: 0° 35' W; altitude: 56 m). The rosebushes were grafted onto *Rosa*
135 *corymbifera* 'Laxa', except for the 'Sweet Promise' variety, which was grafted onto *Rosa*
136 *canina* 'Schmids Ideal'. Experiments were conducted in a greenhouse from November 2008
137 to April 2010 and outdoors from April 2010 to September 2011.

138

139 2.1.1. Growing conditions in the greenhouse

140

141 In November 2008, 60 rosebushes (6 per variety) were planted in 7-litre pots, in a
142 substrate composed of peat, coconut fibre and perlite (60/30/10, v/v/v). The pots were
143 randomly placed on a shelf in six rows, 0.75 m apart and then pruned. The plants were drip
144 fertiirrigated with a liquid fertiliser (Servital®, with a 3–2–6–0.6 balance of N–P₂O₅–K₂O–
145 MgO, a pH of 5.8 and a mean electrical conductivity (EC) of 1.8 mS cm⁻¹, including the EC
146 of water, which was 0.3 mS cm⁻¹). Each plant received between 330 mL of solution every two
147 days in winter and 1330 mL per day in summer. Pests and diseases were controlled.

148 Additional lighting (60 μmol m⁻² s⁻¹ of photosynthetically active radiation) was provided by
149 sodium vapour lamps when total radiation levels outside the greenhouse fell below 200 W m⁻²

150 ². Daylength was extended to 16 h. From March to September 2009, corresponding
151 approximately to the measurement period, mean diurnal temperature was 25.6 °C (minimum:
152 18.4 °C and maximum: 45.0 °C) and mean humidity was 48% (minimum: 15% and
153 maximum: 85%).

154

155 2.1.2. Outdoor growing conditions

156 In mid-April 2010, the 53 surviving rosebushes (7 had died) were transferred outside,
157 together with new rosebushes to replace those that had died, to obtain six replicates per
158 variety. They were planted randomly in six blocks, 2 m apart, on a silty clay soil covered by a
159 porous plastic mulching film. They were drip irrigated with 500 mL of water per plant every
160 non-rainy day, from April to September. Pests and diseases were controlled. From mid-April
161 to September 2010, corresponding approximately to the measurement period for 2010, mean
162 diurnal temperature was 19.5 °C (minimum: 3.1 °C; maximum: 36.7 °C) and total rainfall was
163 156 mm. During the 2011 measurement period, corresponding approximately from April to
164 September, mean diurnal temperature was 19.1 °C (minimum: 6.2 °C; maximum: 35.9 °C)
165 and total rainfall was 230 mm.

166

167 2.2. Morphometric measurements

168

169 2.2.1. Leaves

170 Measurements were made on the UPOV reference varieties for leaf dimension: ‘Tancary’,
171 ‘Mullard Jubilee’, ‘Kolima’, ‘New Daily Mail’, ‘Starina’ and ‘Meiblam’, from 12 April to 10
172 August 2009 in the greenhouse and from 3 May to 10 August 2010 outdoors. The length of
173 the rachis, and the length and width of all leaflets of the leaves located in the central third of
174 each flowering shoot were measured when the terminal flower carried by this shoot withered.

175 As reported for the ‘Radrazz’ variety by Demotes-Mainard et al. (2009), the length of the
176 terminal leaflet was correlated with all the other leaf measurements taken, regardless of the
177 variety considered. We therefore chose to use this character for comparisons of leaf
178 dimensions.

179

180 2.2.2. Flowers

181

182 Measurements of flower diameter were made on the UPOV reference varieties:
183 ‘Meichim’, ‘Pink Wonder’, ‘Kolima’, ‘Sweet Promise’, ‘Starina’ and ‘Meiburenac’, from 3
184 April to 2 September 2009 in the greenhouse and from 8 April to 29 September 2010
185 outdoors. We measured the diameter and height of almost all the flowers at anther dehiscence
186 during the first flush of flowering (ending in mid-July).

187 The numbers of flowers (buds, open and withered flowers) were counted on the
188 rosebushes of the UPOV reference varieties for flower number (‘Meichim’, ‘Kolima’, ‘Sweet
189 Promise’ and ‘Meiburenac’) during the first flowering period, on days determined according
190 to plant development, generally when withered flowers were observed on the rosebush.

191 Almost all the replicates of the varieties used for floribundity measurements in the greenhouse
192 (in 2009) and a single rosebush per variety outside (in 2010 and 2011), were photographed,
193 about once per week. The relative flower area, that is the ratio of the area covered by flowers
194 to that covered by the entire plant (Figure 1), was determined with ImageJ (Rasband, 2011).

195 This ratio and the number of flowers were considered as floribundity indices.

196

197 2.3. Sensory measurements

198

199 These measurements were carried out on the reference varieties ‘Meichim’, ‘Kolima’,
200 ‘Sweet Promise’ and ‘Meiburenac’. One field-grown plant per variety was photographed
201 about once weekly, and we selected three photographs for each plant, some of which were
202 taken at peak flowering. We trained a jury of 16 assessors, to ensure that they interpreted the
203 overall level of flowering in the same way, and established a structured nine-level scale with
204 three photographs for each odd-numbered level (Figure 2). The photographs used for training
205 purposes were, of course, different from those subsequently used for assessment. After the
206 training session, the assessors were asked, individually, (i) to sort the 12 chosen photos into
207 ascending order of flower quantity, taking into account buds and withered flowers, (ii) to sort
208 them according to the relative area occupied by the open flowers, that is the ratio of coloured
209 flower area to total plant area, (iii) to score the level of flowering on the nine-level scale they
210 had previously established (Figure 2). Each assessor carried out three scoring sessions, at one-
211 week intervals.

212

213 2.4. Supplementary data

214

215 As part of the sensory evaluation carried out by Boumaza et al. (2010), 10 rosebush
216 photographs (Fig. 3) were evaluated by 14 judges in three sessions. The judges provided
217 scores for some descriptors, three of which were related to floribundity: “Number of flowers”,
218 “Flower enhancement” and “Number of buds”. These scores were used to rank the 10
219 rosebushes for each descriptor/session/judge. Then, for each descriptor, we averaged the 42
220 ranks of each rosebush to get a mean rank per rosebush/descriptor. The relative flower area of
221 each rosebush was measured independently, with the image analysis method described in
222 section 2.3. All these data are reported in the table associated with figure 3.

223

224 2.5. Statistical analyses

225

226 All statistical analyses were carried out in the R environment (R Development Core Team,
227 2011), with the stats, graphics and agricolae packages. Analysis of variance was used for
228 variety comparisons. When the conditions for the application of this method were not
229 fulfilled, nonparametric tests (Kruskal-Wallis or Friedman test) were used (Conover, 1999).

230

231 3 Results

232

233 3.1. Leaf dimensions

234

235 Both in the greenhouse and outdoors, the ranking of varieties (Table 2) matched that of
236 the UPOV scale (Table 1), except for ‘Mullard Jubilee’, the level 7 (large leaves) reference
237 variety. It was not possible to distinguish this variety from the ‘Tancary’ and ‘New Daily
238 Mail’ varieties, level 9 (very large leaves) reference varieties on the basis of our
239 morphometric measurements. We were therefore able to construct a four-level scale for leaf
240 dimensions, with specific reference varieties: “very small” with ‘Meiblam’, “small” with
241 ‘Starina’, “medium” with ‘Kolima’ and “large or very large” with ‘Mullard Jubilee’, ‘New
242 Daily Mail’ and ‘Tancary’.

243

244 3.2. Flower dimensions

245

246 The diameters of the terminal flowers were found to be significantly greater than those of
247 the other flowers for the ‘Starina’ and ‘Meiburenac’ varieties. We therefore excluded the
248 terminal flowers of plants of these two varieties from the calculations of mean diameter, as

249 recommended by UPOV (1990). By contrast, for ‘Pink Wonder’, we found no difference
250 between the diameters of terminal and non-terminal flowers, and the difference between these
251 two types of flowers was very small for ‘Kolima’. Hence, as fewer data were available for
252 these two varieties, we considered all the flowers, both terminal and non-terminal, in the
253 calculation of mean flower diameter.

254 The mean flower diameters for each variety (Table 3), obtained in two consecutive years
255 in very different growing conditions (one year in the greenhouse and the second year
256 outdoors), were of the same order of magnitude. The largest difference was that for ‘Kolima’,
257 which produced flowers with a mean diameter of 74 mm in the greenhouse and 83 mm
258 outdoors. Pairwise comparisons of rosebushes growing outside led to the identification of two
259 groups. The first consisted of the varieties ‘Starina’ and ‘Meiburenac’, the reference varieties
260 for level 1 (very small) and level 3 (small), respectively, on the UPOV scale (Table 1). The
261 second group consisted of the varieties ‘Kolima’ and ‘Pink Wonder’, the reference varieties
262 for level 5 (medium-sized) and level 7 (large), respectively. Three groups were identified in
263 greenhouse conditions: the first consisted of ‘Starina’ and ‘Meiburenac’, the second of
264 ‘Kolima’ and the third of ‘Pink Wonder’.

265 Thus, flower diameter measurements did not discriminate between reference varieties with
266 very small and small flowers either in the greenhouse or outdoors, or between reference
267 varieties with medium-sized or large flowers outdoors. It was therefore possible to construct a
268 two-level scale for rosebush flower diameter from morphometric measurements: very small or
269 small flowers, with ‘Starina’ and ‘Meiburenac’ as the reference varieties, and medium-sized
270 or large flowers, with ‘Kolima’ and ‘Pink Wonder’ as the reference varieties. This scale partly
271 confirms the UPOV scale but, with only two levels, it is not suitable for use in practice.

272

273 3.3. Floribundity

274

275 3.3.1. Number of flowers

276 When we considered the number of flowers during the first full flowering of each plant,
277 the ranking of the varieties (Table 4) did not perfectly match the UPOV classification (Table
278 1). Indeed, our measurements suggest that ‘Meiburenac’ is a highly floriferous variety (105
279 flowers/plant in the greenhouse and 213 flowers/plant outdoors), followed at some distance
280 by ‘Kolima’ (24 and 33 flowers/plant, respectively). ‘Sweet Promise’ systematically produced
281 fewer flowers (15 and 17 flowers/plant, respectively) than these two varieties. However,
282 ‘Meichim’, the least floriferous variety according to UPOV, behaved inconsistently,
283 producing a similar number of flowers to Sweet Promise in the greenhouse (12 flowers/plant),
284 but a number of flowers between the values obtained for ‘Kolima’ and ‘Sweet Promise’
285 outdoors (23 flowers/plant).

286

287 3.3.2. Sensory data

288 When dealing with sensory data, the first step is the use of several techniques to evaluate
289 jury repeatability and reproducibility (Dijksterhuis, 1995, Rossi, 2001). The detailed results of
290 this process are not shown. From the analysis of sensory data through studies of the
291 distribution of ranks or scores, we noted that the consensus between the judges was best for
292 classification by number of flowers and slightly weaker for scores of flowering level and for
293 classification by the ratio of flower area to total plant area, but the use of these results did not
294 affect the principal findings for variety classification.

295 For each of the three previous sensory evaluation tests (classification by number of
296 flowers, area of the photograph covered by flowers and scores for flowering level),
297 comparisons of varieties gave identical results (Table 5), confirming the UPOV classification

298 for the number of flowers per flowering branch: few (with ‘Meichim’ as the reference
299 variety), medium (‘Sweet Promise’), many (‘Kolima’) and very many (‘Meiburenac’). Thus,
300 the perception of floribundity by the human eye is entirely consistent with UPOV
301 measurements.

302

303 3.3.3. Morphological measurements and their relationship to sensory data

304 For the 12 photographs of rosebushes used for sensory evaluation, we determined the
305 coefficients of correlation between the relative flower area, the number of flowers counted in
306 the field and the mean scores provided by the jury (Table 6). These correlations were found to
307 be strong. This finding opens up interesting new possibilities, in that it suggests that
308 floribundity, as perceived by the human eye, can be assessed simply from a photograph. We
309 will consider this aspect further.

310

311 3.3.4. Longitudinal floribundity

312 In the previous sections, only the instantaneous measurements of floribundity were
313 considered, in analyses of measurements corresponding to peak flowering. So, what about the
314 longitudinal floribundity (i.e. changes in floribundity over time)?

315 For one rosebush per variety, we plotted changes in relative flower area and in number of
316 flowers over time (Fig. 4; graphs on the left). The two curves had the same shape, with peaks
317 occurring at approximately the same dates. Similarly, the times at which the area was null or
318 small corresponded to periods in which there were few, if any, flowers. The Spearman’s rank
319 correlation coefficients for the relationship between these two measurements were high
320 (Fig. 4; graphs on the right).

321 If we consider the longitudinal floribundity obtained by counting the number of flowers
322 (Fig. 5), then ‘Meiburenac’ appeared to be much more floriferous than the other varieties.

323 Similarly, ‘Kolima’ produced more flowers at peak flowering than ‘Sweet Promise’ or
324 ‘Meichim’, but this was not always the case for other rosebushes from the same varieties, as
325 some ‘Meichim’ rosebushes (not shown here) had larger numbers of flowers than ‘Kolima’
326 rosebushes in early autumn.

327

328 3.3.5. Supplementary data

329

330 Relative flower area was strongly correlated with the mean rank inferred from the
331 descriptor “Number of flowers” (Spearman’s rank correlation coefficient (R_s): 0.78, $n = 10$,
332 $p = 0.01$). It was not correlated with the mean rank inferred from the descriptors “Flower
333 enhancement” ($R_s = 0.45$, $p = 0.19$) and “Number of buds” ($R_s = -0.14$, $p = 0.70$).

334

335 4 Discussion

336

337 We used all three methodologies to assess floribundity, whereas only the UPOV and
338 morphometric methodologies were used to assess the dimensions of leaves and flowers. This
339 study focused on the choice of methodology for the simple assessment of these features in the
340 most universal and efficient manner possible.

341

342 4.1. Leaflet and flower dimensions: can we propose classes of values?

343

344 Based on the measurement protocol proposed by UPOV and specified in the materials and
345 methods section, the use of value classes, corresponding to the UPOV scores for terminal
346 leaflet length or flower diameter, would greatly simplify the evaluation of leaves or flowers
347 by the sensory methodology. We initially planned to define such classes on the basis of the

348 mean characteristics (terminal leaflet length and flower diameter) of the UPOV reference
349 classes. Despite the high degree of consistency of the mean characteristics obtained in
350 different growing conditions, the results obtained raise questions about this approach, in that
351 the varieties did not behave in the expected manner. The 1990 UPOV reference varieties do
352 not appear to be appropriate for the constitution of these classes, because there was
353 insufficient discrimination between the reference varieties, particularly for flower diameter.
354 Two alternative strategies are possible. The first would involve repeating the experiments
355 with the 2010 reference varieties (UPOV, 2010), checking that the relative behaviour of these
356 new reference varieties matched UPOV descriptions and determining whether these classes of
357 values could be considered valid for the Angers region. Given the cost of the experiment, an
358 alternative strategy, based on arbitrarily fixing five classes on the basis of the lengths or
359 diameters reported in tables 2 and 3, respectively, might be preferable. We chose to use the
360 same number of classes as the UPOV protocol: very small, small, medium, large, and very
361 large. For example, in outdoor conditions, the classes for terminal leaflet length could be
362 <25 mm (very small), 25-40 (small), 40-55 (medium), 55-70 (large), >70 mm (very large);
363 those for flower diameter could be <50 mm (very small), 50-65 (small), 65-75 (medium), 75-
364 90 (large), >90 mm (very large). These empirically and somewhat arbitrarily defined classes
365 have the advantage of simplicity and are suitable for use in the Angers region. However, they
366 are not valid for all conditions, because the upper limits of the very small and large classes
367 defining the limits of the three central classes, are not exactly the same in the greenhouse and
368 outdoors.

369

370 4.2. Which measurements best reflect the level of flowering of a rosebush?

371

372 Given the importance of flowering in ornamental plants, it would appear surprising that
373 UPOV considers only one flowering characteristic in its classification: the number of flowers
374 per flowering branch. Furthermore, the way in which this character should be assessed is not
375 specified in the UPOV guidelines, leaving plenty of room for differences in interpretation.
376 However, all the possible ways of assessing this character that we tested were sufficiently
377 highly correlated (Table 6), generating a consensus. Nevertheless, although the sensory
378 evaluations fully confirmed the UPOV scale, the morphometric measurements (number of
379 flowers and relative flower area) only partially confirmed the UPOV scale.

380 The main advantage of the sensory method is that it focuses on the consumer's perception
381 of the plant. Furthermore, the scoring scale can be refined and adapted for the products that
382 the jury is asked to assess. However, it is cumbersome to implement and very time-
383 consuming, due to the requirement for jury recruitment and training, for example.

384 Morphometric methods are less subjective than sensory methods, although flower
385 counting may be tedious. By contrast, the relative flower area on a photograph proved to be a
386 suitable indicator of the level of flowering of the plant perceived by an observer. However,
387 this measurement does not match the definition of floribundity, in that two rosebushes may
388 have equivalent ratios but very different numbers of flowers. For example, figure 6 shows two
389 rosebushes: 'Sweet Promise' and 'Meiburenac', corresponding to the "medium" and "very
390 many" categories of the UPOV (1990) scale. Their peak flowering area ratios were 45%, with
391 30 flowers, for the 'Sweet Promise' rosebush and 47%, with 205 flowers, for the
392 'Meiburenac' rosebush. This problem can be alleviated, for example by dividing the ratio by
393 an estimate of the area of a flower from the corresponding variety. The advantage of this
394 approach is that the calculation of ratios from photographs can be automated, and this would
395 accelerate the analysis, provided that all the photographs analysed were taken in good lighting
396 conditions. This is a necessary condition to ensure that the colour of the flowers is reproduced

397 accurately on the photograph. Another advantage of this approach is that it is not necessary to
398 photograph the entire rosebush, as this measurement is a ratio that could be estimated on the
399 basis of a photograph of the heart of the rosebush alone. Image analysis would therefore be a
400 useful tool for estimating floribundity and changes in floribundity over time.

401

402 4.3. Is the relationship between the results of sensory methods and image analysis
403 confirmed?

404

405 The results obtained for the supplementary data highlighted the link between the
406 descriptor “Number of flowers” and relative flower area. They thus provide an additional
407 argument for using the relative flower area measured by image analysis as a possible
408 measurement of rosebush floribundity.

409 There was no link between the descriptor “Number of buds” and relative flower area. This
410 is not surprising as it no buds were visible on the photograph (if the petal colour was not
411 visible) or only a very small proportion of the area was covered by buds (when the petal
412 colour first became visible).

413

414 5 Conclusion

415

416 We compared the results of morphometric and UPOV methodologies for classifying
417 varieties on the basis of flower diameter and leaf dimension, and we identified several
418 discrepancies. We also compared these two methodologies with sensory methodology for
419 floribundity assessment. Our analysis highlighted a convergence of the results obtained with
420 the various methods and suggested that it should be possible to assess floribundity as
421 perceived by the human eye, by image analysis techniques. The main advantages of image

422 analysis methods over sensory methods are their rapidity and universal nature. Such methods,
423 which would be relatively simple to carry out, might prove very useful for quantitative and
424 objective measurements on large samples. This method would therefore be useful for studying
425 processes such as the progression of flowering, which is currently being studied in relation to
426 the genetic determinism of flowering (Kawamura et al., 2011) and is of interest to rose
427 breeders for the assessment of new cultivars.

428

429 Acknowledgements

430

431 We thank the experimental domain team (INEM) of Agrocampus Ouest, Angers, who took
432 great care of the roses, the people who helped us to take the photographs, all the judges who
433 assessed the rosebushes, Morgan Garbez who introduced us to the use of ImageJ software for
434 our image analyses and Michel Laffaire, recently retired, for his work and advice during the
435 three years of experimentation.

436

437 References

438

439 Boumaza, R., Demotes-Mainard, S., Huché-Thélier, L., Guérin, V., 2009. Visual
440 characterization of the esthetic quality of the rosebush. *J. Sens. Stud.*, 24, 774-796.

441 Boumaza, R., Huché-Thélier, L., Demotes-Mainard, S., Le Coz, E., Leduc, N., Pelleschi-
442 Travier, S., Qannari, E.M., Sakr, S., Santagostini, P., Symoneaux, R., Guérin, V., 2010.
443 Sensory profiles and preference analysis in ornamental horticulture: the case of the
444 rosebush. *Food Qual. Pref.*, 21, 987–997.

445 Conover, W.J., 1999. *Practical Nonparametric Statistics*, Wiley, New York.

446 Crespel, L., Sigogne, M., Donès, N., Relion, D., Morel, P., 2013. Identification of relevant
447 morphological, topological and geometrical variables to characterize the architecture of
448 rose bushes in relation to plant shape. *Euphytica*. DOI 10.1007/s10681-013-0902-6.

449 Demotes-Mainard, S., Guéritaine, G., Boumaza, R., Favre, P., Guérin, V., Huché-Théliér, L.,
450 Andrieu, B., 2009. Coordinated development of the architecture of the primary shoot in
451 bush rose. In: B. Li, M. Jaeger, Y Guo (eds.). *Plant Growth Modeling, Simulation,*
452 *Visualization and Applications*. IEEE Computer Society, pp. 214-221.

453 Dijkshoorn-Dekker, M.W.C., 2002. Crop quality control system: A tool to control the visual
454 quality of pot plants. Thesis, Wageningen University, The Netherlands.

455 Dijksterhuis, G. , 1995. Assessing panel consonance. *Food Qual. Pref.*, 6, 7–14.

456 Giorgioni, M.E., 2007. Evaluation of Landscape Roses for Low-Maintenance Gardening.
457 *Acta Horticulturae*, 751, 323-330.

458 Habib, R., Triboï, E., Génard, M., & Le Bail, M., 1997. La nutrition azotée des cultures et la
459 qualité des produits. In: *Maîtrise de l'azote dans les agro-systèmes*. Paris: INRA (Les
460 colloques, no. 83). Reims (France), 19-20 novembre 1996.

461 Heuvelink, E., Tijssens, P., Kang, M.Z., 2004. Modelling Product Quality in Horticulture: an
462 Overview, *Acta Hort.*, 654, 19-30.

463 Huché-Théliér, L., Boumaza, R., Demotes-Mainard, S., Canet, A., Symoneaux, R., Douillet,
464 O., Guérin, V., 2011. Nitrogen deficiency increases basal branching and modifies the
465 visual quality of the rose bushes. *Sc. Hort.*, 130, 325-334.

466 Kawamura, K., Hibrand-Saint Oyant, L., Crespel, L., Thouroude, T., Lalanne, D., Foucher, F.,
467 2011. Quantitative trait loci for flowering time and inflorescence architecture in rose.
468 *Theor. Appl. Genet.*, 122, 661-675.

469 Morel, P., Galopin, G., Donès, N., 2009. Using architectural analysis to compare the shape of
470 two hybrid tea rose genotypes. *Sc. Hort.*, 120, 391-398.

471 Rasband, W.S., 2011. ImageJ, U. S. National Institutes of Health, Bethesda, Maryland, USA,
472 <http://imagej.nih.gov/ij/>, 1997-2011.

473 R Development Core Team, 2011. R: A language and environment for statistical computing,
474 R Foundation for Statistical Computing, Vienna, Austria, 2011, ISBN 3-900051-07-0,
475 URL <http://www.R-project.org>.

476 Rossi, F., 2001. Assessing sensory panelist performance using repeatability and
477 reproducibility measures. *Food Qual. Pref.*, 12, 467–479.

478 UPOV, 1990. Guidelines for the Conduct of Tests for Distinctness, Homogeneity and
479 Stability. Rose (Rosa L.), UPOV/TG/11/7, International Union for the Protection of New
480 Varieties of Plants, Geneva, Switzerland.

481 UPOV, 2010. Guidelines for the Conduct of Tests for Distinctness, Homogeneity and
482 Stability. Rose (Rosa L.), UPOV/TG/11/8, International Union for the Protection of New
483 Varieties of Plants, Geneva, Switzerland.

484 Figure captions

485

486 Figure 1. Measurement of the relative flower area by the morphometric methodology, with
487 ImageJ software. The colour photograph (a) is first transformed into black and white (b) and
488 the proportion of the picture area covered by the plant is calculated (0.28). A threshold is then
489 set on the colour (here, red) to separate the flowers from the foliage (c), and the proportion of
490 the picture area covered by the flowers is calculated (0.12). The relative area of the plant
491 covered by the flowers is the ratio $0.12/0.28 = 0.45$ in this case.

492

493 Figure 2. The structured nine-level scale established by the jury for the assessment of
494 floribundity by the sensory methodology. Each odd-numbered level is illustrated by three
495 examples.

496

497 Figure 3. Photographs of the 10 rosebushes (Boumaza et al., 2010) and the corresponding
498 data – used as supplementary data for validation. The numbers under each photograph
499 correspond to the relative flower area and the mean rank according to the sensory descriptors:
500 “Number of flowers”, “Flower enhancement” and “Number of floral buds”.

501

502 Figure 4. In the left column, for one plant (outdoors, 2010) per variety, we have plotted
503 changes in relative flower area (●) and in the number of open or withered flowers (▲) over
504 time. Time is shown on the x-axis (indicated by date). The left y-axis scale corresponds to
505 relative flower area and the right y-axis scale, to flower number. In the right column, the
506 relative flower area is plotted against the number of open or withered flowers, when these two
507 measurements were made on the same date. R_s denotes Spearman’s rank correlation

508 coefficient between the two measurements and n is the number of common date
509 measurements.

510

511 Figure 5. The number of open or withered flowers over time for one plant for each of the
512 varieties 'Meiburenac', 'Kolima', 'Sweet Promise' and 'Meichim'.

513

514 Figure 6. Each photograph corresponds to the maximum ratio of areas shown on the
515 corresponding graph. For this 'Meiburenac' rosebush, the maximum was 45%, with 205 open
516 and withered flowers. For this 'Sweet Promise' rosebush, the maximum was 47%, with only
517 30 flowers.

- 1 Table 1. The reference varieties of the UPOV scales for the studied characteristics: flower
 2 diameter, leaf size and number of flowers (UPOV, 1990).

Characteristics	UPOV score				
	1	3	5	7	9
Leaf: size	Meiblam	Starina	Kolima	Mullard	– Tancary
				Jubilee	– New Daily Mail
Flower: diameter	Starina	Meiburenac	Kolima	Pink	– ^a
				Wonder	
Flowering shoot: number of flowers	– ^b	Meichim	Sweet	Kolima	Meiburenac
			Promise		

- 3 ^a The variety Meinatac corresponding to a score of 9 was not found in the market.

- 4 ^b A score of 1 has not been assigned to any variety.

5

6 Table 2. Leaf dimensions: average length (mm) and confidence interval (at 95% level) of the
 7 terminal leaflet per variety. For each year, the letters indicate significant differences between
 8 the varieties (LSD method, $p < 5\%$).

Variety	2009, greenhouse				2010, outdoors			
	Number of plants	Mean	Confidence interval		Number of plants	Mean	Confidence interval	
Tancary	6	79.9	[74.7 , 85.1]	a	6	72.8	[71.4 , 74.2]	a
New Daily Mail	6	80.3	[78.1 , 82.4]	a	6	71.1	[65.1 , 77.1]	a
Mullard Jubilee	3	83.7	[74.1 , 93.3]	a	6	67.5	[61.6 , 73.4]	a
Kolima	6	48.7	[45.5 , 52.0]	b	6	53.5	[48.7 , 58.4]	b
Starina	5	34.0	[32.7 , 35.2]	c	6	30.0	[26.8 , 33.3]	c
Meiblam	5	27.1	[24.5 , 29.7]	d	6	23.4	[20.2 , 26.5]	d

9

10 Table 3. Flower diameter (mm): mean and confidence interval (at 95% level) per variety. For
 11 each year, the letters indicate significant differences between varieties (LSD method, $p < 5\%$).
 12 For Starina and Meiburenac, we considered all the flowers except the terminal ones. For Pink
 13 Wonder and Kolima, we considered all the flowers.

Variety	2009, greenhouse			2010, outdoors		
	Number of plants	Mean	Confidence interval	Number of plants	Mean	Confidence interval
Pink Wonder	6	84.8	[78.9 , 90.6] a	6	83.7	[80.3 , 87.1] a
Kolima	6	73.9	[69.6 , 78.1] b	6	82.5	[80.1 , 85.0] a
Starina	5	48.9	[46.3 , 51.5] c	6	46.5	[45.2 , 47.8] b
Meiburenac	5	47.1	[46.5 , 47.8] c	6	46.2	[44.2 , 48.3] b

14

15

16 Table 4. Number of flowers (buds, open or withered flowers) per plant at the first flowering
 17 peak. Mean values with the same letters indicate that the corresponding varieties do not differ
 18 significantly at $p < 5\%$, using non-parametric test on ranks.

Variety	2009, greenhouse			2010, outdoors		
	Number of plants	Mean (standard deviation)		Number of plants	Mean (standard deviation)	
Meiburenac	5	104.5 (30.3)	a	6	212.7 (94.2)	a
Kolima	6	23.7 (2.3)	b	6	32.7 (8.0)	b
Meichim	5	11.6 (4.9)	c	6	23.3 (13.9)	bc
Sweet Promise	6	15.2 (3.1)	c	6	17.2 (5.3)	c

19

20 Table 5. Floribundity measurements of 3 rosebushes per variety (2010, outdoors) using the
 21 sensory methodology: mean rank according to the quantity of flowers, mean rank according to
 22 the relative area occupied by the open flowers and mean score for the flowering level. Mean
 23 values with different letters indicate that the corresponding varieties are significantly different
 24 at $p < 5\%$, using non-parametric tests on ranks.

Variety	Number of measures	Mean rank (increasing order from 1 to 12)		Mean score (1 to 9 scale) for flowering level	
		Quantity of flowers	Relative area occupied by the open flowers		
		Meiburenac	48		
Kolima	48	6.9	7.0	6.7 (1.2)	b
Sweet Promise	48	4.3	4.9	4.8 (2.1)	c
Meichim	48	4.0	4.1	4.4 (2.2)	d

25

26 Table 6. Spearman correlations between the 3 sensory measurements on photographs of the
 27 plants (Table 5), the relative area occupied by the flowers measured by ImageJ and the
 28 number of flowers counted on the real plants on the days when the photographs were taken.

Measurement	(1)	(2)	(3)	(4)	(5)
Ranking: quantity of flowers	(1) 1	0.91	0.88	0.96	0.86
Ranking: relative area occupied by the open flowers	(2)	1	0.90	0.88	0.92
Score of the flowering level	(3)		1	0.83	0.90
Number of flowers on the real plants	(4)			1	0.82
Relative area occupied by the flowers (ImageJ)	(5)				1

29

Figure 1

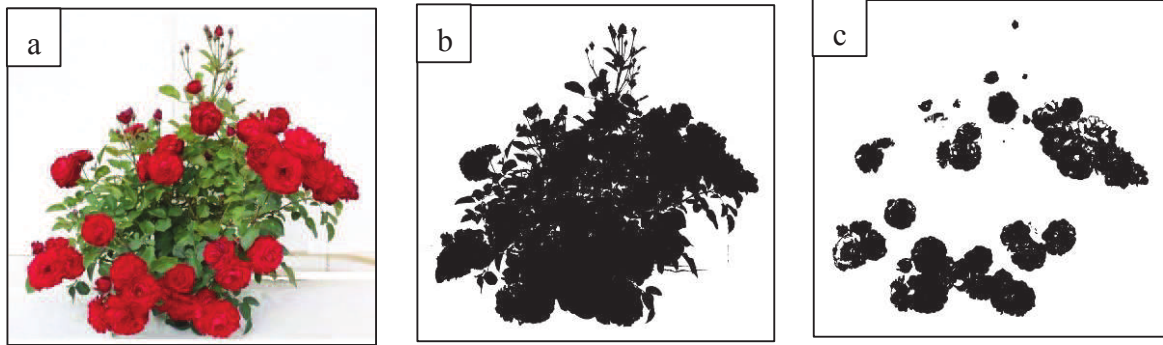
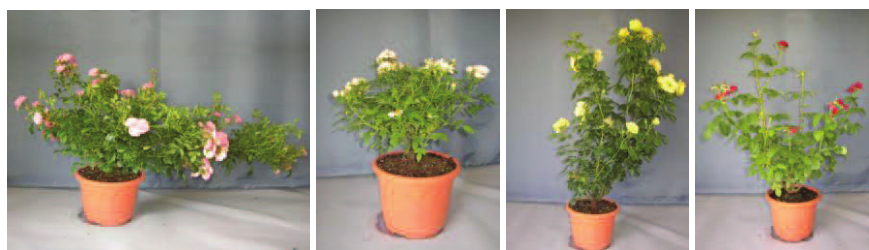


Figure 2



Figure 3



Relative flower area	0.124	0.122	0.083	0.032
No. of flowers	8.5	8.3	8.2	5.5
Flower enhancement	5.6	7.0	7.1	5.8
No. of buds	8.0	5.5	4.3	1.9



0.024	0.021	0.020	0.015	0.004	0.001
5.3	2.9	2.8	6.2	4.6	2.8
3.5	6.3	6.7	5.9	4.5	2.7
8.8	2.7	3.2	6.9	8.1	5.6

Figure 4

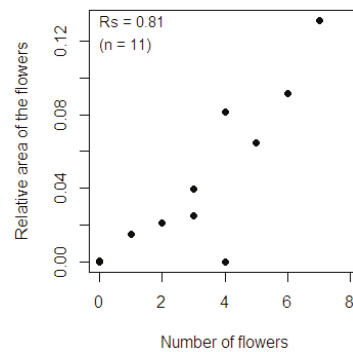
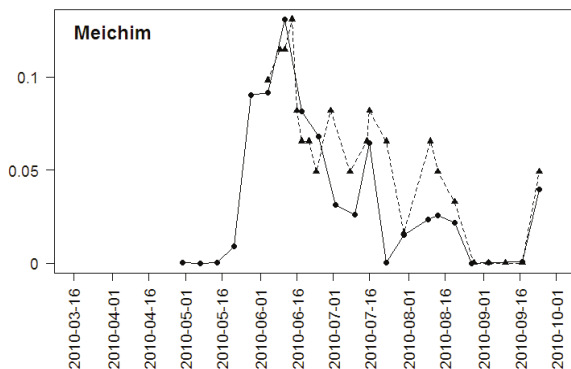
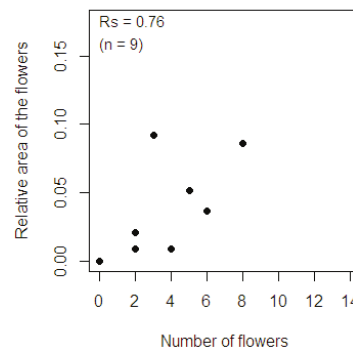
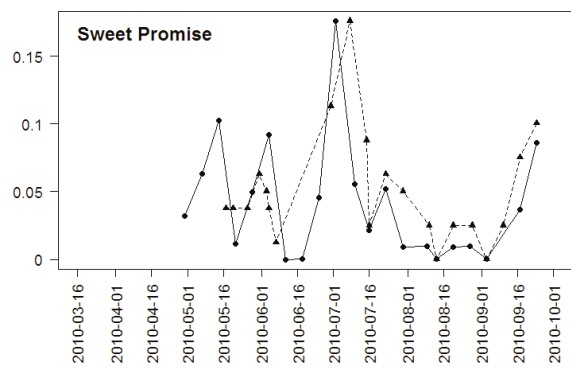
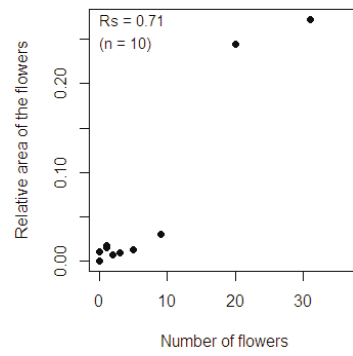
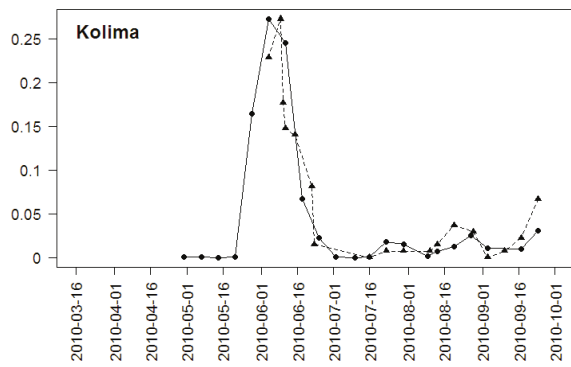
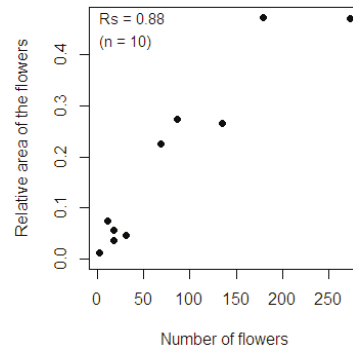
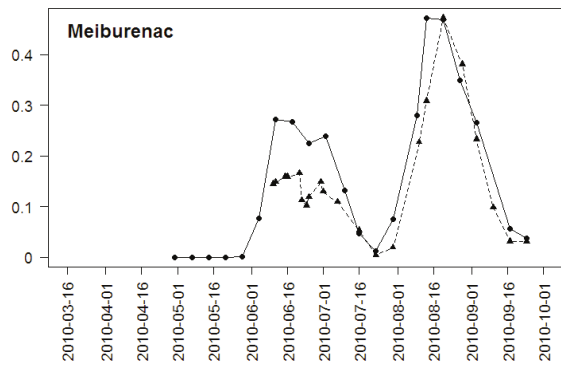


Figure 5

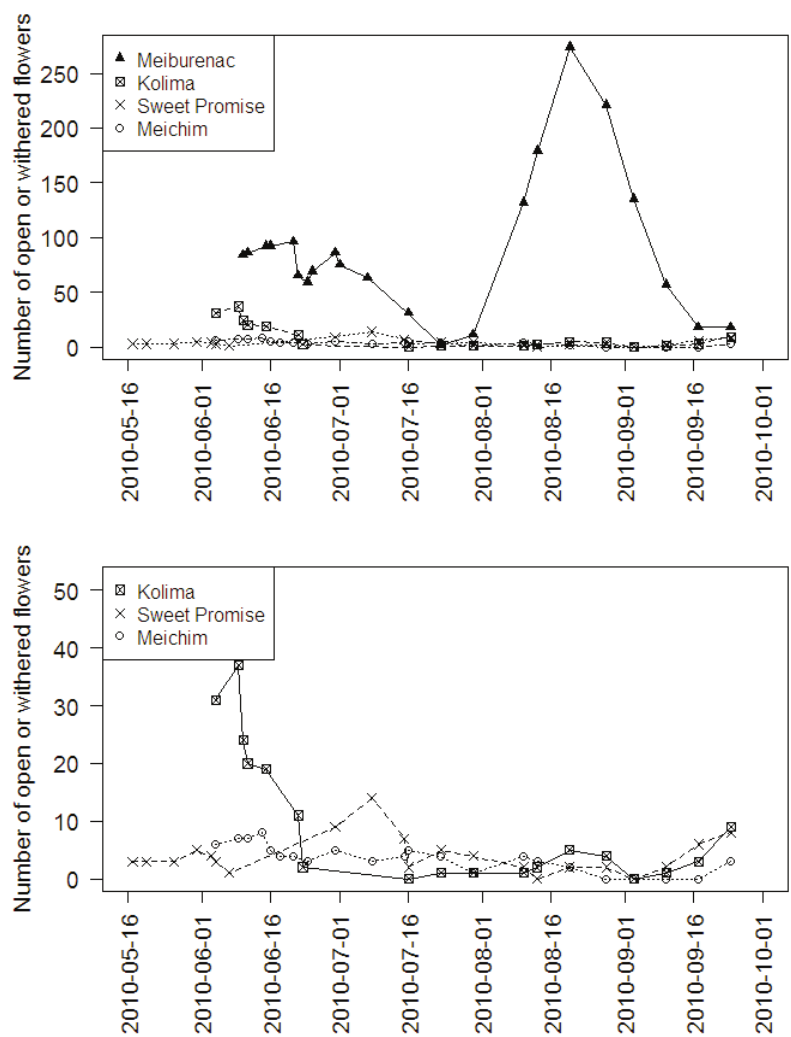


Figure 6

