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

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ABSTRACT

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

Keywords

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

Abbreviations

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

1 Introduction

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

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

Floribundity is defined as “the capacity of a plant to produce abundant flowers at high density on each of its branches” (http://fr.wiktionary.org/, 10/11/2012). However, should we take into account the number of flowers at peak flowering or throughout the year? In its guidelines, UPOV specifies that all observations should be made when the plant is in full flower (UPOV, 2010). Hereafter, we refer to this measurement as the peak floribundity index. The longitudinal floribundity index is the variation of the floribundity index during a season. Another related question concerns the stage at which flowers should be counted. Should we count all flowers, regardless of their stage of development (buds, opened, withered, rose hips) or only fully opened flowers? If we focus on the vitality of the plant, it would be tempting to consider all the flowers. However, if we are more concerned about visual quality, we may wish to restrict the flower count to opened flowers – that is, flowers with visible petals – and rosehips. Indeed, these two types of organ are brightly coloured and stand out from the foliage of the rosebush, which is usually green once the leaves have fully emerged. The peak floribundity index reported here takes into account all flowers but not the rosehips, whereas the longitudinal floribundity index takes only open flowers into account. We characterised floribundity by three types of methods or methodologies: the morphometric methodology, the sensory methodology and the UPOV methodology. The flower and leaf dimensions were characterised by the morphometric and UPOV methodologies.

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

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

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

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

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

The aim of this study was, therefore, to compare these three methodologies. We evaluated floribundity, and the flower and leaf dimensions of UPOV reference roses, and then compared the results obtained and considered the advantages and disadvantages of each methodology. For validation of some of the findings of these comparisons, we also considered the data obtained for rosebushes by Boumaza et al. (2010), referred to hereafter as supplementary data.

2 Materials and Methods

2.1. Plant material and growing conditions

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

2.1.1. Growing conditions in the greenhouse

In November 2008, 60 rosebushes (6 per variety) were planted in 7-litre pots, in a substrate composed of peat, coconut fibre and perlite (60/30/10, v/v/v). The pots were randomly placed on a shelf in six rows, 0.75 m apart and then pruned. The plants were drip fertiirrigated with a liquid fertiliser (Servital®, with a 3–2–6–0.6 balance of N–P_2O_5–K_2O–MgO, a pH of 5.8 and a mean electrical conductivity (EC) of 1.8 mS cm^{-1}, including the EC of water, which was 0.3 mS cm^{-1}). Each plant received between 330 mL of solution every two days in winter and 1330 mL per day in summer. Pests and diseases were controlled. Additional lighting (60 µmol m^{-2} s^{-1} of photosynthetically active radiation) was provided by sodium vapour lamps when total radiation levels outside the greenhouse fell below 200 W m $^{-}$

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

2.1.2. Outdoor growing conditions

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

2.2. Morphometric measurements

2.2.1. Leaves

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

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

2.2.2. Flowers

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

The numbers of flowers (buds, open and withered flowers) were counted on the rosebushes of the UPOV reference varieties for flower number (‘Meichim’, ‘Kolima’, ‘Sweet Promise’ and ‘Meiburenac’) during the first flowering period, on days determined according to plant development, generally when withered flowers were observed on the rosebush. Almost all the replicates of the varieties used for floribundity measurements in the greenhouse (in 2009) and a single rosebush per variety outside (in 2010 and 2011), were photographed, about once per week. The relative flower area, that is the ratio of the area covered by flowers to that covered by the entire plant (Figure 1), was determined with ImageJ (Rasband, 2011). This ratio and the number of flowers were considered as floribundity indices.

2.3. Sensory measurements

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

2.4. Supplementary data

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

2.5. Statistical analyses

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

3 Results

3.1. Leaf dimensions

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

3.2. Flower dimensions

The diameters of the terminal flowers were found to be significantly greater than those of the other flowers for the 'Starina' and 'Meiburenac' varieties. We therefore excluded the terminal flowers of plants of these two varieties from the calculations of mean diameter, as recommended by UPOV (1990). By contrast, for ‘Pink Wonder’, we found no difference between the diameters of terminal and non-terminal flowers, and the difference between these two types of flowers was very small for ‘Kolima’. Hence, as fewer data were available for these two varieties, we considered all the flowers, both terminal and non-terminal, in the calculation of mean flower diameter.

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

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

3.3. Floribundity

3.3.1. Number of flowers

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

3.3.2. Sensory data

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

For each of the three previous sensory evaluation tests (classification by number of flowers, area of the photograph covered by flowers and scores for flowering level), comparisons of varieties gave identical results (Table 5), confirming the UPOV classification for the number of flowers per flowering branch: few (with ‘Meichim’ as the reference variety), medium (‘Sweet Promise’), many (‘Kolima’) and very many (‘Meiburenac’). Thus, the perception of floribundity by the human eye is entirely consistent with UPOV measurements.

3.3.3. Morphological measurements and their relationship to sensory data

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

3.3.4. Longitudinal floribundity

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

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

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

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

3.3.5. Supplementary data

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

4 Discussion

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

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

Based on the measurement protocol proposed by UPOV and specified in the materials and methods section, the use of value classes, corresponding to the UPOV scores for terminal leaflet length or flower diameter, would greatly simplify the evaluation of leaves or flowers by the sensory methodology. We initially planned to define such classes on the basis of the mean characteristics (terminal leaflet length and flower diameter) of the UPOV reference classes. Despite the high degree of consistency of the mean characteristics obtained in different growing conditions, the results obtained raise questions about this approach, in that the varieties did not behave in the expected manner. The 1990 UPOV reference varieties do not appear to be appropriate for the constitution of these classes, because there was insufficient discrimination between the reference varieties, particularly for flower diameter. Two alternative strategies are possible. The first would involve repeating the experiments with the 2010 reference varieties (UPOV, 2010), checking that the relative behaviour of these new reference varieties matched UPOV descriptions and determining whether these classes of values could be considered valid for the Angers region. Given the cost of the experiment, an alternative strategy, based on arbitrarily fixing five classes on the basis of the lengths or diameters reported in tables 2 and 3, respectively, might be preferable. We chose to use the same number of classes as the UPOV protocol: very small, small, medium, large, and very large. For example, in outdoor conditions, the classes for terminal leaflet length could be <25 mm (very small), 25-40 (small), 40-55 (medium), 55-70 (large), >70 mm (very large); those for flower diameter could be <50 mm (very small), 50-65 (small), 65-75 (medium), 75-90 (large), >90 mm (very large). These empirically and somewhat arbitrarily defined classes have the advantage of simplicity and are suitable for use in the Angers region. However, they are not valid for all conditions, because the upper limits of the very small and large classes defining the limits of the three central classes, are not exactly the same in the greenhouse and outdoors.

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

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

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

Morphometric methods are less subjective than sensory methods, although flower counting may be tedious. By contrast, the relative flower area on a photograph proved to be a suitable indicator of the level of flowering of the plant perceived by an observer. However, this measurement does not match the definition of floribundity, in that two rosebushes may have equivalent ratios but very different numbers of flowers. For example, figure 6 shows two rosebushes: 'Sweet Promise' and 'Meiburenac', corresponding to the "medium" and "very many" categories of the UPOV (1990) scale. Their peak flowering area ratios were 45%, with 30 flowers, for the 'Sweet Promise' rosebush and 47%, with 205 flowers, for the 'Meiburenac' rosebush. This problem can be alleviated, for example by dividing the ratio by an estimate of the area of a flower from the corresponding variety. The advantage of this approach is that the calculation of ratios from photographs can be automated, and this would accelerate the analysis, provided that all the photographs analysed were taken in good lighting conditions. This is a necessary condition to ensure that the colour of the flowers is reproduced accurately on the photograph. Another advantage of this approach is that it is not necessary to photograph the entire rosebush, as this measurement is a ratio that could be estimated on the basis of a photograph of the heart of the rosebush alone. Image analysis would therefore be a useful tool for estimating floribundity and changes in floribundity over time.

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

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

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

5 Conclusion

We compared the results of morphometric and UPOV methodologies for classifying varieties on the basis of flower diameter and leaf dimension, and we identified several discrepancies. We also compared these two methodologies with sensory methodology for floribundity assessment. Our analysis highlighted a convergence of the results obtained with the various methods and suggested that it should be possible to assess floribundity as perceived by the human eye, by image analysis techniques. The main advantages of image analysis methods over sensory methods are their rapidity and universal nature. Such methods, which would be relatively simple to carry out, might prove very useful for quantitative and objective measurements on large samples. This method would therefore be useful for studying processes such as the progression of flowering, which is currently being studied in relation to the genetic determinism of flowering (Kawamura et al., 2011) and is of interest to rose breeders for the assessment of new cultivars.

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Figure captions

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

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

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

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

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

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

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

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

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

[a] The variety Meinatac corresponding to a score of 9 was not found in the market.

[b] A score of 1 has not been assigned to any variety.

Table 2. Leaf dimensions: average length (mm) and confidence interval (at 95% level) of the terminal leaflet per variety. For each year, the letters indicate significant differences between 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

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

Table 4. Number of flowers (buds, open or withered flowers) per plant at the first flowering peak. Mean values with the same letters indicate that the corresponding varieties do not differ 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

Table 5. Floribundity measurements of 3 rosebushes per variety (2010, outdoors) using the sensory methodology: mean rank according to the quantity of flowers, mean rank according to the relative area occupied by the open flowers and mean score for the flowering level. Mean values with different letters indicate that the corresponding varieties are significantly different 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	10.8	10.0	7.8 (1.0)	a
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

Table 6. Spearman correlations between the 3 sensory measurements on photographs of the plants (Table 5), the relative area occupied by the flowers measured by ImageJ and the 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

Figure_1

Figure 1

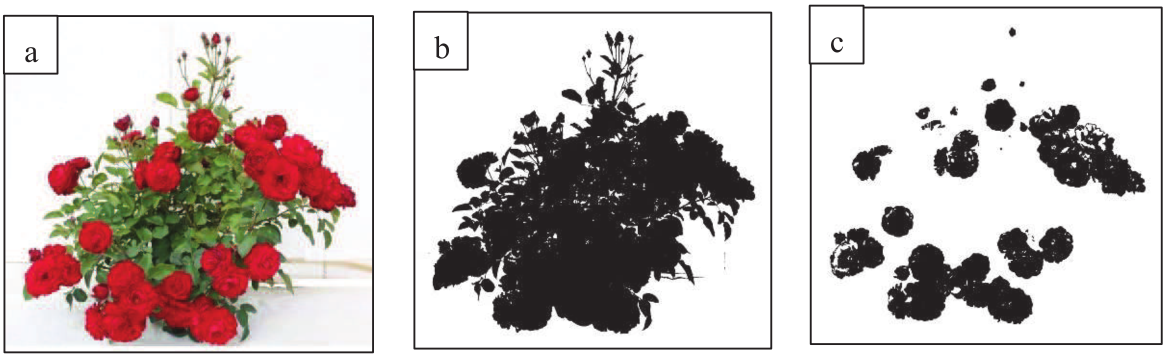


Figure_2

Figure 2

Figure_3

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 4

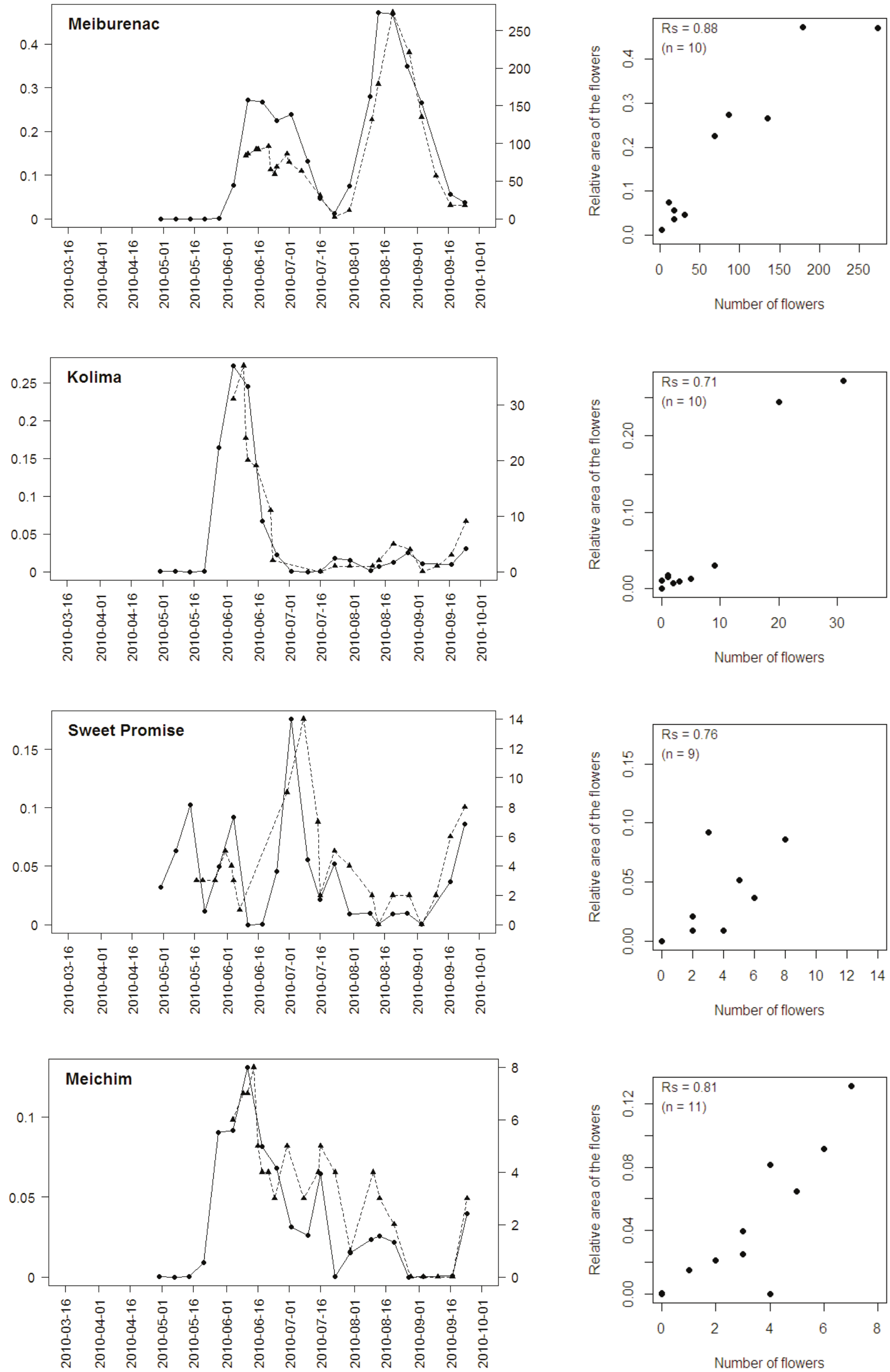
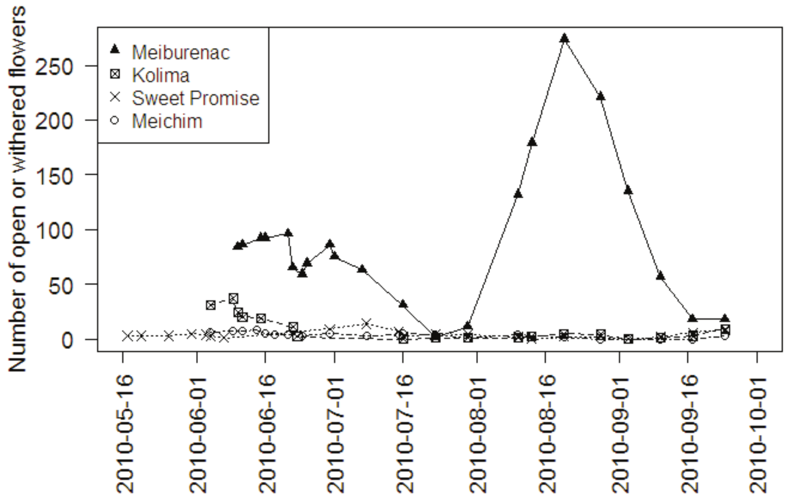


Figure_5

Figure 5



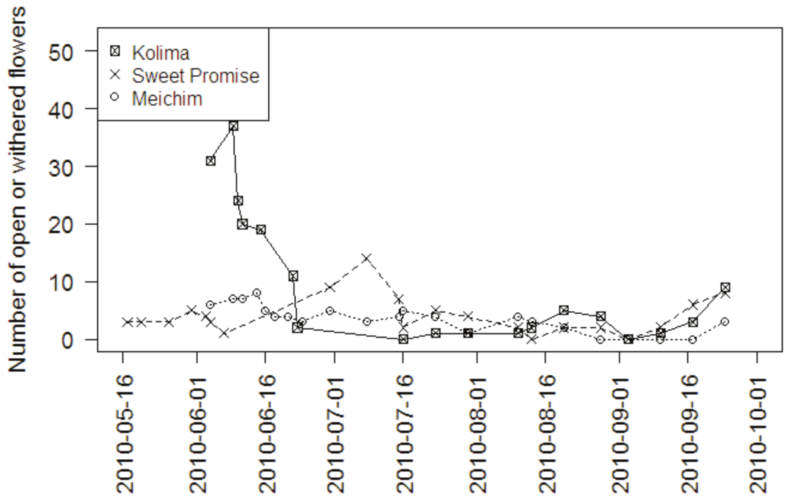


Figure_6

Figure 6