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Research Article

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Assessing the Dormant Bud Fruitfulness in Grapevines Spur for Yield Estimation

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Abstract

Bud dissection is generally done to determine potential bud fruitfulness (average number of potential inflorescence primordia), can be used to predict the next season's crop yield and make decision on pruning by analyzing fruitfulness of bud with respect to its position on cane/spur in order to achieve desired crop load. Comparison of potential inflorescence primordia with actual bunches with respect to each node give reliability on data from bud-dissection. The objective of this study was to detect potential inflorescence primordia and correlate it with observed bunches in vine. Bud dissection was carried out in a spur (having 4 buds from basal node towards apex) per vine of var. Himrod and var. Steuben from a vineyard of Warm Temperate Horticulture Centre, Kirtipur, Kathmandu, Nepal with the help of micro-dissection tools under stereo-microscope. It was revealed that cultivars 'Himrod' and 'Steuben' were both more prolific toward the buds located on distal nodes in comparison to buds situated on basal nodes; as a result, it was found that bud dissection can be used as a decisive tool for the detection of bud fruitfulness, thus for yield prediction and to develop appropriate management practice.

Keywords : Bud, bunches, dissection, potential inflorescence, primordia

Introduction:

Grape (*Vitis vinifera* L.) is a perennial woody plant, belonging to the family Vitaceae. Grape consists of axillary buds which are immature, compressed shoot covered by scales or bracts, often situated at the axil of a shoot and a leaf. Mostly three types of buds are mentioned namely; prompt buds, latent buds, and dormant buds (Keller, 2020). According to Gerrath and Posluszny (2007), prompt buds or lateral buds are responsible for development of lateral shoots. The latent buds remain dormant for several years as permanent part of the vines, and are only activated when the vines are severely pruned (Galet, 2000; Lavee & May, 1997). The dormant buds are the overwintering compound buds which consist of one primary bud in the middle, along with two secondary buds located on each sides (Gerrath & Posluszny, 2007; Pratt, 1974). The primary bud normally contains one or two inflorescence primordia depending upon varieties while, the secondary buds may have an inflorescence primordium which is comparatively smaller and inferior in quality as compared to that of the primary bud (Carroll, 2011). The compound bud, situated at the axil of leaves on the shoot has the potential to remain as a leaf bud (producing shoots or tendrils) or might convert into floral bud (Khanduja & Balasubrahmanyam, 1972). Boss and Thomas (2000), Palma and Jackson (1989) and Srinivasan and Mullins (1981) reported the development of an anlagen into an inflorescence and/or tendril (or, less frequently, a shoot) is influenced by amounts of carbohydrates and hormones as well as environmental condition.

The reproductive cycle in case of grapevine is biennial, since the inflorescences primordia for the coming season are formed in the axils of the leaves during the current season flowering at late spring or summer (Dunn & Martin, 2000). The inflorescence primordia goes through three phases of floral development- initiation, differentiation and development of flower in which two phases are completed in the current season, while the final phase starts at the current season, but only completes during the beginning of budburst in the coming season (Bennett, 2002; Mullins, Bouquet, & Williams, 1992;

Srinivasan & Mullins, 1981; Swanepoel & Archer, 2015; Watt, Dunn, May, Crawford, & Barlow, 2008).

Bud fruitfulness is defined as the ability of a bud to produce one or more inflorescence primordia. A bud is considered fruitful if it contains at least one inflorescence primordia. The bud fruitfulness differs between cultivars, regions and vintages due to cultural practices, nutritional condition, diseases and environmental situations (Li-Mallet, Rabot, & Geny, 2016). Bud fruitfulness is assessed through analysis of bud dissection, and counting inflorescence primordia during the dormant season (Carroll, 2011; Martinson, Lasko, & Bates, 2012). Grapevine bud dissection is generally done to determine potential bud fruitfulness, which is a destructive method, often laborious, time-consuming and costly but it can be used to predict the next season's crop yield and make decision on pruning by analyzing fruitfulness of bud with respect to its' position on cane/spur in order to achieve desired crop load (Vasquez & Fidelibus, 2006). Microscopic analysis of buds should not be destined for production, but those that would be suppressed in pruning (Monteiro, Malheiro, & Bacelar, 2021).

Comparison of potential bud fruitfulness with actual bud fruitfulness gives reliability on data from bud-dissection. Thus, potential bud fruitfulness helps in prediction of actual yield of a vine in the coming year thus, making informal decisions on demand and supply chain of market as well as severity and type of pruning. If the potential bud fruitfulness of basal buds come out to be low, additional canes may be retained making grapevines more bushy or spur pruned cultivars may require cane pruning to produce adequate yield and vice-versa. Peacock, Tartaglia, and Mills (2006) and Williams (2000) mentioned there were variations in actual yield justified by bud dissections ranging from 50% to 90%. The lower accuracy might be due to overlooking of tiny inflorescence primordia by inspectors, non-representative sample of vineyard, death of buds due to plant-mediated necrosis, injury-related necrosis, bud mites or several other physiological and environment factors (Carroll, 2011). Nevertheless, if the bud fruitfulness data is collected accurately, it could be effective in determining number of inflorescences per vine thereby total yield per vine (Carroll, 2011; Vasquez & Fidelibus, 2006).

The number of bunches per vine accounts 60% seasonal variation in yield, while number of berries per bunch and weight per berry explains 30% and 10% seasonal variation in yield (Clingeleffer, Martin, Dunn, & Krstic, 2001; Dunn & Martin, 2007; Guilpart, Metay, & Gary, 2014). Therefore, the potential yield of the following season can be predicted during the current season growth through bud dissection of selected cane in sample vine for a given vineyard (Christensen, 2000; Dunn & Martin, 2000).

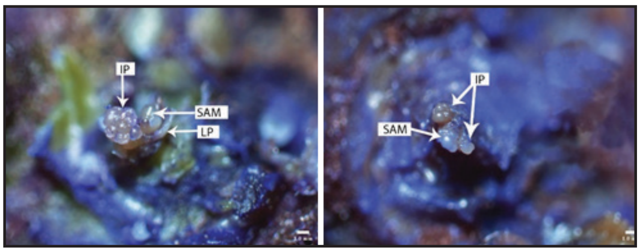
In high-humidity region of subtropical growth condition, spur pruning is generally recommended to make the vine less bushy in comparison to cane pruning. For spur pruning basal buds need to be more fruitful than apical buds. Therefore, bud dissection could be used as effective tool to identify basal bud fruitfulness thus, spur pruned/less bushy cultivars in the growing condition. The objective of the study was to assess potential bud fruitfulness of primary bud from basal to distal node through bud dissection and correlate the data of potential bud fruitfulness with observed bunch number in the grapevine.

Materials and methods:

Node samples were collected from a vineyard of Warm Temperate Horticulture Centre (WTHC), Kirtipur, Kathmandu, Nepal (27°-30'N latitude and 85°-15'E longitude and 1,320 masl altitude) from var. Himrod (~30 years old vines) and var. Steuben (~20 years old vine) during 2019/2020. The vines were selected randomly from a vineyard of 'Himrod' and 'Steuben' at the time of pruning (1st Dec., 2019). One spur per vine was selected and pruned off for bud dissection. Buds of node position 1-4 starting from base and associated node of each cane were preserved in 10% neutral buffer formalin in separate air-tight plastic tube with proper labeling and stored at room temperature until dissection was done.

As indicted in Noyce, Harper, Steel, and Wood (2015) procedures, the bud/node/cane/vine was dissected under stereo-microscope with the help of micro-dissection tools (Proscitech®, Queensland, Australia). Each sampled node compound latent bud was dissected for primary latent bud as it holds the most advanced inflorescence primordia (Sánchez & Dokoozlian, 2005). Secondary buds weren't considered for dissection since they typically burst late which delay bunch development, thus making them of little or no use in the growing condition.

The dissection was carried out from the top of the bud down towards the growing point, exposing leaf primordia and inflorescence primordia (IP) (Dahal, Bhattarai, Walsh, Midmore, & Oag, 2022). In accordance dissecting microscope images of Dahal et al. (2022), stages 4-5 were recognized. Primary buds with one or more inflorescence primordia were considered as fruitful buds and the quantity of inflorescence primordia within a primary bud served as the expression for the concept of bud fruitfulness (Dahal et al., 2022). After budburst, the



A B

Figure 1: A. A complete dissected bud of stage 5 containing an IP, a SAM and LP
B. A complete dissected bud of stage 5 containing IPs and a SAM; IP-Inflorescence primordia; SAM-Shoot Apical Meristem; LP-Leaf Primordia

number of bunches from each bud/node/cane/vine were assessed to determine actual fruitfulness i.e., observed bunch number of the vine. The linear regression was carried out to determine variation in actual bunches due to potential inflorescence primordia with respect to vine and regression significance was also tested. Furthermore, Root Mean Square Error (RMSE) was calculated to identify either the potential inflorescence primordia overestimated or underestimated observed bunches by using the given formula.

$$RMSE = \sqrt{\sum_{i=1}^{N} \frac{(Predicted_i - Actual_i)}{N}}$$

Where, Predicted = Potential Inflorescence Primordia, Actual = Observed Bunch, N = Number of observations

Results:

Bud fruitfulness with respect to node position

In var. Himrod, potential bud fruitfulness was increased with node position from basal node towards distal node. The mean IP of bud position starting from base 1, 2, 3 and 4 were found as 0.95±0.09, 1±0.15, 1.25±0.16 and 1.45±0.17, respectively (Figure 2). Similarly, the observed bunches on buds position from base 1, 2, 3 and 4 were averaged out 0.16±0.08, 0.23±0.07, 0.91±0.11 and 1.22±0.14 correspondingly (Figure 2).

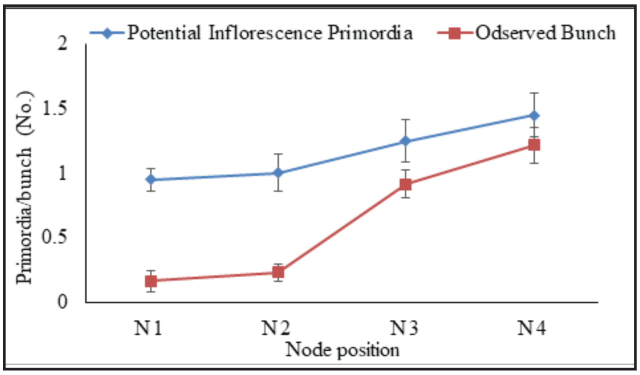


Figure 2: Effect of node position on potential inflorescence primordia and observed bunch in var. Himrod (Error bar represents the standard error of mean). N represent the node position with value from basal towards distal end.

The potential bud fruitfulness was also found to be increased from basal towards distal nodes in var. Steuben (Figure 3). The mean IP of each bud was determined to be 1.05±0.09, 1.45±0.14, 1.80±0.14 and 1.70±0.16 correspondingly, at node positions 1, 2, 3 and 4 from the basal towards distal. The average number of observed bunches located at node positions 1, 2, 3 and 4 from base were 0.13±0.04, 0.30±0.08, 0.97±0.08 and 1.41±0.11 respectively.

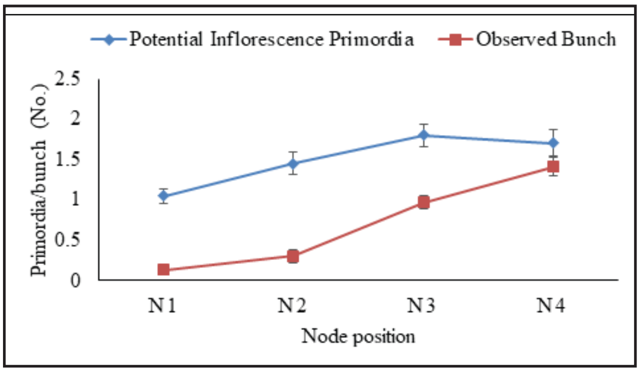


Figure 3: Effect of node position on potential inflorescence primordia and observed bunch in var. Steuben (Error bar represents the standard error of mean). N represent the node position with value from basal towards distal end.

Potential and observed fruitfulness

Potential IP and actual bunches were found to be correlated in both varieties. The variation in potential IP with respect to vine (n=20) was largely explained (R2 = 68.04%) by observed bunches in var. Himrod (Figure 4). Similarly, in var. Steuben, observed bunched accounted for 67.64% of the variation in the potential IP (Figure 5). The regression for both varieties were found to be significant with p-value 0.077811 and 0.248317 for 'Himrod' and 'Steuben' respectively. These results suggested that bud dissection to identify potential IP could be a good measure to forecast the actual bunch.

Additionally, the RMSE value for varieties 'Himrod' and 'Steuben' was calculated to be 0.6884 and 0.8159, respectively, which guaranted the precision of the predicted and actual bunches.

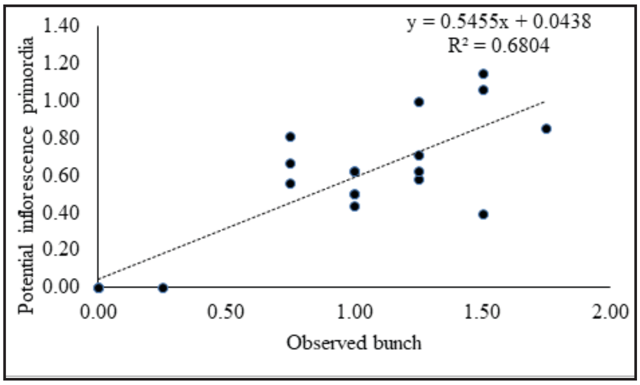


Figure 4: Linear regression showing the potential inflorescence primordia relation to observed bunch in var. Himrod.

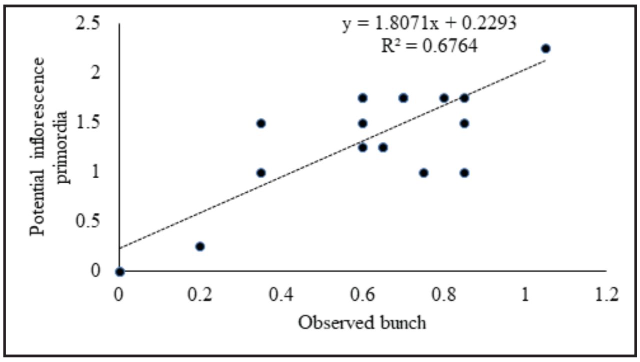


Figure 5: Linear regression showing the potential inflorescence primordia relation to observed bunch in var. Steuben.

Discussion:

The bud fruitfulness was found to be increased with increase in node position from basal nodes towards distal nodes in both varieties 'Himrod' and 'Steuben'. As most of the buds in node position 1st and 2nd did not get burst while majority of the buds present in node position 3rd and 4th got burst and observed to be more fruitful than basal buds. Similar bud fruitfulness pattern from basal to distal nodes was observed in var. Red Globe (Peacock et al., 2006). Depending on the cultivar and trellis method, bud fruitfulness can fall at distal node positions but was often lower at the 1st and 2nd node positions and increased throughout the shoot (Li-Mallet et al., 2016; Sánchez & Dokoozlian, 2005; Sommer, Islam, & Clingeleffer, 2000). The varieties 'Riesling' and 'Cabernet-Sauvignon' had fewer IP at the lower node positions upon dissection, as reported by Wohlfahrt, Collins, and Stoll (2019). Many researchers agreed that basal buds have lower levels of bud fruitfulness, which gradually increase to maximum values in the third and fourth buds before declining in many varieties (Khanduja & Balasubrahmanyam, 1972; Vasconcelos, Greven, Winefield, Trought, & Raw, 2009). In var. Thompson Seedless, buds situated on basal nodes (especially first node) considered to be less fruitful than the mid-cane region while, in case of var. Concord buds from first two basal nodes were less fruitful but buds on node position 3 to 6 from base were considered more fruitful (Martinson et al., 2012). Thus, the bud fruitfulness differs along the nodes of a cane or spur and it gives reason for spur pruning or cane pruning.

If the buds of basal nodes are less fruitful, the variety is cane pruned to retain all the buds along the cane but if the buds of basal nodes are considered more fruitful, spur pruning (retaining 3 to 6 basal buds) would not affect the potential yield. However, growers need to know accurate information about bud fruitfulness in reference to node position (Collins & Rawnsley, 2004). If the basal 2-4 buds are fruitful, leaving extra nodes on a spur or cane may suppress sprouting of basal buds due to apical dominance caused by auxins and nutrient pulling by distal buds and if the basal 2-4 buds are unfruitful, one or two kicker canes are added which caused vines to grow taller, making vines difficult to prune in the coming year (Peacock et al., 2006).

More than 90% of the variability in actual bud fruitfulness measured by counting clusters in var. Thompson Seedless were explained by potential bud fruitfulness, which was ascertained through bud dissection (Xylem, 2000). In contrary, a very poor correlation was found between potential and observed bud fruitfulness in var. Red Globe as the bud dissection method underestimated bud fruitfulness (Peacock et al., 2006). As indicated by RMSE value of var. Himrod and var. Steuben, potential IPs were discovered to overestimate actual bunches in every node position, this may be the result of some primary buds failing to produce normal bunches especially buds situated at basal region. Primary bud necrosis due to high temperature, other environmental factors, insect pests like mite infestation, nutritional factors, nutrient pulling by distal buds or vine physiology all contributed to the development of this condition. It was also caused by physical damage to primary buds sustained during vine management practices.

Conclusion:

Both cultivars 'Himrod' and 'Steuben' were considered to be more fruitful towards the buds situated on distal nodes up to 4th nodes. Bud dissection was found to be an important tool for the identification of bud fruitfulness thus, helps in effective management of vineyard and pruning intensity. Since the basal buds are failed to burst, the estimation based on bud dissection is less sensitive specially for the first two basal buds. The study area experienced high humidity thus spur pruned varieties which are less bushy having more fruitful buds on basal nodes are of great importance. It is suggested for yearly observation and series of data with more than 4 node positions starting from basal node of similar cultivars and other adaptable varieties for further recommendation.

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Declaration of conflict of interest and ethical approval:

The concept of the paper was designed by K.C. Dahal and P. Poudel documented, analyzed the data and drafted this manuscript. All other authors have contributed to improve the manuscript. We declare that the authors don't have competing financial or personal interest that could appear to influence the work reported in this paper.

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