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Effect of Shoot Orientation on Growth, Biochemical Changes and Fruitfulness in Thompson Seedless (*Vitis vinifera* L.) Grapes

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Abstract: Studies on biochemical changes and fruitfulness in relation to shoot orientation of horizontally, downward and upward position of shoots were carried out in Thomson Seedless (*Vitis vinifera* L.) grapes at the experimental farm of National Research Centre for Grapes, Manjri Farm, Pune during the year 2005-2006. The results revealed that the maximum shoot length and higher shoot diameter were recorded at upward positioned shoot. Increase in shoot length, numbers of leaves and leaf area was also found maximum in the same treatment. The upward positioned shoots recorded higher chlorophyll content. However, the carbohydrate content in petiole was higher in downward positioned shoots than the horizontal and upward positioned shoots. The higher photosynthesis and conductance was recorded in downward positioned shoots. The transpiration rate was higher at shoot positioned horizontally and vertically as compared to downward shoot positioned. The internal CO_2 was increased with the increase in leaf age and it was higher in shoot positioned in upward direction. Higher protein content was recorded in leaf in vertically positioned shoots. There was reduction in reducing sugar content with the increase in age of the vine. Maximum bud fruitfulness was recorded in the vertically positioned canopy and the most fruitful zone was recorded 5th to 7th bud in Thompson Seedless grapes.

Key words: Thompson Seedless, canopy architecture, shoot length, photosynthesis, carbohydrate, protein, fruitfulness

INTRODUCTION

Grape (*Vitis vinifera* L.) is one of the major important commercial fruit crop grown in India for table, raisin, wine and juice purpose. In grape, yield is directly dependent on the fruitfulness of the variety. Fruitfulness of any variety is of considerable importance in viticulture as it has direct bearing on productivity of vines (Reddy and Prakash, 1990). Fruitfulness is the quantitative measure of the potential of a vine to produce fruit. It is the consequence of the transformation of vegetative primordial into reproductive primordial (Satyanarayana and Shikhamany, 1986). The fruit in the form of inflorescence primordial estimated before or after the bud burst. After the bud burst, estimation of fruitfulness is often expressed as percent fruitful shoots and is defined as the percentage of nodes producing shoots at which at least one shoot is fruitful (Sommer *et al*., 2000). A shoot is considered to be fruitful when it carries one or more inflorescence (Antcliff and Webster, 1955). Early steps in the reproductive cycle of grapevine include induction and subsequence initiation of inflorescence in the season proceeding flowering and development of fruit (Sommer *et al*., 2000). The induction appears to be a pre-requisite for successful inflorescence initiation (Lavee *et al*., 1967; Buttrose, 1974).

Different varieties behave differently for fruitfulness depending on environment, training system and position of shoot, pruning time etc. Among these practices, shoot orientation plays an important role in fruitfulness. The light environment within grapevine canopies is affected by the distribution and

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density of the leaf area within the canopy (Smart, 1985; Nabrouk and Sinoquet, 1997). Increase in the light exposure in the canopy improves vine yield, berry composition and subsequently the wine quality (Narbrouk and Sinoquet, 1998). This is generally possible when sufficient light penetrates into the canopy. The fruitfulness in any given canopy is mainly dependant on the amount of light received by the individual bud on the cane. Leaf area plays an important role in contribution for food formation in the form of photosynthesis through light. But, excess leaf area leads to the higher vigor of the shoot that ultimately leads to the reduction in fruitfulness. The process of bud differentiation during foundation phase determines fruitfulness in grape. It is also dependent on CHO content and other nutrient contents through biochemical reaction. The utilization of light is governed by the canopy arrangements. In Maharashtra, the vines are pruned twice in a year, once after the harvest of fruits is called back pruning and during October for fruits. The fruitfulness takes place on after back pruning. During this period light is more important for effective fruitfulness where the orientation plays a major role. Considering these factors, the present investigation was aimed to study the effect of different shoot orientation systems (canopy architecture) in relation to biochemical changes and fruitfulness in canes.

MATERIALS AND METHODS

The present investigation was carried out at the research farm of National Research Centre for Grapes, Manjri farm, Pune during the year 2005-2006. Five years old vines of Thompson Seedless grafted on Dog Ridge rootstock were selected for the study. The vines were spaced at 10 feet between row and 6 feet between the vines and trained to flat roof gable system of training. All the vines received uniform cultural practices during the period of study. After April pruning the shoot thinning was done at 4-5-leaf stage and healthy, disease free and vigorous shoots were retained. The newly growing shoot was trained as per the treatments. The shoots were then positioned/ trained as upward, downward and horizontal under each treatment. The position of the shoot was maintained during the entire season. The observations on growth parameters viz., shoot length, shoot diameter, inter nodal length, number of leaves, leaf area and rate of photosynthesis recorded during different growth stages are as follow.

Growth Parameters

The cane diameter was recorded at 4th to 5th inter nodal position with the help of vernier caliper. To study the bud fruitfulness of cane under microscope, the matured and uniform canes from each treatment were selected. The bud at each position was dissected by cutting at half position with sharp blade and examined under stereo binocular microscope. The primordial visible under microscope were categorized into flower primordial and vegetative buds. The growth parameters were recorded manually with the help of measuring tape and vernier caliper. However, Leaf area was measured with the help of leaf area meter and the values were expressed as cm^2. Infra Red Gas Analyzer (IRGA) model No. LI 6400 was used to record observations on photosynthesis activity of the leaf, transpiration rate, stomata conductance and internal CO_2 concentration under different shoot orientation. The observations by IRGA were recorded during the sunshine hours at natural epiphytotic condition. The experiment was conducted in randomized block design having three treatments and seven replications. Five vines were taken under each replication. The data was analyzed statistically as Panse and Sukhatme (1985).

Biochemical Analysis

The different parts of the vine (leaf and petiole) were collected at different growth stages for biochemical analysis. The methods followed for each parameter while doing biochemical analysis are given below.

Total Carbohydrate Contents on Dry Weight Basis (mg g^{-1})

Total carbohydrate content was estimated as per the procedure of Anthrone method, the principle of which carbohydrates are first hydrolyzed into simple sugars using dilute hydrochloric acid. In hot acidic medium glucose is dehydrated to hydroxy methyl furfural. This compound forms with anthrone a green colored product with absorption maximum at 630 nm (Sadashivam and Manickam, 1992).

Protein Estimation (by Lowry's Method) (mg g^{-1})

Protein estimation was carried out in different parts of the plant as per the methods followed by Lowry's. The estimated protein was expressed in mg g^{-1} samples.

Chlorophyll Content on Fresh Weight Basis (mg g^{-1})

For estimation of chlorophyll, 1 g fresh sample was grinded by adding 20 mL of 80% acetone and was then centrifuged at 5000 rpm for 5 min. The volume was then made up to 100 mL with 80% acetone. The absorbance of the solution was then read at 645, 663 and 652 nm against the solvent (80% acetone) blank.

Reducing Sugar Content (mg g^{-1})

The reducing sugar was estimated by following Dinitrosalicylic acid method and was expressed in terms of mg g^{-1}.

RESULTS AND DISCUSSION

The data analyzed for different parameters are discussed in the text given below.

Growth Parameters

Significant differences were recorded for shoot length. The shoot length was higher (108.34 cm) in upward positioned shoots followed by horizontal and downward positioned shoots (Table 1). The downward positioned shoots had lowest shoot length. The results of this experiments confirms the previous observations recorded by Lovisolo and Schubert (2000), May (1966), Kliewer *et al.* (1989) and Schubert *et al.* (1995a, b). Higher shoot diameter of 7.98 mm and medium inter nodal length was recorded in the shoots positioned upward as compared to the downward positioned shoots. This helps in the receiving uniform sunlight by every bud on the cane. The increase in shoot length was related to the number of leaves/shoot in the same treatment. Higher leaf area was recorded in the upward positioned shoots followed by downward positioned shoots.

The chlorophyll content in leaf gives an indication of the efficiency of leaf to prepare food through photosynthesis. Significant differences were recorded for the chlorophyll content in leaf. Higher chlorophyll was noticed in shoot positioned upward followed by downward positioned shoots at 45 day after back pruning. This might be due to the exposure of all the leaves to the sunlight. There was increase in chlorophyll content with the increase in days after pruning. However, the transpiration rate was more in the shoots positioned upward during back pruning while it was higher in horizontal positioned shoots during fruit pruning (Table 2). Carbohydrate content was increased with the increase in petiole age. Higher carbohydrate was recorded in downward positioned shoots compared to other canopy types. Reducing sugar in petiole was higher in horizontally placed shoots than in other treatments. A difference in the protein content was recorded in the petiole. Higher protein content in petiole was recorded in downward positioned shoots followed by upward while the least protein content was recorded in horizontally placed shoots.

Table 1: Effect of shoot positioning on growth performance in Thompson Seedless grapes (at 75th day after fruit pruning)

Shoot position	Shoot length (cm)	Shoot diameter (mm)	Inter nodal length (cm)	No. of bunches/vine	Leaf area (cm^2)
Downward	78.73	6.70	4.93	21.90	123.40
Horizontal	100.94	7.84	5.99	36.80	116.39
Upward	108.34	7.98	5.07	48.90	145.54
$LSD_{0.05}$	7.21	0.37	0.29	6.41	5.95

Table 2: Effect of shoot positioning on photosynthesis, stomatal conductance and transpiration rate after back pruning in Thompson Seedless grapes

Shoot position	Photosynthesis (μmol CO_2 cm^{-2} sec^{-1})	Stomatal conductance (mm sec^{-1})	Transpiration rate (mmol sec^{-1})	Internal CO_2 concentration (μmol CO_2)
Downward	10.44	0.228	3.01	176.90
Horizontal	8.39	0.125	3.26	182.79
Upward	8.01	0.127	3.60	189.40
p = 0.05	0.06	0.001	0.03	1.67

Table 3: Effect of shoot positioning on chlorophyll content, carbohydrate, reducing sugars and proteins after back pruning in Thompson Seedless grapes

Shoot position	Chlorophyll in leaf (mg g^{-1}) on fresh weight basis	Carbohydrate in petiole (mg g^{-1}) on dry weight basis	Reducing sugar in petiole (mg g^{-1}) at 45th day	Protein in petiole (mg g^{-1}) at 45th day
Downward	1.92	1.28	1.64	2.60
Horizontal	1.54	0.80	1.96	2.20
Upward	2.25	1.16	1.68	2.50
p = 0.05	0.03	0.03	0.04	0.04

Table 4: Effect of shoot orientation on bud fruitfulness at different bud position in Thompson Seedless grapes (after back pruning)

	Bud position									
Shoot position	1	2	3	4	5	6	7	8	9	10
Downward	20.00	23.40	32.40	42.60	36.00	42.50	38.20	32.60	20.20	22.40
Horizontal	17.90	18.60	35.50	36.70	48.50	48.60	36.00	38.60	32.00	28.20
Upward	20.70	21.40	36.60	56.00	76.01	80.41	74.00	60.00	48.80	44.00
p = 0.05	0.43	0.68	0.78	1.58	1.60	2.40	2.60	2.84	0.90	1.70

The rate of photosynthesis was higher during back pruning than in fruit pruning time. During fruit pruning, higher rate of photosynthetic activity was recorded in upward positioned shoots compared to other type. The leaf borne on upward positioned shoots having erectness might have helped to harvest maximum sunlight. The stomatal conductance was significantly differed in different shoot positions. Higher stomatal conductance was recorded in upward positioned shoots however; it was reduced in downward positioned shoots. These results are in accordance with the results obtained by Lovisolo and Schubert (2000). The internal CO_2 content was higher during back pruning. The reduced CO_2 content was recorded in downward positioned shoots during back pruning. The internal CO_2 concentration in vacuoles was increased with increased in stomata conductance during back pruning (Table 3).

The bud differentiation differed significantly among the different shoot position. Maximum bud fruitfulness was recorded in the shoots positioned upward. Among the different treatments studied, the maximum bud differentiation was recorded at 6th bud position in upward position shoots followed by 5th and 7th bud position compared to horizontal and downward positioned shoots (Table 4). The minimum bud fruitfulness was recorded at basal bud (Somkuwar *et al*., 2006). The shoots positioned downward produced minimum number of bunches per vine during fruit pruning. In general, maximum bud differentiation was recorded in 5th to 7th bud position. These results are in conformity with the results of Satyanarayana (1978), who reported the most fruitful buds in the middle portion of the canes (5 to 7 bud position). The higher percentage of fruitfulness in upward positioned shoots indicates that these type of shoots receives maximum sunlight which helps in bud differentiation in that bud.

Table 5: Correlations between different parameters

Parameters	1	2	3	4	5	6	7	8	9	10
Bunch No.	1	0.395	-0.292	0.162	-0.273	-0.909**	-0.854**	0.851**	0.939**	0.868**
Chlorophyll content		1	0.737**	-0.810	0.727**	-0.106	0.053	0.456*	0.527*	0.748**
Carbohydrate			1	-0.959**	0.971**	0.574**	0.695**	-0.198	-0.158	0.136
Reducing sugar				1	-0.959**	-0.460*	-0.591*	0.081	0.029	-0.244
Protein					1	0.568**	-0.688**	-0.222	-0.146	0.124
Photosynthetic rate						1	0.985**	-0.852**	-0.886**	-0.727**
Stomatal conductance							1	-0.790**	-0.806**	-0.609**
Internal CO_2 conc.								1	0.932**	0.859**
Trans. rate									1	0.944**
Bud position										1

1: Bunch No., 2: Chlorophyll content, 3: Carbohydrate, 4: Reducing sugar, 5: Protein, 6: Photosynthetic rate, 7: Stomatal conductance, 8: Internal CO_2 conc., 9: Trans. rate and 10: Bud position, *: Correlation is significant at 0.05 levels, **: Correlation is significant at 0.01 levels

CORRELATIONS

In Table 5 the positive and negative correlations were found between biochemical, physiological and yield parameters due to shoot orientation in Thompson Seedless grapes. Among the different parameters bunch number was significantly having positive correlation with photosynthetic rate, internal CO_2 concentration in leaf, transpiration rate and bud position. However, it was having strong negative relationship with Stomatal conductance. Chlorophyll content was having significantly positive correlation with carbohydrate content, protein content in leaves, bud position and internal CO_2 concentration and transpiration rate. The carbohydrates were shown significantly positive relations with protein content in leaf, photosynthetic rate and Stomatal conductance. Similarly, reducing sugar content in leaf was negatively correlated with protein content, photosynthetic rate and Stomatal conductance. Protein content in leaves was having positive relationship with photosynthetic rate but strong negative correlation with Stomatal conductance. Photosynthetic rate was strongly associated with Stomatal conductance, transpiration rate, bud position, however, negative association with internal CO_2 concentration, transpiration rate and bud position. Internal CO_2 concentration in leaf was having strong association with transpiration rate and bud position.

In brief, the shoot position was having positive relationship with bunch number, chlorophyll content, internal CO_2 concentration and transpiration rate. However, it was negatively correlated with photosynthetic rate and Stomatal conductance. From this study, it can be concluded that bud position is an important factors, which controls the biochemical, physiological and fruitfulness. Upward orientation of shoot resulted in high fruitfulness, chlorophyll content in leaves and finally the maximum bunch number. Therefore, upward shoot orientation is found to be beneficial to increase the production in grape.

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