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Primary bud-axis necrosis of grapevines. I. Natural incidence and correlation with vigour

by

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Summary: The incidence of primary bud-axis necrosis (PBN) was studied from 1980 to 1985 in Australian vineyards of varying vigour. Fifteen cultivars of *Vitis vinifera* L. were initially examined for the presence of PBN and, because Shiraz (syn. Syrah) proved to have the highest incidence, subsequent work emphasized this cultivar. Compound buds at nodes 2 to 9 from the base of the shoot (node 9 being the most distal node) were scored for the presence of PBN. PBN was found to be a significant cause of unfruitfulness in the Australian vineyards examined. Incidence was higher in seeded compared with seedless cultivars. Shiraz had the highest incidence but not as great as for other cultivars reported in Israel, Japan, Chile and USA. PBN incidence was highest in the basal nodes of thick shoots, especially if the node bore a lateral shoot. Buds with PBN produced more shoots but fewer bunches. Thinning of shoots ten days before and after flowering increased both shoot vigour and PBN incidence. This association was attributed to the greater vigour *per se* and not to any change in canopy light environment. PBN-caused loss of primary shoots is concluded to be a major cause of unfruitfulness in basal nodes of grapevines.

Key words: bud-axis necrosis, vigour, shoots, shoot thinning, Shiraz.

Introduction

Dormant buds of grapevines are compound buds, located at a node (a node is defined as the enlarged portion of a shoot or cane from which the leaves, bunches, tendrils and lateral shoots arise). Such compound buds have a large central bud axis (primary) and two smaller buds on either side of the primary bud (secondary buds).

The primary bud axis is subject to necrosis as has been widely reported; it is said to be one of the causes of poor node fruitfulness and low vineyard yield. This condition is preferably known as "primary bud-axis necrosis" (PBN) because it is usually just the primary bud axis which is affected and not the secondary bud axes. The external appearance of a dormant bud with PBN is identical to that of a normal bud: however, dissection reveals the necrosed primary bud axis coupled with better development of the secondary bud axes (Lavee *et al.* 1981, Morrison and Iodi 1990, Perez and Kliewer 1990). Sometimes the better development of the secondary bud axes results in a "split bud" (Lavee *et al.* 1981) .

The incidence of PBN varies between cultivars and with viticultural practices. Cultivars of *Vitis vinifera* L. reported to be susceptible to this disorder include Dattier de Beirouth (Bernstein 1973), Queen of the Vineyard (Bernstein 1973, Lavee *et al.* 1981), Anab-e-Shahi (Bindra and Chohan 1975), Kyoho (Naito *et al.* 1986), Thompson Seedless (Morrison and Iodi 1990, Perez and Kliewer 1990), Flame Seedless (Morrison and Iodi 1990) and Riesling (Wolf and Cook 1992). High vine and shoot vigour (Bindra 1977, Lavee *et al.* 1981, Naito *et al.* 1986, Wolf and Cook 1992), high levels of soil nitrogen (Bindra and Chohan 1977, Perez-Harvey 1991), canopy shading (Perez and Kliewer 1990, Perez-Harvey 1991, Wolf and Cook 1992) and exogenous application of gibberellic acid, GA (Ziv *et al.* 1981, Naito *et al.* 1986), have been shown to be correlated with high levels of PBN.

Climatic and cultural conditions that favour excessive shoot vigour and induce low bud fruitfulness also favour a high incidence of PBN (Lavee *et al.* 1981, Perez and Kliewer 1990). Girdling (Dabas *et al.* 1980) and foliar application of the growth retardant, succinic acid -2,2-dimethyl hydrazide (SADH), have been shown to reduce incidence (Naito *et al.* 1986).

Bud sectioning shows that PBN develops after flowering and reaches maximal levels at one to three months post-flowering depending on location (Lavee *et al.* 1981, Morrison and Iodi 1990, Perez-Harvey 1991). The incidence of PBN is highest at basal nodes, particularly nodes 1 to 8 (Lavee *et al.* 1981, Naito *et al.* 1986, Morrison and Iodi 1990, Perez-Harvey 1991) but may also occur at more distal nodes (Lavee *et al.* 1981).

The present work describes investigations of the natural incidence of PBN in Australian vineyards and its correlation with vine and shoot vigour and with node fruitfulness. The effect of shoot thinning on PBN incidence was also examined. Because the use of cane pruning (bearers of 10 - 15 nodes) rather than spur pruning (bearers of 2 nodes) in vigorous vineyards is often attributed to the poor fertility of basal nodes, a consequence of the poor light environment of dense canopies, we assessed whether PBN, rather than reduced inflorescence initiation of primary buds, was the cause of low fertility of basal nodes.

Further papers will examine the effects of summer pruning operations and exogenous GA application on the incidence of PBN, the correlation of endogenous GA levels with PBN and the effect of PBN on vineyard productivity and implications for viticultural operations.

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Materials and methods

Mature canes were sampled from 1980 to 1985 from vineyards ranging in vigour from high to low and the compound buds examined for the presence of PBN. In some cases, canes were collected from mature commercial vineyards with normal management during the previous growing season supplemented by data from control vines in experiments which examined the effect of various treatments on PBN incidence. Where the effect of shoot vigour on PBN incidence was examined, a range of canes was sampled; otherwise, the most vigorous shoots (i.e. the longest and thickest canes) were sampled (see Results). The number of mature canes sampled from each vineyard ranged from 20 to 120.

Fifteen cultivars of *Vitis vinifera* L. were initially examined for the presence of PBN and, because Shiraz (syn. Syrah) proved to have the highest incidence, subsequent work emphasized this cultivar. In the Shiraz vineyards sampled, vine age ranged from 11 to 32 years, row x vine spacing from 2.7 to 3.9 m x 1.5 to 3.0 m, trellis type was a single wire or 0.45 - 1.0 m wide tee, and pruning was spur or cane.

Compound buds at nodes 2 to 9 from the base of the shoot (node 9 being the most distal node) were scored for the presence of PBN, unless otherwise indicated. Preliminary measurements indicated that PBN was rarely found at nodes distal to node 9 under natural conditions. The bud at node one was not examined because it had the characteristics of a 'base bud' (POOL *et al.* 1978).

The presence of PBN was readily determined by making a transverse cut with a scalpel at half the height of the bud; additional cuts were used to check the state of the secondary buds. A 10 x hand lens was used as a check. Nodes where the compound bud was absent, externally damaged, completely dead or had burst, were excluded (this was always < 10 % of all nodes and usually < 3 %). The percentage of nodes with PBN was calculated from the remaining nodes.

To determine correlations with vigour, additional measurements were made when PBN was scored: cane diameter was measured at the mid-point between nodes one and two, cane length from base to tip (for shoots which had not been summer-pruned), and presence or absence of persistent lateral shoots at each node (defined as woody laterals longer than 25 mm).

In winter 1984, 42 canes were collected from a vigorous Shiraz vineyard at Virginia, South Australia. Canes were collected over as wide a range of diameters as possible and divided into 3 groups based on cane diameter i.e. 2–9 mm, 10–12 mm and > 12 mm. Percentage PBN was determined for the node groups: 2–4, 5–7 and 8–11.

Canes were retained on the same vines as used for cane samples to determine correlations between PBN incidence scored in winter and the ratio of secondary to primary shoots and node fruitfulness in the following spring for the equivalent node positions. In 1981, 8 vines each of Shiraz, Pedro Ximenes and Sultana in the Roseworthy College vineyard, South Australia had 10 canes sampled and 8 x 10 node canes retained at pruning. After budburst, shoots at each node were scored as either primary or secondary, based on the phyllotaxic plane of the shoot relative to the cane (CARBONNEAU and CASTERAN 1979). At the same time, shoot number per node and bunch number per shoot (for each shoot type) were determined. In the 1984/85 season, mean bunch weight and total fruit weight by node position were also measured on primary and secondary shoots.

In 1981 and 1982, experiments were established to examine the effect of shoot thinning on the incidence of PBN to test the hypothesis that a large reduction in shoot number per vine increased shoot vigour and thus the incidence of PBN. Vigorous Shiraz grapevines at Roseworthy College were used in both years. For the preliminary experiment in 1981, four vines had 65 % of shoots removed 10 days after flowering and were compared with 4 control vines: 12 canes per vine were sampled in winter 1982 and 4 canes retained at pruning for spring measurements. In 1982, two levels of thinning (75 and 85 % of shoots removed) were compared with unthinned controls: thinning was carried out 10 d before flowering and the most vigorous shoots were retained. There were 4 single vine replicates per treatment in a randomised block design. In winter 1983, 10 canes per vine were harvested for determination of PBN and per cent nodes with persistent lateral shoot (nodes 2–10) and measurement of cane diameter.

Unless otherwise indicated, all tests for significant difference were conducted using single vine plots. Percentage data were transformed to degrees before analysis.

Results

The appearance of PBN on *V. vinifera* L. cultivars in Australia was identical to that described by LAVEE *et al.* (1981), MORRISON and IODI (1990) and PEREZ and KLIEWER (1990). The incidence of PBN at nodes 2 to 9 ranged from 0 to 16 % for 10 seeded cultivars and 0 to 2 % for 5 seedless cultivars in the Roseworthy College vineyard. The cultivars with the highest incidence were Shiraz of the seeded and Sultana of the seedless.

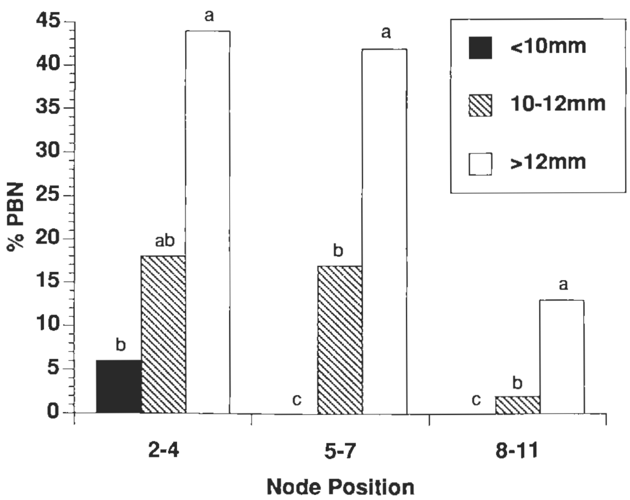

Fig. 1: Relationship between shoot vigour (as indicated by cane diameter) and node group on incidence of primary bud-axis necrosis (% PBN) of Shiraz (Virginia, South Australia, 1984).

Table 1

Difference in incidence of primary bud-axis necrosis (% PBN) of Shiraz vineyards of three vigour classes

Vigour class[a]	Vineyard location	Year	Shoot number sampled[d]	% PBN (mean of nodes 2 to 9) ± SE
High	Swan WA[b]	1985	20	27 ± 4
	Waikerie SA[c]	1981	40	16 ± 2
	Virginia SA[c]	1984	42	14 ± 3
Moderate	Waite SA[c]	1983	40	23 ± 3
	Roseworthy SA[c]	1980-1983	40 - 60	12 ± 2[e]
	Barossa SA[c]	1983	40	8 ± 1
	Waite SA[c]	1983	24	7 ± 2
Low	Barossa SA[b]	1985	40	8 ± 2
	Barossa SA[b]	1983	40	5 ± 1

[a] High = many, long shoots with many laterals, dense canopy; Low = few, short shoots with few laterals, open canopy. [b, c] Irrigated, non-irrigated respectively. [d] Most vigorous shoots (as canes) selected for all except Swan and Virginia, where a range of shoots was sampled. [e] 4-year mean. WA = Western Australia, SA = South Australia.

Table 2

Correlation of primary bud-axis necrosis (% PBN)[a] with shoot vigour as indicated by cane diameter, lateral shoot number and lateral shoot incidence) (Shiraz, Adelaide Plains[b], South Australia)

Shoot vigour index	Expt.	Shoot number sampled	Correlation coefficient	Level of significance
Cane diameter	81/1R[c]	120	+0.73	***
	81/5R	80	+0.32	**
	82/2R[c]	40	+0.58	***
	84/V	42	+0.73	***
Number of lateral shoots per cane	81/5R	80	+0.75	***
% nodes with lateral shoots[a]	81/1R[c]	120	+0.57	***
	81/5R	80	+0.81	***

[a] Mean value per cane for nodes 2 to 9. [b] Roseworthy (R) and Virginia (V). [c] Unthinned and thinned vines included in average. **, *** indicates significant at 1 and 0.1% levels, respectively.

The incidence of PBN was highest in the most vigorous vineyards (Tab. 1) and was positively correlated with indices of shoot vigour (cane diameter, total number of lateral shoots per cane, per cent nodes with lateral shoots) (Tab. 2). Thick shoots had a higher incidence of PBN than thin shoots at all node positions, and this difference was most pronounced at basal nodes 2 - 7 (Fig. 1). The incidence of PBN was higher at basal nodes than more distal nodes: this was observed over 4 seasons (Fig. 2). The difference between basal and distal nodes was magnified as shoot diameter increased (Fig. 1, Tab. 3).

On a per node basis for Shiraz, there was a strong relationship between PBN and the presence of a lateral shoot: that is, for any node with PBN, there was a 2 - 4 times greater chance of that node having a lateral shoot than not. Similarly, for any node with a lateral shoot, there was a 2 - 4.5 times greater chance of a bud at that node having PBN than not (Tab. 4).

There was a strong correlation between % PBN determined in winter and per cent nodes where the primary shoot was recorded as absent in the following spring (r = 0.84, significant at 0.1% level, pooled over 3 cultivars in 1981). The absence of a viable primary bud at basal nodes did not necessarily affect budburst (expressed as shoot number per node number) relative to distal nodes (Tab. 5). However, this absence did have an effect on node fruitfulness. For

Table 3

Effect of shoot thinning on incidence of primary bud-axis necrosis (% PBN) by node position and on cane diameter (Shiraz, Roseworthy, South Australia, 1982/1983)

Treatment	% PBN for nodes[b]: – 2 – 4	5 – 7	8 – 10	Cane diameter[c] (mm)
Control	26 a	10 a	2 a	11.4 a
75% shoot removal[a]	30 ab	17 ab	10 ab	12.7 b
85% shoot removal[a]	47 b	36 b	24 b	12.9 b

Means in columns followed by the same letter are not significantly different at the 5 % level. [a] Shoots removed 10 d before flowering in spring 1982. [b] Mean of 4 single vine replicates (% PBN for each node group calculated from 30 nodes per vine). Mean of 40 canes per treatment.

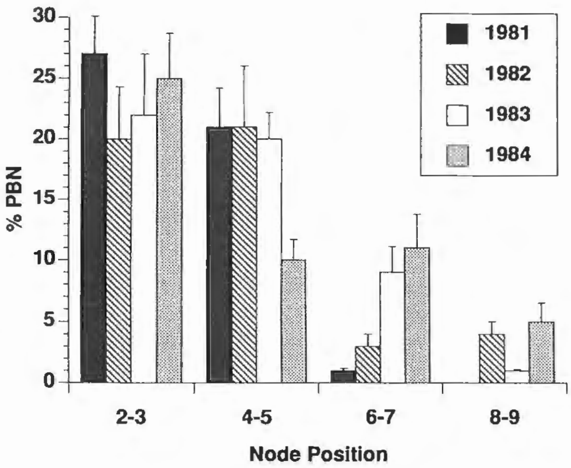

Fig. 2: Effect of node position on incidence of primary bud-axis necrosis (% PBN) of Shiraz for 1981-1984 (Roseworthy, South Australia): Mean of six single vine replicates (% PBN for each 2-node group calculated from 20 nodes per vine). Vertical bars indicate standard error.

basal nodes (2 - 5) relative to distal nodes (6 - 9) there was an increase in per cent nodes with 2 or more shoots and in the ratio of secondary to primary shoots (Tab. 5). The presence of PBN at a node may be expressed as twin shoots (where both shoots are secondary shoots with phyllotaxic planes at right angles to that of the spur or cane bearing them) (Fig. 3).

The greater proportion of secondary shoots, which are known to be less fruitful than primary, accounts for the fewer bunches per shoot at basal nodes relative to distal (in 1981, primary and secondary Shiraz shoots averaged 3.0 and 1.9 bunches per shoot respectively). The presence of PBN at a node did not significantly increase the fruitfulness of secondary shoots at the same node (in 1981, secondary Shiraz shoots with or without a primary shoot at the same node averaged 2.0 and 1.8 bunches per shoot respectively). Also, because bunches on secondary shoots tended to be smaller than those on primary, the presence of PBN at basal nodes was correlated with reduced fruit weight per node (Tab. 5).

Table 4

Proportion of buds[a] affected and not affected with primary bud-axis necrosis (% PBN) on nodes with and without laterals on two types of vine – unthinned and shoot thinned[b] (Shiraz, Roseworthy, 1982)

Vines	% buds normal	% buds PBN affected	Total
Unthinned			
- without laterals	85	4	89
- with laterals	2	9	11
Total	87	13	100
Thinned			
- without laterals	56	6	62
- with laterals	12	26	38
Total	68	32	100

[a] % derived from 60 shoots per treatment, nodes 2 to 9.
[b] 65 % of shoots removed 10 days after flowering.

Table 5

Comparison of basal nodes (2–5) with distal nodes (6–9) with respect to primary bud-axis necrosis (% PBN) and node fruitful ness (Shiraz, Roseworthy, South Australia, 1984/1985)

Variable	Node position 2 to 5[d]	6 to 9[d]	
% PBN[a]	18	4	**
Shoots/node[b]	0.9	1.0	ns
Bunches/shoot[c]	1.45	1.70	*
Mean bunch weight(g)[c]	125	195	**
Fruit weight/node(g)[c]	163	331	**
% nodes with ≥ 2 shoots/node[b]	20	0	na
Ratio secondary/primary shoots[b]	0.80	0.11	na

*, ** indicates means significantly different at 5 % and 1 % level respectively; ns = not significant; na = not applicable. [a, b, c] Variables measured in winter 1984, spring 1984 and autumn 1985 respectively. [d] Mean of 4 single vine replicates (% PBN for each 4-node group calculated from 40 nodes per vine; all other variables calculated from 16 nodes per vine.

Fig. 3: Twin shoots due to primary bud-axis necrosis. The remains of the primary bud are visible between two secondary shoots (Shiraz, Adelaide Plains, South Australia).

Shoot thinning (75 or 85 % of shoots removed) near flowering time significantly increased shoot vigour (measured as cane diameter (Tab. 3) and per cent nodes with lateral shoots (Tab. 4). Shoot thinning also increased the incidence of PBN at all node positions from 2 to 10 (Tab. 3). The severity of shoot thinning was positively correlated with PBN incidence. Furthermore, the increase in PBN caused by shoot thinning was associated with an increase in shoots per node, per cent nodes with 2 or more shoots and ratio of secondary to primary shoots and a decrease in shoot fruitfulness (as bunches per shoot) (Tab. 6).

Table 6

Effect of shoot thinning on incidence of primary bud-axis necrosis (%PBN), budburst and fruitfulness at nodes 2 to 13 (Shiraz, Roseworthy, 1981/82)

Variables	Control[d]	Shoot thinned[c,d]	
% PBN[a]	16	60	**
Shoots/node[b]	0.96	1.16	*
Bunches/shoot[b]	1.88	1.58	*
% nodes with ≥ 2 shoots/node[b]	10	36	na
Ratio of secondary to primary shoots[b]	0.25	2.3	na

*, ** indicates means are significantly different at 5 % and 1 % levels respectively; na = not applicable. [a,b] Variables measured in winter 1982 and spring 1982 respectively. [c] 65 % of shoots removed 10 d after flowering in spring 1981. [d] Means of 4 single vine replicates (% PBN calculated from 144 nodes per vine; all other variables calculated from 48 nodes per vine).

Discussion

Shiraz had the highest levels of PBN of the cultivars examined in South Australia. However, the levels for vigorous Shiraz vines in different regions of Australia, were always lower than those cited by Lavee *et al.*(1981), Naito *et al.* (1986) and Perez and Kliewer (1990), Morrison and Iodi (1990), who found up to 80 % of nodes with PBN. The highest levels in Australia were more comparable with those of low to moderate vigour vineyards in other countries. Nevertheless, the high incidence of PBN at basal nodes, particularly 2 - 5, is in agreement with these other authors, particularly Morrison and Iodi (1990) who did not find PBN more distal than node 8 in fruitful vineyards. The low incidence of PBN for Sultana and other seedless cultivars examined is in contrast to the high levels recorded for Thompson Seedless in California (Morrison and Iodi 1990) and Chile (Perez-Harvey 1991).

Vineyard vigour is often assessed subjectively but, using several correlated measures, we found positive correlations between vigour and PBN incidence. The difference in PBN incidence between thick and thin shoots was greatest at basal nodes, agreeing with Lavee *et al.* (1981).

This appears to be the first report of a positive correlation between the presence of a lateral shoot and incidence of PBN at the same node. It should therefore follow that, at least for Shiraz, nodes with lateral shoots will have lower fertility due to the loss of the primary bud. By contrast, for Sultana, the presence of strong lateral shoots on canes has been used as a high fertility indicator (Antcliff *et al.* 1958).

The correlation between node fertility and incidence of PBN has also been noted by others. Lavee *et al.* (1981) suggested that the endogenous factors leading to low inflorescence differentiation also initiates the processes leading to necrosis of the primary bud. On the other hand, Morrison and Iodi (1990) found no correlation between PBN and the degree of inflorescence primordia development in individual buds.

Our results suggest that the low fertility of basal nodes in vigorous vineyards and/or on vigorous shoots is a consequence of the replacement of the relatively fruitful primary shoot by one or more relatively unfruitful secondary shoot(s) at a node where the primary bud has aborted. The death of the primary bud at a node does not necessarily decrease budburst at that node: on the contrary, the better-than-normal development of the secondary buds, as a consequence of PBN (Morrison and Iodi 1990), may lead to the development of two secondary shoots at that node (Fig. 3). But, the better development of the secondary buds does not lead to their increased fruitfulness. As a consequence, bunches per node is reduced due to PBN, despite an increase in shoots per node.

The results of shoot thinning experiments further confirmed the strong correlation between shoot vigour and PBN. Increased severity of thinning resulted in increased vigour of the remaining shoots and increased incidence of PBN. It is noticeable that shoot thinning increased the incidence of PBN at all node positions examined, not just the basal nodes, indicating a systemic effect within the shoot. Shoot thinning also resulted in an increase in shoots per node and nodes with two or more shoots, and decreased bunches per shoot because of the increased ratio of secondary to primary shoots. Perez and Kliewer (1990), Perez-Harvey (1991) and Wolf and Cook (1991) concluded that the high incidence of PBN in Thompson Seedless was related to low levels of radiation within these canopies, particularly at basal nodes. Removal of 8 - 10 shoots per vine from the crown reduced the incidence of PBN (Perez and Kliewer 1990). However, shading of individual shoots did not induce more PBN in fruitful vineyards (Morrison and Iodi 1990). In our work, more severe shoot thinning than that used by Perez and Kliewer (1990) significantly improved the light environment of the remaining shoots but also increased the level of PBN (Tab. 6). Therefore, we conclude that any potential decrease in PBN resulting from the improved light environment was more than counteracted by the PBN-inducing effect of increased shoot vigour. We believe, like Morrison and Iodi (1990), that shading is not a major cause of PBN: any association between shading and PBN incidence is an indirect consequence of the poor light environment within the canopies of vigorous vines.

Under natural conditions, nodes proximal to node 6 have a higher incidence of PBN than distal nodes. Low fertility of basal nodes is common in many cultivars in vigorous situations. Also, there are many reports in the literature where the reduced node fertility which is a consequence of vigour-inducing treatments, eg. irrigation, has been attributed to increased canopy density and decreased light interception by basal nodes. Since there may not have been any detrimental effects on budburst (shoots per node) in these cases, those authors have assumed that the decreased node fertility is solely a consequence of reduced (primary) bud fruitfulness (expressed as a decrease in bunches per shoot). However, we propose that there is another possible cause of the reduction in bunches per shoot associated with high vigour, namely, an increased incidence of PBN which results in a change in the ratio of secondary to primary shoots, particularly at basal nodes where the effects of vigour-induced PBN appear to be most readily expressed: average shoot fruitfulness (bunches per shoot) is decreased by the replacement of the relatively fruitful primary shoots by less fruitful secondary shoots. Unless shoots are identified after budburst as primary or secondary by their phyllotaxy, this phenomenon will go undetected. One of the few reports of a vigour-induced effect on fertility attributed to an increase in the ratio of secondary to primary shoots, is that of CARBONNEAU and CASTERAN (1979): they did not propose any explanation for this phenomenon.

We recommend that the secondary to primary shoot ratio be determined along with the usual measurements of yield components in situations where an increase in vigour is associated with a decrease in yield to indicate the possible effect of PBN.

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