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Preliminary results on the use of a modified point quadrat method for estimating canopy structure of grapevine training systems

by

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S u m m a r y : The reliability of a modified point quadrat method designed to describe the structure and seasonal canopy dynamics of the training systems simple curtain (SC) and traditional spur-pruned cordon (SPC) was tested in a two-year study. The method relies upon an unbiased sampling procedure as each canopy insertion is first identified within a ground-projected area by a random number generation routine (RND). From each insertion, the height of each contact with either leaves or clusters is then recorded along the vertical axis. Although the method suffered from a somewhat low percentage of effective insertions early in the season, the total leaf area-to-surface area ratio and the leaf layer number calculated for both canopy types are in accordance with those reported by others for high vigour canopies. Canopy dynamics showed an asymmetric growth in the SC starting at bloom. Both trellises resulted in similar canopy density indices and a high correlation was found between total leaf area and total number of leaf contacts.

K e y w o r d s : Vitis vinifera L., leaf area, training system, canopy density, canopy shape.

Introduction

Every grapevine training system displays a typical canopy structure, which in turn determines the microclimate within the canopy profile. Many biological processes of the utmost importance (total vine photosynthesis, bud differentiation, fruit ripening, and wood maturity) are thus closely related to seasonal canopy development. Also, the application of specific management operations (e.g. shoot topping and positioning, leaf removal) can modify the canopy of differently trained vines. The scorecard proposed by Smart *et al.* (1985) enables a visual assessment of various grapevine canopies on an index of 8 characters to which are assigned a maximum of 10 points each. Accordingly, a high score should ideally correspond to canopies with adequate gaps, low leaf layer number (LLN) and high cluster exposure. In a few cases canopy density has been estimated using indices like total leaf area-to-exposed canopy surface area (LA/SA) or LLN, parameters that have also been used for correlations with yield and quality (Smart 1985; Intrieri 1987; Smart and Robinson 1991). Canopy assessment in grapevine has also been attempted via the "point quadrat" method developed by Levy and Madden (1933) and then extensively used for non-destructive estimation of foliage area index and inclination in grassland or other low-growing crops (Warren Wilson 1960; 1965). On vertical grapevine canopies, measurements have been taken by horizontally inserting a metal rod into the fruit zone using a grid pattern and then by recording contact points with leaves and clusters for each insertion to determine percent gaps, leaf layer number and percentages of interior leaves and fruit (Smart and Smith 1988).

The aim of the present study was to test the validity of a modified point quadrat method employing an unbiased random sampling to describe canopy structure and dynamic changes of two grapevine training systems that are becoming widespread in northern and central Italy.

Materials and methods

The trial was carried out in 1994-95 at the Settefonti experimental vineyard (Bologna, 44°52' N) on five-year-old Chardonnay/SO4 vines trained to simple curtain (SC) and traditional spur-pruned cordon (SPC). The scheme of the two training systems is reported in Fig. 1. Two vines with good wood maturity from previous season's growth

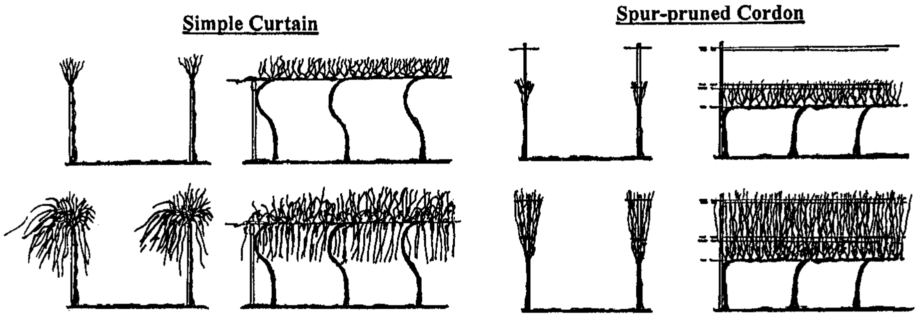

Fig. 1: Cross sections and front views of vines trained to a simple curtain (SC) and a spur-pruned cordon (SPC).

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were chosen for each system in the middle row of N-S oriented panels. Row x vine spacing was 2 m x 1.5 m (SC) and 2.5 m x 1.5 m (SPC). Bud load was adjusted to 12-14 nodes/m of canopy in both trellises. Each year the vines were allowed to develop fully until bloom, then shoot topping was applied on the same day to both trellises so as to leave 12-14 mature leaves on the main shoot. Lateral growth was left undisturbed throughout the season.

Measurements began in late May when canopy filling was visually estimated to be around 30-40 %. To assure an unbiased random canopy sampling, 40 sampling points per vine were first identified on the soil surface within a hypothetical projected area at full canopy of 160 cm row cross section width (X) and 120 cm row length (Y) using a random number generator routine (RND) (MC LAUREN and MARSAGLIA 1965; WHEELER 1976). This generator assures randomness for each number in the series of 40 and, in this particular case, the RND had a starting seed of 37480660.

The size of the assumed ground projected canopy area (1.92 m^2) was the same for both training systems to warrant equal sampling density per unit of soil surface. A width of 160 cm (80 cm off both sides from the row axis) was chosen to account for the wider canopy of the SC vines with its free hanging shoots; 120 cm canopy length (30 cm shorter than vine distance in the row) was set to minimize effects of canopy discontinuity which can occur as a result of cordons slightly shorter than vine distance within the row.

Measurements were taken 5 and 4 times during the season in 1994 and 1995, respectively. On each date, the height (Z) of each leaf and cluster detected by a telescopic probe along the vertical axis starting from each random point on the soil surface was recorded with a yardstick. The relative position of each organ (either leaf or cluster) within the canopy volume was thus precisely identified by 3 coordinates (X,Y, Z). Contacts with cordon, stems, petioles and peduncles were ignored as in a previous application of the original method (SMART 1985). Insertions not resulting in any contact were classified as "gaps" if they occurred within the range of the maximum and minimum X contact values.

The LLN was calculated as the ratio between the total number of leaf contacts and the total number of insertions that produced either leaf contacts or gaps. To estimate the total leaf area of each 1.2 m-canopy section, the total number of unfolded main and lateral leaves (minimum midrib length of 3 cm) was recorded on each date and multiplied by the mean leaf area determined with a LI-COR 3100 area meter on a sample of 30 leaves per leaf type taken from extra vines. Sampling of these leaves was performed using basal, median and apical shoot zones to account for variation in leaf size along the shoot. The exposed canopy surface area (SA) per unit row length (1.2 m) was calculated for each date on the basis of the distance between the maximum and minimum X, thereby producing at least one leaf contact (canopy width), and the distance between the lowest and the highest contact (canopy height). The canopy surface facing downwards was not included in this calculation.

At the last 1994 measurement, leaves were stripped off the vines and then counted to determine with increased accuracy the percentage of natural defoliation for main and lateral shoots. Leaf stripping was not performed in 1995 measurements since no defoliation had occurred on lateral shoots and the defoliation of main shoots was visually assessed to be less than 5 % in both systems.

In 1995 leaf inclination (angle between the perpendicular to the leaf surface and the vertical) was also recorded for any leaf contact in one of the two vines chosen for each trellis. Being limited to a single vine per system, these data are to be regarded as a preliminary assessment of the leaf inclination pattern. The vertical sampling chosen in this study may in fact underestimate leaf density in erect-leaved species and overestimate the contribution of species having more nearly horizontal leaves. Inclination was measured directly by holding a protractor, fitted with a levelling device, against the steepest part of the lamina. Care was taken not to modify leaf position during inclination measurements. The resulting data were then grouped into 6 frequency classes with an inclination range of 15 °.

Results and discussion

S i m p l e c u r t a i n (S C) : The total number of leaf contacts were significantly correlated (r = 0.89; $p \leq 0.01$) with the estimated total leaf area for data pooled over the two years (Fig. 2 A). In general, the total number of leaf and cluster contacts increased over the season (Tab. 1), although the latter was too low to allow an estimate of relative light exposure (percent interior *vs* exterior clusters).

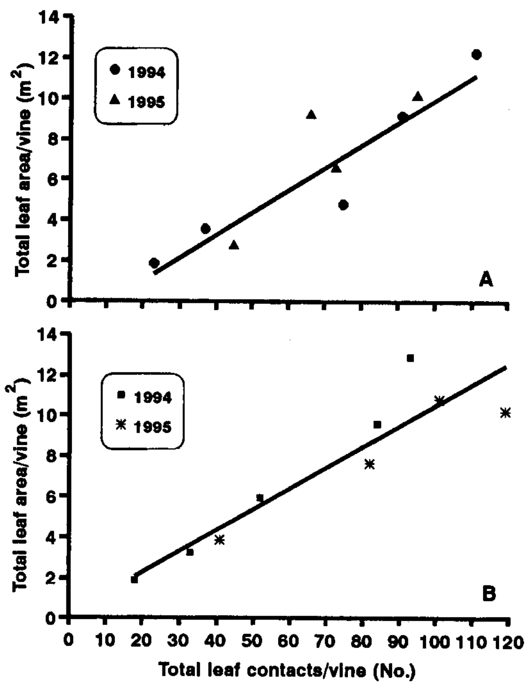

Fig. 2: Correlation between total number of leaf contacts and total leaf area per vine for the SC (A) and SPC (B). Data were pooled over the two growing seasons.
Linear equations are: y = -1.191+0.116x, r = 0.89 (SC) and y = 0.232+0.103x, r = 0.899 (SPC).

Table 1

Precision of sampling and canopy parameters estimated for an SC trellis in 1994-95. Data represent means of two vine-replicates

	1994					1995			
	30 May	7 June	14 June	8 July	4 September	26 May	10 June	23 July	7 September
Effective insertions(%)[1]	30	60	60	53	64	66	59	60	61
Leaf contacts	23	37	75	91	111	45	73	95	66
Cluster contacts	1	3	5	7	9	1	3	3	-
Gaps (%)	17	32	0	0	0	41	4	4	8
LLN	2.0	1.5	3.1	4.3	4.3	1.7	3.1	4.0	2.7
LA (m^2)	1.88	3.59	4.83	9.21	12.30	2.82	6.66	10.23	9.29
SA (m^2)	1.60	3.05	2.73	4.04	5.34	3.15	4.03	4.55	4.56
LA/SA	1.2	1.2	1.8	2.3	2.3	0.9	1.7	2.3	2.0

[1] Calculated as percent of total insertions per vine (40) resulting in any contact or canopy gap.

In 1994 the percentage of canopy gaps, calculated over the two vine replicates, was 17 on the first day of sampling (30 May), peaked at 32 on 7 June and was nil for the rest of the season. The gap percentage of the first date is in accordance with the relatively low LA/SA ratio (1.2), but it is also associated with a LLN of 2, which seems to be unseasonably high (Tab. 1). This LLN value may be overestimated since sampling precision on this date was lower due to the still limited canopy size (only 12 of 40 insertions produced contacts or gaps while the remaining ones were off target), although it could also be the result of the spatial location of the free-growing SC shoots which at this stage are still erect and enclosed in a limited canopy volume. In the latter case, the high LLN would primarily result from leaf distribution tending to overlap along the vertical canopy profile. The next date resulted in an even higher gap percentage (32) and in a reduced LLN (1.5).

Both responses can be explained by considering the seasonal canopy dynamic reported in Fig. 3. The absence of supporting wires let the SC shoots bend progressively downwards as the clusters get heavier and hence, the SC trellis widens, so occupying a large volume and masking the increment of leaf area. Proof of this effect is found in the LA/SA ratio calculated for 7 June, which was the same as for the previous date despite a doubling in total leaf area. However, an important feature of the SC canopy is the asymmetric growth habit caused by the cordon's rotation around the supporting wire (Fig. 3). Asymmetry was first observed on June 7 and is frequent in young vineyards trained to SC but tends to be reduced in older vine-

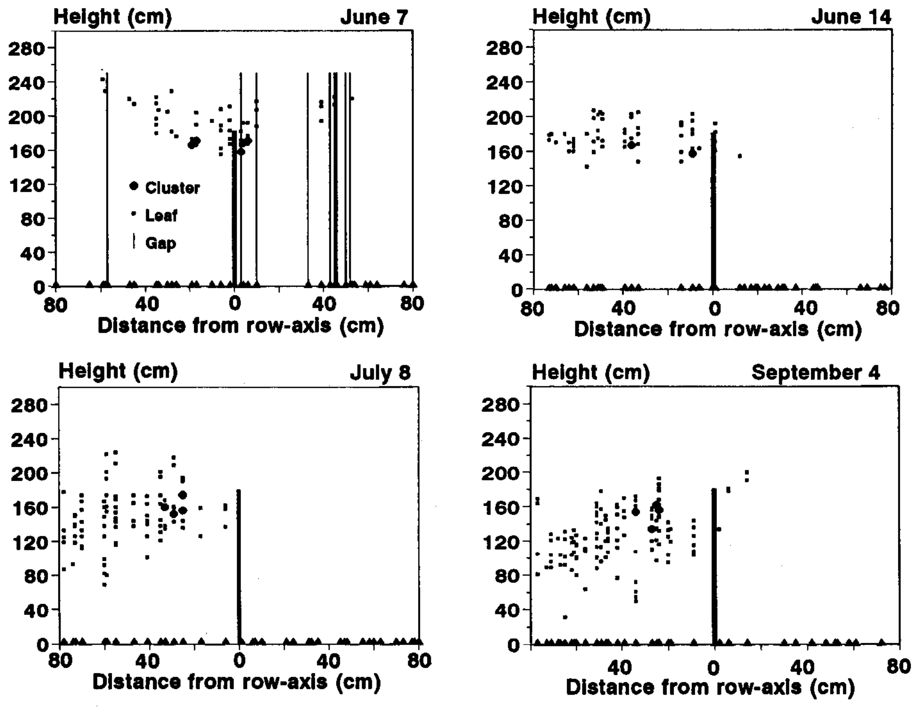

Fig. 3: Seasonal canopy dynamic (cross-section view) of a SC-trained vine in 1994. Symbols on the x axis indicate the distance of each random insertion from the row axis.

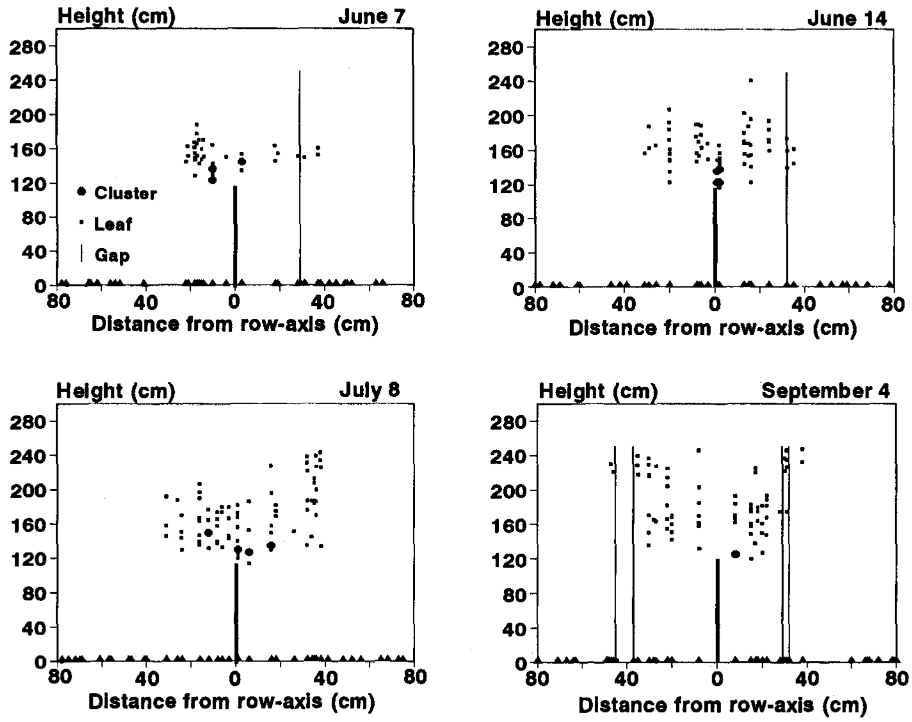

Fig. 4: Seasonal canopy dynamic (cross-section view) of a SPC-trained vine in 1994. Symbols on the x axis indicate the distance of each random insertion from the row axis.

yards where the bigger cordon size may prevent its rotation. Starting from 14 June and for the two remaining dates, both SC-trained vines evinced an asymmetric canopy without gaps (Tab. 1). Furthermore, LLN increased along with the LA/SA ratio to a final value of 4.3, which clearly exceeds the limit of 2 generally considered optimum for both high sunlight capture and adequate cluster exposure for good quality and good spray penetration (SMART 1985; INTRIERI 1987; LAKSO 1993). Thus, the asymmetric canopy growth in the SC trellis represents a negative characteristic since it leads to a much higher canopy density than expected with symmetrical growth and, as a consequence, to a reduced exposed functional leaf area per gram of fruit (WEAVER 1963; PONI *et al.* 1994).

Many of the characteristics of SC canopy growth seen in 1994 were confirmed the next season (Tab. 1) when faster canopy filling occurred, as shown by almost twice the leaf contact number recorded at the end of May. As in 1994, maximum gap percentage occurred when growth of both experimental vines started to proceed downwards, while still being symmetrical, with at least some shoots growing on each side of the row. Then, from 10 June onward, an asymmetric canopy shape set in, causing a drastic reduction of canopy gaps and an increase in LLN (Tab. 1). In 1995, total number of leaf contacts and LLN markedly decreased by September, although total leaf area was only slightly reduced and sampling precision almost equal (60 % contacts out of a total of 40 insertions) to that of the previous date. Because of the early ripening of Chardonnay the September measurements were taken after harvest and the absence of a crop probably loosened the canopy, as indirecly confirmed by the increased percentage of gaps. In addition, data reported in Fig. 5 A showing the distribution of leaf inclination over the season for SC indicate a tendency of the leaf lamina to bend downward, thereby assuming steep angles (75-90°). Since our method implies a vertical canopy sampling, leaf contacts can be underestimated in canopies where the fraction of erect leaves is high. This may have been the case for the final 1995 measurements.

S p u r - p r u n e d c o r d o n (S P C) : A close linear correlation ($r = 0.90$, $p \leq 0.01$) between total number of

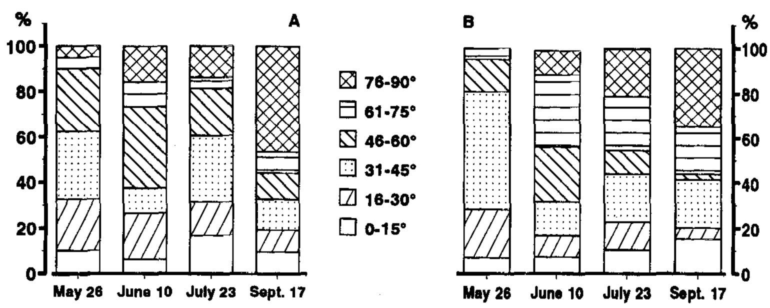

Fig. 5: Leaf angle distribution recorded on a SC- (A) and a SPC-trained vine (B) at 4 sampling dates during the 1995 growing season. Sample sizes (number of leaves) for subsequent dates were 37, 64, 102, 52 for SC, and 42, 93, 111, 82 for SPC.

Table 2

Precision of sampling and canopy parameters calculated for a SPC trellis in 1994 and 1995. Data represent means of two vine-replicates

	1994					1995			
	30 May	7 June	14 June	8 July	4 September	26 May	10 June	23 July	7 September
Effective insertions (%)[1]	30	40	41	51	77	29	50	65	79
Leaf contacts	18	33	52	84	93	41	82	119	101
Cluster contacts	1	2	3	7	5	0	2	5	-
Gaps (%)	17	3	3	5	12	0	10	16	18
LLN	1.5	2.1	3.2	4.1	3.0	3.5	4.1	4.6	3.2
LA (m^2)	1.88	3.25	5.95	9.60	12.88	3.87	7.66	10.23	10.80
SA (m^2)	1.86	2.19	3.47	3.92	4.45	3.27	4.29	4.22	4.37
LA/SA	1.0	1.5	1.7	2.4	2.9	1.2	1.8	2.4	2.5

[1] Calculated as percent of total insertions per vine (40) resulting in any contact or canopy gap.

leaf contacts and estimated total leaf area at varying dates was found for the data pooled over 1994-95 (Fig. 2 B). Similarly to SC, the number of cluster contacts recorded during the season was inadequate to assay cluster exposure. Sampling precision in both years increased steadily over the season, being proportional to progressive canopy growth and density (Tab. 2). In 1994 the percentage of canopy gaps was highest early in the season (17 %), decreasing thereafter with a progressive increase in canopy density as demonstrated by the steady enhancement of LLN and the LA/SA ratio (Tab. 2). The LA/SA peaked at 2.9 by September, indicating a higher density than that of SC, although on the same date LLN had decreased and gap percentage increased as compared to earlier samplings. The moderate increase in the total number of leaf contacts as compared to the significant gain in total leaf area from July to September may also depend on the balance between late-season lateral growth and precocious defoliation of shaded, basal main shoot zones, quantified as 47 % leafless nodes. The combination of these phenomena could have resulted in a higher number of small-sized leaves (laterals developed mainly after main shoot topping) and in a markedly reduced number of large, basal main shoot leaves. The probability of contacts within the canopy might thus have been decreased despite the larger total leaf area. Another important feature of the spur-pruned cordon for the 1994 growing season was that canopy gaps generally occurred in the exterior of the canopy, indicating a concentration of foliage in the inner part of the system which was evident already early in the season (Fig. 4).

Some canopy characteristics of the spur-pruned vines reported for 1994 were also observed the next season. Total number of leaf contacts increased up to the end of July along with LLN (Tab. 2). The absence of canopy gaps on the initial date of measurements may again result from insufficient sampling precision (only 29 % of total insertions produced either contacts or gaps), although it is in accordance with an early canopy filling. Canopy gaps recorded later in the season occurred mostly at the canopy exterior, which confirmed the 1994 results. Similarly to the findings for the SC, total leaf contacts were fewer at the last sampling date, as compared to the previous recording, despite a slight increase in total leaf area (Tab. 2). This pattern again would be related to crop removal and steep leaf angles causing a less compact canopy late in the season (Fig. 5 B). Maximum values of LLN calculated over the two-year period for SPC were close to those reported by SMART and ROBINSON (1991) for a high density vertical trellis of Traminer, despite the different sampling direction and the lower number of effective insertions per vine.

Conclusions

There are several remarks to be made regarding advantages and weaknesses of this method of canopy structure assessment after the two-year period. Random sampling and analysis of canopy dynamics are the major improvements of the method as compared to pioneer work on grapevine by SMART *et al.* (1985), whose technique of point quadrat usually concentrates most of the insertions at the fruit zone. Analysis of seasonal canopy dynamics in the present study provided information on canopy development that cannot be inferred from maximum LLN or LA/SA alone. The density of the SC trellis was elevated only when the canopy had a totally asymmetric shape. Before that, the system was associated with a very high percentage of canopy gaps and low LA/SA ratios. To achieve even distribution of growth throughout the season, adjustments in trellising have been studied and a coiled wire has been used to prevent rotation of the cordon on young vines (INTRIERI and PONI 1995). Research is also in progress to verify the degree of natural upright growth of specific cultivars, which could help to distribute growth evenly on both row-sides.

Sampling precision is low early in the season when canopy size may be considerably smaller than the ground-projected sampling area. This effect may be more pronounced in restrictive canopy training systems like the spur-pruned cordon, although in the present study it was also found in the simple curtain, typically presenting a natural vertical growth habit early in the season. However, the SC trellis also showed a fairly high rate of off-target insertions later in the season, primarily as a result of the asymmetric canopy shape. When such situations are expected to occur, an increase in the total number of insertions or an adjustment in the size of the projected sampling area should be considered. Future applications of the method should also investigate variability of results under different insertion angles.

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