

DEVELOPMENTAL FACTORS AFFECTING ROSA AXILLARY SHOOT DEVELOPMENT: I. EFFECT OF PRUNING POSITION AND LEAF REMOVAL ON AXILLARY SHOOT DEVELOPMENT

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Abstract

The interaction between the node position to which a stem was cut, leaf removal and time of year on subsequent total axillary, flowering, blind, and self-pinched shoot development on *Rosa* was studied. *Rosa x hybrida* L. cvs 'Royalty' and 'Lovely Girl' plants in an established canopy were cut back to node 1, 3, 5, 7, 9, 11, or 13 from the base of the stem at harvest, which coincided with the reflexing of the outermost flower petal. No leaves, the most distal node leaf only, or all leaves on the immediate shoot were removed at harvest. The experiment was conducted in the fall (10 moles irradiance day⁻¹) and spring (20 moles irradiance day⁻¹). Axillary shoot number on Lovely Girl and Royalty increased from 1.7 to 2.6 and from 1.5 to 4.5 shoots, respectively, as node position increased from 1 to 13. Blind shoot number did not decrease on Lovely Girl but increased on Royalty from 0.7 to 1.2 as node position increased from 1 to 13 across time of year. Flower number increased across cv and time of year from 0.5 to 2.6 as node position increased from 1 to 13 when no leaves were removed. Removal of all leaves at pruning decreased axillary shoot number on Royalty and flower number on Lovely Girl and Royalty. Removal of all leaves increased blind shoot number on Lovely Girl. Pruning in spring versus fall resulted in fewer axillary and blind shoots, but more flowers per stem.

Introduction

Greenhouse cut rose (*Rosa x hybrida* L.) production is characterized by continuous flower production via terminal flowers arising from lateral shoots (Zieslin and Moe, 1985). Cut rose sales vary during the year. In order for commercial greenhouses to maximize sales and profit, production must vary throughout the year as well. U.S. sales are greatest during the fall, winter, and spring and have a peak prior to Valentine's day.

The rose stem is characterized by three distinct zones (Figure 1) (Zamski et al., 1985). The first zone is located at the base of the stem (nodes 1-4) and is characterized by the presence of bud scars of abscised bud scales, by nodes which are subtended by scale-like leaves, bladeless petioles, and leaves which are composed of 1 to 3 leaflets. The second zone is located in the middle of the stem (nodes 4-8) and is characterized by nodes subtended by leaves composed of 5-7 leaflets. The third zone is located at the top of the stem (nodes 8-13) and is characterized by the presence of leaves composed of 1-3 leaflets or scales.

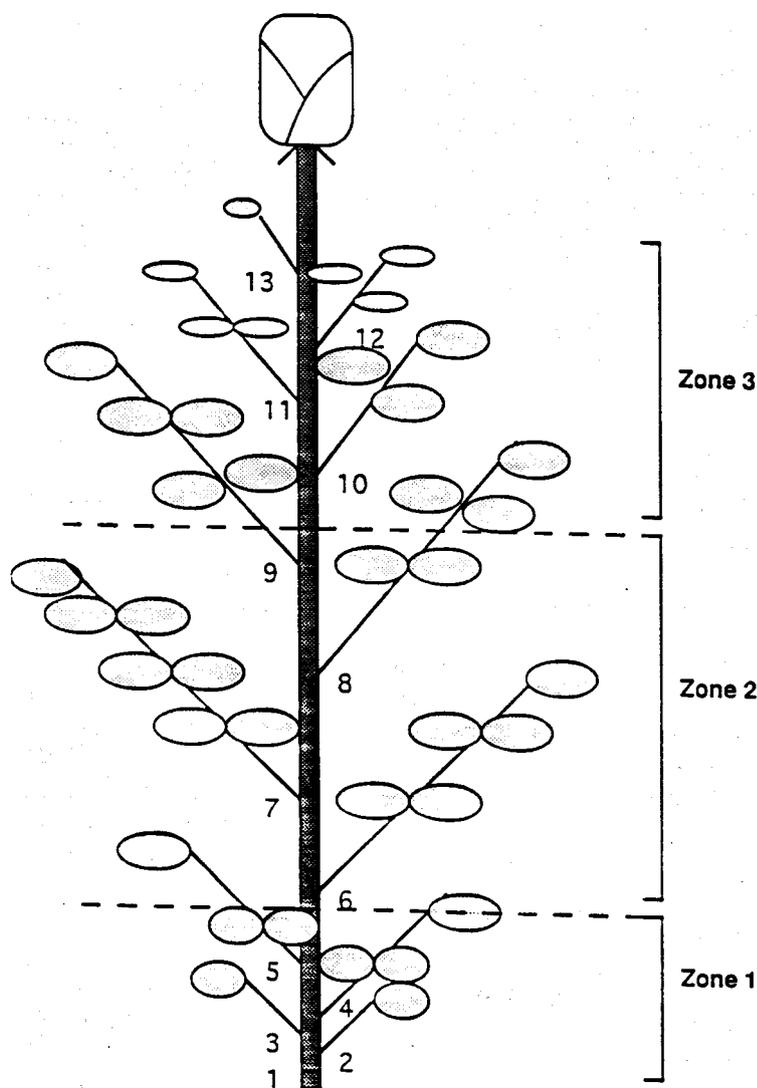
Lateral shoot development arising from each zone differs (Zieslin, 1992). Lateral shoot development in zones one and two only occurs when apical dominance is removed via shoot decapitation (Zieslin and Halevy, 1976; Zieslin et al., 1976; 1978). The process of removing flowers is analogous to decapitation. Lateral shoot development in the third zone can occur during the latter stages of flower development without decapitation. Stems are typically cut back to nodes 5-7 from the base of a stem, i.e. the second zone, in commercial production (Etzel and Wittman, personal communication).

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Figure 1. Figure identifying the three zones of a typical rose stem (Zieslin, 1992) and the assignment of node numbers in this experiment.



shoot development by an adjacent leaf was reported on *Xanthium pensylvanicum* L. (McIlrath and Bogorad, 1960) and *Euphorbia pulcherrima* Willd. ex Klotzsch (Berghage et al., 1989). In addition to the leaf, the stem segment above an axillary bud can also inhibit subsequent axillary shoot development in *Rosa* (Zieslin and Halevy, 1976) as well as in *Pisum sativum* L. (Nagao and Rubenstein, 1976) and *Glycine max* L. (Peterson and Fletcher, 1975).

Increasing axillary shoot number and subsequent flower number is desirable in commercial production. In specific, increasing flower production at Valentine's Day would have a significant impact on the profitability of a business. The interaction between axillary bud position and the presence or absence of subattending leaves on the degree of axillary shoot development

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The degree of lateral branching which occurs following decapitation varies depending on the age of the axillary buds which remain. In general, inhibition of axillary shoot development is positively correlated with bud age in *Rosa*. When stems are decapitated to the 5-7th node, some but not all of the axillary buds immediately below the cut develop; lower bud development, i.e. nodes 1-3, is often inhibited.

The degree of lateral branching which occurs following decapitation is also influenced by the tissue which surrounds an axillary bud. For instance, the leaf subattending an axillary bud can inhibit subsequent axillary shoot development in *Rosa* (Durkin, 1965; Zieslin and Halevy, 1976). Similar inhibition of axillary

(or flower development) following decapitation in *Rosa* has not been determined. In addition, the interaction between axillary bud position and the presence or absence of subattending leaves on subsequent axillary shoot flower initiation has not been determined.

The objectives of the research presented in this paper were to 1) quantify the interaction between axillary bud position and leaf removal on subsequent axillary shoot development in *Rosa*, 2) determine the interaction between axillary bud position and the presence or absence of leaves on axillary shoot morphology in *Rosa*, and 3) determine how the time of year influences the interaction between axillary bud position and leaf removal on subsequent axillary shoot development

The Interaction between axillary bud position and the presence or absence of subattending leaves on the degree of axillary shoot development (or flower development) following decapitation in *Rosa* has not been determined.

Table 1. Analysis of variance identifying the impact of node pruning position, leaf removal technique, cultivar, and time of year on return axillary (TB), 'self-pinched' (SP), blind (BS), and flower (FN) number per *Rosa x hybrida* L. cvs. 'Royalty' and 'Lovely Girl' mother stem. Mother stems received experimental treatments when the flower on the mother stem was harvested, i.e. reflexing of the first petal.

Term	TB	FN	BS	SP
Node Position	*** Z	***	***	*
Leaf Removal	**	***	n.s.	*
Cultivar	n.s.	n.s.	n.s.	n.s.
Time	***	*	**	***
Node Position x Leaf Removal	**	***	n.s.	***
Node Position x Cultivar	***	n.s.	***	n.s.
Node Position x Time	n.s.	n.s.	n.s.	n.s.
Leaf Removal x Cultivar	*	n.s.	**	n.s.
Leaf Removal x Time	*	n.s.	*	n.s.
Cultivar x Time	n.s.	n.s.	n.s.	n.s.

^Z Significance of terms in the ANOVA as nons-significant (n.s.); P=0.05, (*); P=0.01, (**); P<0.001 (***).

Approximately 100 established plants (4 years old 3x plants) each of *Rosa x hybrida* L. cv 'Royalty' and 'Lovely Girl' budded on Moretii rootstock were selected in an established canopy for use in experimentation.

Three leaf removal techniques were evaluated: 1) no leaf removal, 2) removal of the node leaf only, or 3) removal of all leaves on the stem.

A 'self-pinched' shoot was a axillary shoot in which axillary bud development started prior to harvest. A self-pinched shoot is usually composed of 3-7 nodes below the flower.

in *Rosa*. Specific morphological characteristics (shoot length, leaf number, and flower quality) of axillary shoots are reported in the second paper in this series. The practical impact of this research on cut rose production will be discussed.

Materials and Methods

Approximately 100 established plants (4 years old 3x plants) each of *Rosa x hybrida* L. cv 'Royalty' and 'Lovely Girl' budded on Moretii rootstock were selected in an established canopy for use in experimentation (Len Busch Roses, Inc., Plymouth, Minnesota). Plants were grown with $21 \pm 1.5^{\circ}\text{C}$ day and $16 \pm 1.5^{\circ}\text{C}$ night temperatures in a double acrylic greenhouse (Exolite). Temperature was maintained using an environmental control computer. Plants received natural daylight from Nov. 15-Jan., 1992 (time 1) or Feb. 18-Apr., 1992 (time 2). Daylength was extended to 18 hrs using high pressure sodium lamps ($100 \mu\text{mol m}^{-2}\text{s}^{-1}$). Daily molar irradiance levels averaged 10 and 20 moles day^{-1} for time 1 and 2, respectively.

Treatments were conducted on flowering stems at harvest. Harvest was defined as the reflexing of the outermost petal of the flower bud. The stem which was cut will be referred to as the 'mother stem' and subsequent lateral shoot development will be referred to as 'axillary shoots' in this paper. Mother stems were cut to node 1, 3, 5, 7, 9, 11, or 13 from the base of the immediate stem

(Figure 1). Most mother stems were composed of 13 nodes, therefore, pruning to the 13th node involved removing the flower only.

Three leaf removal techniques were evaluated: 1) no leaf removal, 2) removal of the node leaf only, or 3) removal of all leaves on the stem. Leaf removal treatments were conducted when mother stems were cut back at harvest.

Data were collected on subsequent axillary shoot development at harvest. Data were collected on total axillary, flowering, 'blind', and 'self-pinched' shoot number per mother stem. A 'blind shoot' was an axillary shoot in which flower initiation failed to continue and the flower aborted during development (Zieslin and Moe, 1985). A 'self-pinched' shoot was an axillary shoot in which axillary bud development started prior to harvest. A self-pinched shoot is usually composed of 3-7 nodes below the flower.

The experiment was organized as a $2 \times 7 \times 3 \times 2$ factorial design with cultivar, mother stem node position, leaf removal technique, and time of year as the main factors (84 treatment combinations). Treatments were assigned randomly to mother stems as flowers on those stems were harvested. There were 10 replicates (mother stems) per treatment (840 total rose stems).

Results

Total Axillary Shoot Number: Axillary shoot number per mother stem was affected by node position which mother stems were cut to, cultivar, leaf removal technique, and time of year (Table 1). Axillary shoot number increased as the node position which mother shoots were cut to became more distal, i.e. increased from 1 to 13 (Figure 1). For instance, axillary shoot number increased from 1.5 to 4.5 and from 1.7 to 2.6 shoots as the node position which mother stems were cut to increased from 1 to 13 on Royalty and Lovely Girl, respectively, across time of year (Table 2; Figure 2a).

Node position interacted with cultivar to affect axillary shoot number per mother stem (Table

1). Return axillary shoot number was not significantly different on Royalty and Lovely Girl when stems were cut to nodes 1-7 (Figure 2a). However, axillary shoot number per mother stem increased more on Royalty than on Lovely Girl as node position increased from 7 to 13 (Figure 2a). Maximum axillary shoot number was 4.5 and 2.6 on Royalty and Lovely Girl, respectively, across time of year (Figure 2a).

Leaf removal affected axillary shoot development. Removal of the node leaf only did not significantly affect subsequent axillary shoot development (Table 2; Figure 3a). In contrast, removal of all leaves from the mother stem at harvest reduced axillary shoot number (Table 2; Figure 3a). Axillary shoot number decreased from 1.9 to 1.7 shoots when all leaves were re-

Axillary shoot number per mother stem was affected by node position which mother stems were cut to, cultivar, leaf removal technique, and time of year.

Table 2. Node pruning position, leaf removal, and cultivar affect axillary shoot number on *Rosa x hybrida* L. cvs 'Lovely Girl' and 'Royalty'. Data presented are means and standard deviations across time of year. Mother stems were cut to varying node positions when the first petal on the flower reflexed. At that time either no leaves were removed, the leaf immediately subtending the uppermost node was removed, or all leaves on the mother stem were removed.

Node Position		Leaf Removal		
		No Leaves	Node Leaf Only	All Leaves
'Total Break Number'				
1	Lovely Girl	1.7 ± 0.5 ^z a ^y	1.6 ± 0.7 a	1.2 ± 0.4 a
	Royalty	1.5 ± 0.8 a	1.3 ± 0.9 a	1.4 ± 1.3 a
3	Lovely Girl	1.5 ± 0.8 a	1.4 ± 0.7 a	1.6 ± 0.5 a
	Royalty	1.0 ± 0.7 a	1.2 ± 0.6 a	0.5 ± 0.5 a
5	Lovely Girl	1.1 ± 0.3 a	1.7 ± 0.5 a	1.4 ± 0.5 a
	Royalty	1.0 ± 0.5 a	1.2 ± 0.4 a	1.2 ± 0.4 a
7	Lovely Girl	1.8 ± 0.6 a	1.9 ± 0.6 a	1.7 ± 0.5 a
	Royalty	1.4 ± 0.5 a	1.8 ± 0.4 a	1.6 ± 0.5 a
9	Lovely Girl	2.0 ± 0.5 ab	2.4 ± 0.5 a	1.7 ± 0.5 b
	Royalty	2.6 ± 1.0 a	2.3 ± 0.5 a	1.5 ± 0.5 b
11	Lovely Girl	2.7 ± 0.8 a	2.6 ± 1.1 a	2.3 ± 0.7 a
	Royalty	4.0 ± 0.9 a	2.9 ± 1.1 a	1.7 ± 0.7 b
13	Lovely Girl	2.6 ± 0.5 a	3.4 ± 1.2 a	2.8 ± 0.6 a
	Royalty	4.5 ± 1.4 a	4.4 ± 1.0 a	2.8 ± 1.4 b

^z Numerals represent treatment means and standard deviation about the mean.
^y Letters identify significance across leaf removal techniques as identified by Tukey's H.S.D. test for mean separation.

Node position interacted with cultivar to affect axillary shoot number per mother stem.

Leaf removal affected axillary shoot development. Removal of the node leaf only did not significantly affect subsequent axillary shoot development.

Node position interacted with leaf removal to affect axillary shoot development.

moved across cultivar, node pruning treatments, and time of year.

Node position interacted with leaf removal to affect axillary shoot development (Table 1). Reduction in axillary shoot number due to leaf removal was most pronounced when plants were cut to nodes 9 to 13 (Figure 3a). For example, axillary shoot number decreased from 4.5 to 2.8 shoots when Royalty mother stems were cut to node 13 and all when all mother stem leaves were removed (Table 2; Figure 3a).

The effect of leaf removal on axillary shoot number varied across cultivars (Table 1). Leaf removal reduced axillary shoot number on Royalty plants (Figure 4a). In contrast, axillary shoot number was unaffected by leaf removal on Lovely Girl plants (Figure 4a).

Axillary shoot number per stem was affected by the time of year plants were cut and leaf removal treatments were applied.

Axillary shoot number per stem was affected by the time of year plants were cut and leaf removal treatments were applied (Table 1). Axillary shoot number decreased from 2.0 to 1.7 shoots when plants were cut during the fall versus the spring across cultivar, leaf removal technique, and node position treatments (Figure 5).

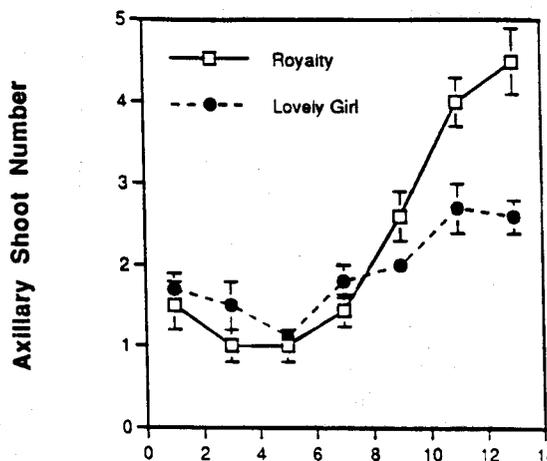
Node position and leaf removal interacted to affect self-pinched shoot number.

Self-Pinched Shoots: Node position and leaf removal interacted to affect self-pinched shoot number (Table 1). Self-pinched shoot number was greatest when mother stems were cut to node 11 or 13 and all leaves were removed (Table 3). For instance, no self-pinched shoots occurred on mother stems which were cut to the 13th node when no leaves were removed. In contrast, 0.63 self-pinched shoots formed after cutting plants to the 13th node and removal of all leaves from the mother stem (Table 3).

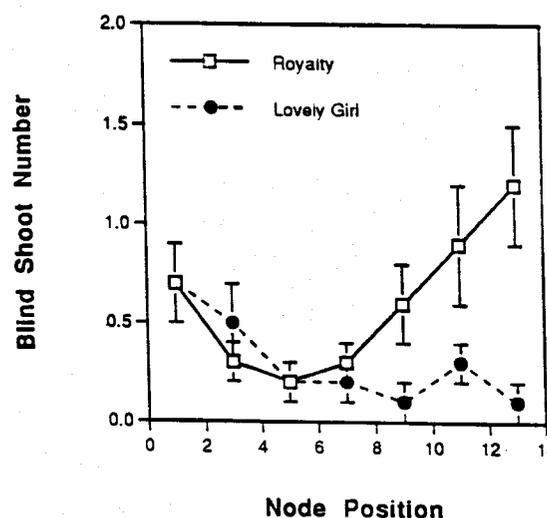
Blind shoot number per stem was affected by node position, cultivar, leaf removal, and time of year.

Figure 2a and b. Effect of pruning position and cultivar on return axillary shoot number (a), and 'blind' shoot number (b), on *Rosa x hybrida* L. cvs 'Royalty' (□) and 'Lovely Girl' (●). Treatment means and standard errors about the treatments means are presented.

a



b



Blind Shoots: Blind shoot number per stem was affected by node position, cultivar, leaf removal, and time of year (Table 1). Blind shoot number decreased from 0.7 to 0.1 blind shoots per stem as node position increased from 1 to 13 on Lovely Girl across time of year (Figure 2b). In contrast, blind shoot number decreased from 0.7 to 0.2 blind shoots as node position in-

creased from 1 to 5 then increased from 0.2 to 1.2 blind shoots per stem as node position increased from 5 to 13 on Royalty (Figure 2b).

Cultivars responded differently to leaf removal with respect to blind shoot development (Table 1; Figure 4b). Blind shoot number decreased from 0.6 to 0.4 blind shoots per stem when all leaves were removed on Royalty across node

pruning treatments. In contrast, blind shoot number increased from 0.3 to 0.6 blind shoots when all leaves were removed on Lovely Girl across node pruning treatments (Figure 4b).

Time of year affected blind shoot development (Table 1). Blind shoot number was less on spring cut versus fall cut plants (Figure 5). For example, blind shoot number decreased from 0.5 to 0.4

shoots per mother stem on fall grown versus spring grown plants across pruning position, leaf removal, and cultivars (Figure 5).

Flower Number: Flower number was affected by node position, leaf removal, and time of year (Table 1). Return flower number per mother stem increased as the node position which mother stems were cut to increased. For instance, flower number increased from 0.5 to 2.6 flowers per stem as node position increased from 1 to 13 across cultivar when no leaves were removed from the mother stem (Figure 3b).

Leaf removal interacted with node position to affect return flower number. Leaf removal decreased return flower number when plants were cut to upper nodes, i.e. nodes 9 to 13 (Figure 3b). For instance, flower number was unaffected by leaf removal when mother stems were cut to the 1st-3rd node. In contrast, flower number decreased from 2.6 to 1.6 flowers per mother stem following removal of all leaves on mother stems cut to the 13th node across cultivar and time of year (Figure 3b).

Flower number increased slightly when plants were cut in the spring versus the fall (Figure 5). For instance, flower number increased from 1.1 to 1.4 flowers per mother stem across cultivar, node position, and leaf removal technique

Cultivars responded differently to leaf removal with respect to blind shoot development.

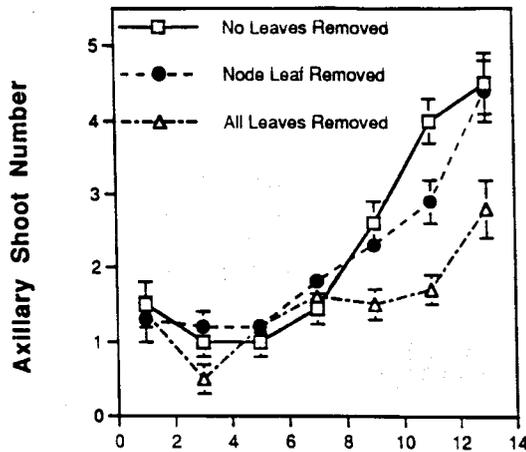
Flower number was affected by node position, leaf removal, and time of year.

Leaf removal interacted with node position to affect return flower number.

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Figure 3a and b. Effect of pruning position and leaf removal technique, no leaves removed (□), node leaves removed (●), all leaves removed (△), on return axillary shoot number (a) and return 'blind' shoot number (b) on *Rosa x hybrida* L. cvs 'Royalty' and 'Lovely Girl'. Treatment means and standard error about the treatment means are presented.

a



b

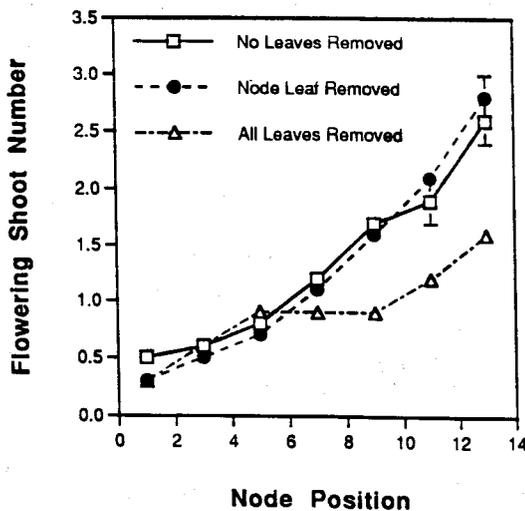


Table 3. Node pruning position, leaf removal, and cultivar affect self-pinched shoot number per stem on *Rosa x hybrida* L. cvs 'Lovely Girl' and 'Royalty'. Data presented are means and standard deviations across time of year. Mother stems were cut to varying node positions when the first petal on the flower reflexed. At that time either no leaves were removed, the leaf immediately subtending the uppermost node was removed, or all leaves on the mother stem were removed.

Node Position		Leaf Removal		
		No Leaves	Node Leaf Only	All Leaves
1	Lovely Girl	0.20 + 0.52 b	0.16 + 0.37 b	0.00 + 0.00 a
	Royalty	0.05 + 0.23 a	0.00 + 0.00 a	-
3	Lovely Girl	0.00 + 0.00 a	0.20 + 0.41 a	0.11 + 0.32 a
	Royalty	0.10 + 0.31 a	0.05 + 0.23 a	0.05 + 0.23 a
5	Lovely Girl	0.17 + 0.38 a	0.10 + 0.45 a	0.10 + 0.32 a
	Royalty	0.00 + 0.00 a	0.26 + 0.45 a	0.00 + 0.00 a
7	Lovely Girl	0.16 + 0.37 a	0.25 + 0.44 a	0.12 + 0.33 a
	Royalty	0.00 + 0.00 a	0.05 + 0.23 a	0.06 + 0.24 a
9	Lovely Girl	0.15 + 0.37 a	0.16 + 0.37 a	0.06 + 0.24 a
	Royalty	0.00 + 0.00 a	0.00 + 0.00 a	0.00 + 0.00 a
11	Lovely Girl	0.15 + 0.37 a	0.25 + 0.64 a	0.35 + 0.59 a
	Royalty	0.00 + 0.00 a	0.00 + 0.00 a	0.56 + 0.89 a
13	Lovely Girl	0.00 + 0.00 a	0.05 + 0.23 a	0.63 + 0.60 b
	Royalty	0.00 + 0.00 a	0.00 + 0.00 a	0.10 + 0.46 a

^z Numerals represent treatment means and standard deviation about the mean.
^y Letters identify significance across leaf removal techniques as identified by Tukey's H.S.D. test for mean separation.

The percent of axillary shoots which developed into flowers versus unusable shoots, i.e. self-pinched and blind shoots, was influenced by node position and leaf removal and time of year.

Leaf removal decreased the percentage of shoots which developed into flowering shoots.

A greater percentage of axillary shoots developed into flowers when mother stems were cut in the spring compared to the fall.

when plants were cut in the spring versus the fall (Figure 5).

Shoot Determination: The percent of axillary shoots which developed into flowers versus unusable shoots, i.e. self-pinched and blind shoots, was influenced by node position and leaf removal and time of year (Table 4). The percent of axillary shoots which developed into flowering shoots increased from 9 to 87% as node position increased from 1 to 13 (Table 4).

Leaf removal decreased the percentage of shoots which developed into flowering shoots. For instance, flowering shoot number decreased from 75 to 50% when all leaves were removed compared to no leaf removal when mother stems were pruned to node 7 in the fall (Table 4).

The reduction in the percentage of axillary shoots which developed into flowers resulting from re-

moval of all leaves increased as node position increased. For example, the reduction in the percentage of axillary shoots which developed into flowers from mother stems cut to nodes 3 and 13 was 7 and 41%, respectively (Table 4).

A greater percentage of axillary shoots developed into flowers when mother stems were cut in the spring compared to the fall. The percent of shoots which developed into flowers in the fall and spring was 61 and 83% on stems which did not have any leaves removed, respectively, across node position and cultivar (Table 4). The increase in the percentage of axillary shoots which developed into flowers versus unusable shoots between seasons was more obvious when mother stems were pruned to lower (nodes 1-3) versus upper nodes (nodes 11-13).

Discussion

Profitability of commercial cut rose production is based on flower production on a per unit area basis over time. Flower production is dependent on the number of axillary shoots which develop following decapitation (cutting flowers) and the number of those shoots which

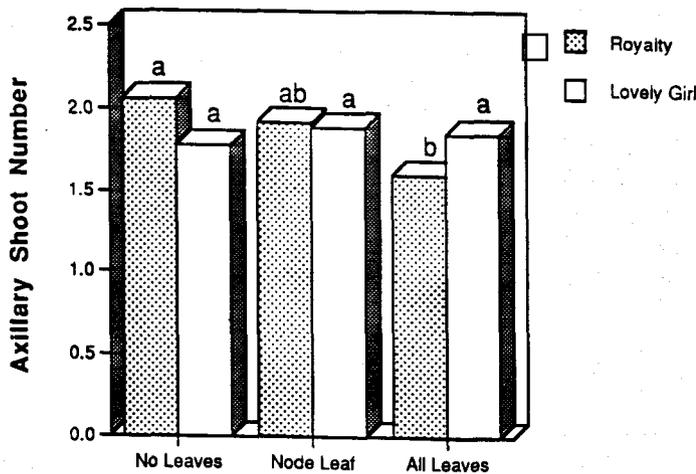
develop into flowers versus unusable, i.e. blind or self-pinched shoots. Axillary shoot number depends on mother shoot vigor, the presence or absence of leaves, and the growth status of the remaining part of the plant (Durkin, 1965).

Mother stems are typically cut to the 5-7th node from the base of the stem in commercial production (Figure 1). Pruning to the 5-7th nodes

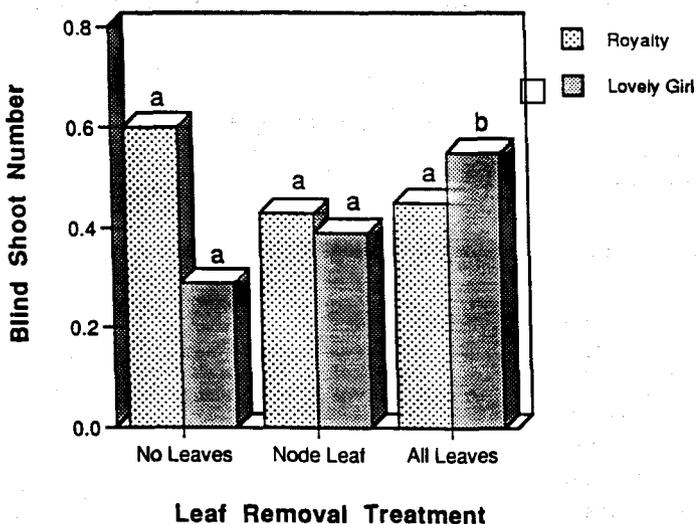
Profitability of commercial cut rose production is based on flower production on a per unit area basis over time.

Figure 4a and b. Effect of leaf removal technique and cultivar on axillary shoot number per mother stem (a) and 'blind' shoot number per mother stem (b) of *Rosa x hybrida* L. cvs 'Royalty' and 'Lovely Girl'. Treatment means across cultivar and node position are presented. Significance was determined across leaf removal techniques on each cultivar using Tukey's H.S.D. analysis for post hoc mean separation.

a



b



results in approximately 1.3 return axillary shoots per stem on Royalty and Lovely Girl plants (Len Busch Roses Inc., personal communication). The response of Royalty and Lovely Girl plants cut to the 5-7th nodes in this experiment was similar to that seen in commercial production (1.4 axillary shoots) (Table 2; Figure 3b).

Pruning mother stems to node positions higher (13th) than the 5-7th nodes significantly increased axillary shoot number in this experiment (Figure 3a). The increase in axillary shoot number as pruning position became more distal was greater on Royalty than on Lovely Girl (Figure 2a). Pruning the mother stem to the 13th node versus the 7th node increased axillary shoot number from 1.4 to 4.5 and 1.8 to 2.6 axillary shoots on Royalty and Lovely Girl, respectively, when no leaves were removed (Table 2).

Pruning mother stems to node positions higher (13th) than the 5-7th nodes significantly increased axillary shoot number in this experiment.

Table 4. Effect of node position, leaf removal technique, and time of year on the proportion of axillary shoots which developed into flowering shoots following pruning mother stems of *Rosa x hybrida* L. across cultivar. Mother stems were pruned at harvest, i.e. reflexing of the first petal, to varying node positions. No leaves, the node leaf, or all leaves were removed from the mother stem when mother stems were pruned.

Node Position		Leaf Removal		
		No Leaves	Node Leaf	All Leaves
1	Fall	9 ^z	22	24
	Spring	79	88	-
3	Fall	43	32	36
	Spring	70	74	81
5	Fall	62	50	71
	Spring	84	72	79
7	Fall	75	63	50
	Spring	89	76	69
9	Fall	79	71	59
	Spring	87	90	71
11	Fall	69	76	68
	Spring	89	91	51
13	Fall	87	82	46
	Spring	85	88	65

Term	Significance
Node Position	*** y
Leaf Removal	***
Time of Year	***
Node Position x Leaf Removal	**
Node Position x Time of Year	***
Leaf Removal x Time of Year	n.s.
Node Position x Leaf Removal x Time of Year	*

^z Numerals represent treatment means.

^y Significance of terms in the ANOVA as nonsignificant (n.s.); P=0.05, (*); P=0.01, (**); P<0.001 (***).

Although Royalty produced significantly more axillary shoots than Lovely Girl when mother stems were cut to the 13th node, flower number per mother stem was not significantly different between cultivars.

The lack of significant difference between Royalty and Lovely Girl flower number when cut to the 13th node, indicated that more axillary shoots on Royalty were developing into blind and self pinched shoots than on Lovely Girl.

Although Royalty produced significantly more axillary shoots than Lovely Girl (Figure 2a) when mother stems were cut to the 13th node, flower number per mother stem was not significantly different between cultivars (Table 1; Figure 3b). When mother stems were cut to the 13th node rather than the first node, flower number per stem on both Royalty and Lovely Girl increased from 1.2 to 2.6 (+108%) flowers (Figure 3b).

The lack of significant difference between Royalty and Lovely Girl flower number when cut to the 13th node, indicated that more axillary shoots on Royalty were developing into blind and self pinched shoots than on Lovely Girl. This conclusion was supported by data shown in Figure 2b and Table 3.

Initially, leaf removal techniques were studied to determine the interaction between node position and the reported promotion of axillary shoot development resulting from removal of the node leaf when stems are cut (Durkin, 1965). Subsequent research suggested that the leaf and stem tissue may inhibit axillary bud development in *Rosa* (Zieslin and Halevy, 1976; Zieslin et al., 1976). Application of this information could increase the productivity of cut rose plants.

Results presented in this paper do not support conclusions of Durkin (1965) which suggested that node leaf removal increased axillary shoot number significantly (Table 1; Figure 3a). Durkin (1965) reported that leaf removal stimulated axillary shoot development but did not increase flower number per shoot. In other words, axillary shoots arising from nodes in which a leaf had been removed were often 'blind'. We found no significant difference in either axillary, flower, or blind shoot development resulting from removal of the leaf subtending a node in our research (Table 1 and 2; Figure 3a). Our data, therefore, do not support the theory that the leaf subtending a node inhibits axillary shoot development and has a significant impact on whether that shoot flowers in *Rosa*.

Removal of all mother stem leaves decreased axillary shoot number (Table 2) and increased the proportion of axillary shoots which developed into unusable shoots versus flowering shoots on Royalty (Table 4). Removal of all leaves did not affect axillary shoot number on Lovely Girl (Table 2). These data suggest that the ability of a Royalty mother stem to produce more flowers, i.e. greater than 2.6 flowering shoots, may be limited by the ability of a mother stem to supply carbohydrates to the developing axillary shoots.

Blind shoot development is associated with the ability of a stem to harvest light.

Reduced ability to harvest light or reduced irradiance levels are associated with higher levels of flower bud abortion and/or lack of flower initiation which results in blind shoot production in *Rosa* (Nell and Rasmussen, 1979). Leaf removal is, to some degree, synonymous to a reduction in irradiance, i.e. the effect of leaf removal on the proportion of shoots which develop into flowers when mother stems are pruned to distal nodes may be the result of manually limiting the ability of a shoot to synthesize carbohydrates.

Increasing irradiance levels may, therefore, increase flower number per mother stem on Royalty beyond 2.6 flowering shoots per mother stem by decreasing blind shoot number. An increase in yield by increasing irradiance may not be possible on Lovely Girl since all shoots essentially developed into flowers when axillary shoot development was maximized by cutting mother stems to the 13th node (Figure 2b). However, it is possible that an increase in irradiance would result in a subsequent increase in axillary shoot number following decapitation which could ultimately result in an increase in yield on Lovely Girl.

An increase in yield associated with increased irradiance has been previously noted on *Rosa* (Zieslin and Mor, 1990; Mortensen et al., 1992;

Removal of all mother stem leaves decreased axillary shoot number and increased the proportion of axillary shoots which developed into unusable shoots versus flowering shoots on Royalty.

Blind shoot development is associated with the ability of a stem to harvest light.

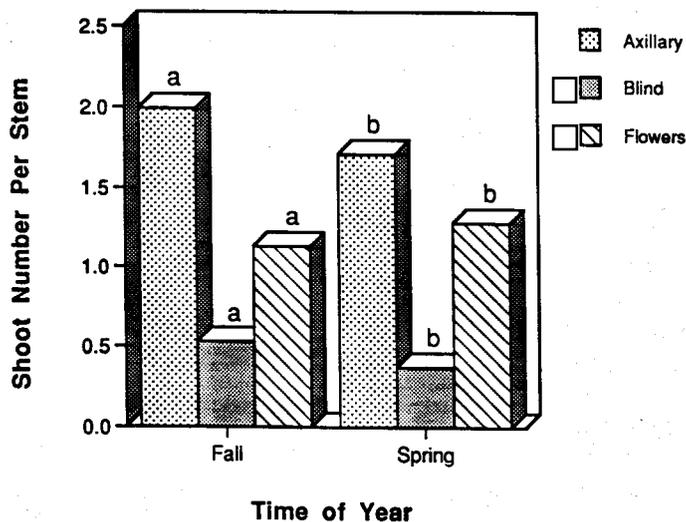


Figure 5. Effect of time of year on axillary shoot, 'blind' shoot, and flower number per mother stem on *Rosa x hybrida* L. Treatment means across cultivar all other factors are presented. Significance was determined across time of year on each cultivar using Tukey's H.S.D. analysis for mean separation.

Increasing irradiance levels may, therefore, increase flower number per mother stem on Royalty beyond 2.6 flowering shoots per mother stem by decreasing blind shoot number.

Flower number increased significantly when shoots were pruned to more distal nodes (nodes 9-13) than what is commercially practiced (nodes 5-7).

The increase in flower number resulting from cutting stems to more distal nodes could be economically significant if a flower is sacrificed during a period of year when the value of a rose is less to gain a flower when the value of a rose stem is high.

This management practice may increase the profitability of a cut rose business.

Mortensen et al., 1993; Carpenter and Anderson, 1972; Carpenter and Rodriguez, 1971; Cockshull, 1975). The increase in yield on *Rosa* associated with increasing irradiance levels is due to both an increase in axillary shoot number (Mortensen et al., 1993) and a decrease in blind shoot development resulting in an increase in flowering shoot number (Nell and Rasmussen, 1979).

Flower number increased significantly when shoots were pruned to more distal nodes (9-13) than what is commercially practiced (nodes 5-7) (Figure 3b). Increased yield resulting from cutting roses to upper nodes has been previously reported by Post (1950) with the cvs 'Cara Mia' and 'Armroy Beauty'. In general, node number on return axillary shoots decreases as node position which shoots are pruned to becomes more distal (Zieslin, 1992). A difficulty in the past with winter grown cut roses has been in achieving the desired stem length needed for Valentine's Day sales of 'long-stemmed' cut roses. Pruning shoots to the uppermost nodes during the winter to achieve maximum production has not been practiced because stem length was not adequate due to 1) reduced node number on axillary shoots arising from upper nodes (> node 7) and 2) reduced internode elongation on winter-grown versus summer-grown roses.

Two recent developments may make cutting *Rosa* shoots to upper nodes commercially feasible. First, return shoot leaf number on new cultivars seems to be less influenced by the position on a mother stem from which a shoot arises (Byrne and Doss, 1981). With 'Cara Mia' the influence of bud position on the developing shoot was seen only on nodes developing above the 10th node on subsequent axillary shoots (Byrne and Doss, 1981). While leaf count was decreased by pruning 'Cara Mia' stems to upper nodes, all shoots were saleable. A similar response was seen on the cultivars used in this experiment. Second, a better understanding of how stem elongation is controlled by DIF may allow growers to elongate shoots to the desired length during low light periods of the year even when node number per axillary shoot is decreased due to upper node pruning.

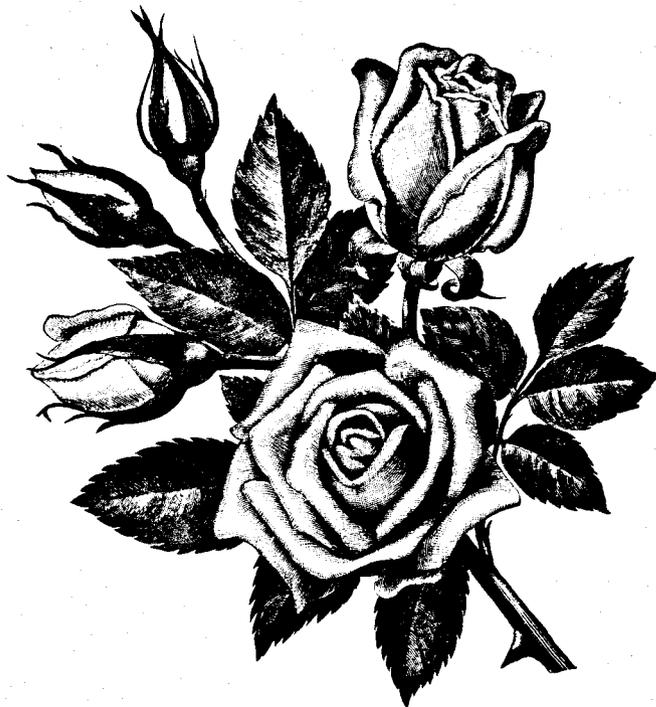
The increase in flower number resulting from cutting stems to more distal nodes could be economically significant if a flower is sacrificed during a period of year when the value of a rose is less to gain a flower when the value of a rose stem is high. The peak production period and period

when a cut rose has the greatest value in the United States immediately prior Valentine's Day. Removal of a flower or pruning mother stems to the 13th node in December would decrease December sales but may increase Valentine's Day sales. This management practice may increase the profitability of a cut rose business.

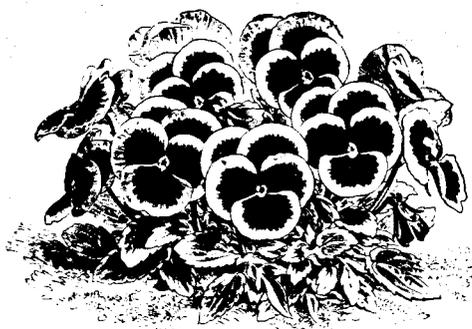
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