

Rootstocks influence the Growth, Biochemical Contents and Disease Incidence in Thompson seedless Grapevines

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ABSTRACT

The alterations in growth, powdery mildew and anthracnose incidence and biochemical changes in Thompson seedless grapevines grafted on Dog Ridge and 110 R rootstocks in comparison to the own rooted grape vines was investigated. Bud sprouting after pruning was achieved earlier in case of own-rooted vines. However, the vine growth pattern studied in terms of the shoot length, internode length, shoot diameter and leaf area was highest in case of vines grafted on Dog Ridge. Foliar powdery mildew and anthracnose incidence was highest in vines grafted on Dog Ridge and own-rooted vines, respectively. The disease incidence was recorded least in vines grafted on 110 R. The biochemical analyses were also influenced by the rootstocks. The vines grafted on Dog Ridge recorded the highest reducing sugars and protein contents and the least total sugars and phenolic contents. The vines grafted on 110 R topped in total phenolic contents and other phenolic derivatives.

Keywords: grape, rootstocks, canopy architecture, diseases, phenolics.

INTRODUCTION

Grape (*Vitis vinifera* L.) is one of the major important commercial fruit crops of India with 1, 06,000 ha area under cultivation and production of 974000 MT (Indian Horticulture Database, 2010). Table grapes occupy more than 90% of the area under grape cultivation in India. Amongst the table grape varieties, Thompson Seedless is a popular cultivar for both fresh consumption (local and export market) and raisin making. Traditional grape cultivation in India involves growing commercial varieties of grapes on own roots. Due to increasing problems of soil salinity, bad quality water and drought condition, the severe decline in the productivity of

vines raised on their own roots in semi arid regions of Maharashtra and North Karnataka have been reported. Owing to the conditions of salinity and drought as a major reason, establishment of grape vineyards on rootstock were became mandatory. In response to this, the use of rootstocks is increasing in grape growing of the country. The primary use of rootstocks is for pest resistance (Pongracz 1983 and Howell 1987). The major functions of the grapevine root system are vine water relations, the uptake and translocation of nutrients, the synthesis and metabolism of plant growth substances and the storage of carbohydrates (Richard 1983). Reynolds and Wardle (2001) outlined seven major criteria for choosing rootstocks in the order of importance. Numerous reports have also proved that rootstock affect vine growth, yield and fruit quality. These effects take place due to the interaction between environmental factors and the physiology of scion and rootstock cultivars. Grape rootstocks have a primary effect on vine size measured in terms of pruning weights, as indicated by Pongraz (1983), Carbonneau and Casteran (1987), Howell (1987) and Pouget (1987). An increase in vine size when the canopy length is fixed, results in crowding of shoots and internal canopy shading (Shaulis, 1982). Most secondary effects of rootstocks are mediated through their influence on vine size and internal canopy shading. The difference in performance of vines grafted on rootstock and own rooted vines is experienced by the grape growers. In the tropical parts of the country where the grapes are being grown for table as well as wine purpose, canopy development is an important aspect for the production of quality grapes and also to minimize the disease incidence.

For sustainable viticulture, it is important to know the interactions among rootstocks, different soil characters and scion productivity (Keller et al., 2001). A rootstock found to be beneficial for one cultivar may not be universally advantageous for others, as the interaction of stock and scion influences the vine performance more than the stock or scion alone (Hartmann et al., 1993). With increased awareness about the use of rootstocks in overcoming the adverse effects of drought and salinity, growers started using Dog Ridge rootstock for the cultivation of Thompson Seedless grapes. However, in the tropical and subtropical climate of India, Dog Ridge induced more vegetative vigor in the scions, which reduced the bud fruitfulness of Thompson Seedless in the long run. In this context, there was an increased demand for an alternative rootstock that would be suitable for Thompson Seedless in the tropical and subtropical climate of the Indian subcontinent. Therefore another rootstock 110 Richter was introduced to overcome these problems.

Use of Dog Ridge and 110 R rootstocks is gaining importance in Indian viticulture and the majority of vineyards are being established on these rootstocks to overcome the adverse effects of abiotic stresses such as drought and salinity. In addition, rootstocks are known to influence the growth pattern of scions after grafting and some may even induce resistance to diseases by various physiological and biochemical changes in grafted vines (Satisha et al. 2005). It also influences the accumulation pattern of phenolics and other important secondary metabolites in the scion leaves grafted onto them and impart tolerance against grape fungal diseases. Grape species and their cultivars differ in their susceptibility to powdery mildew infection (Peros et al 2006). The rootstocks alter the canopy architecture of a grape vine thereby creating favorable or unfavorable microclimate for the development of various diseases. This also alters the biochemical composition of a grapevine as a whole and of final harvest. Hence, this study was initiated with the objective to evaluate the changes in growth behavior, biochemical composition and disease incidence of Thompson Seedless grafted onto Dog Ridge and 110 R rootstocks, with own rooted Thompson Seedless as a control.

MATERIALS AND METHODS

The trial was conducted at the farm of National Research Centre for Grapes, Pune from 2008-2010. The grape rootstock Dog Ridge and 110 R along with own-rooted vines of Thompson seedless were planted during the year 1999 with 3.0 m distance between the rows and 1.8 m between the vines and the grafting of table grape variety Thompson seedless was performed during October 1999. The experimental site is situated in Mid West Maharashtra at an altitude of 559 m above mean sea level; it lies on 18.32°N latitude and 73.51°E longitudes. The climate is mild to slightly dry. The soil is heavy black with pH 7.75 and EC 0.46 dS m⁻¹. The vines were trained on 'extended Y' system of training with four cordons (H shape) developed horizontally with vertical shoot positioning. The height of cordons from the ground surface was 1.20 m and was separated 0.60 m wide cross arms. The distance from the fruiting wire to the top of foliage support wire was 0.60 m.

Growth parameters

The investigation was carried out after April pruning. The canes were pruned during mid-April leaving only a single visible bud at the base on a cordon. The days taken for sprouting were recorded on day to day basis by visual observations. The shoot length was measured at 30, 60 and 90 days after pruning (DAP) with the help of measuring tape. Internode length, shoot

diameter and leaf area were also measured after 90 DAP with the help of measuring scale, vernier caliper and leaf area meter (CID, Inc), respectively. Days taken for cane maturity was also recorded by visual observation.

Disease assessment

Powdery mildew incidence and anthracnose were assessed in situ by visual observations as the percent number of the leaves and canes infected at 90 days after pruning.

Biochemical analyses

The total sugar content was measured by hydrolyzing the polysaccharides into simple sugars by acid hydrolysis and estimating the resultant monosaccharides by Anthrone method (Hedge and Hofreiter 1962). Quantity of the carbohydrate was expressed as glucose equivalent as determined from linear regression obtained by plotting (ΔA) against known standard glucose concentration.

Reducing sugars were estimated by using Dinitrosalicylic Acid (DNSA) method (Miller 1972). The results were expressed as glucose equivalent as determined from linear regression obtained by plotting the absorption (ΔA) against known standard glucose concentration.

Proteins were estimated by using Lowry et al., (1951) method. The blue colour developed by the reduction of the phosphomolybdic- phosphotungstic components in the Folin-Ciocalteu reagent by the amino acids tyrosine and tryptophan present in the protein plus the colour developed by the biuret reaction of the protein with the alkaline cupric tartarate are measured in Lowry's method. The blue colour developed was read at 660nm on UV-visible spectrophotometer (Shimadzu- 1601). The quantity of protein was determined from linear regression obtained by plotting (ΔA) against known standard BSA (Bovine serum albumin- Fraction V) concentration. The proteins were expressed as mg g^{-1} fresh weight of sample.

Total phenolic content: One gram fresh samples of leaf were homogenized in 80% ethanol repetitively and final volume made up to 10.0ml. The mixtures were sonicated for 15min for complete extraction and centrifuged at 9000rpm for 10min. The supernatants were utilized for analysis of total phenolic contents and other phenolic derivatives. The total phenolic contents were determined by Folin-Ciocalteu method (Singleton and Rosi 1965), using gallic acid as the standard. The total polyphenolic concentration was calculated from a calibration curve using gallic acid as a standard ($0-10 \text{ mg L}^{-1}$). Data were expressed in mg g^{-1} GAE.

Total flavan-3-ol content was estimated using DMACA method (Arnous et al. 2001). The concentration of total flavan-3-ols was expressed as the CE (mg g⁻¹) of the fresh sample.

Flavonol content was estimated by measuring the absorbance of the extract at 360 nm after the addition of 2% HCl (Mazza 1999) and was expressed as the quercetin equivalent (QE mg g⁻¹).

Total flavonoids were determined colorimetrically, following the procedures proposed by Kim et al. (2003). The amount of total flavonoids was expressed as the catechin equivalent (CE, mg g⁻¹).

RESULTS

The results on days taken for sprouting (Table 1) revealed that grafted Thompson seedless vines take significantly more time to sprout (13-14 days) after pruning. Own-rooted vines exhibit the trend of early sprouting (10 days) after pruning. However, the shoot growth lead in case of grafted vines and the vines grafted on Dog Ridge exhibit more vigor. The results on shoot length measurements make it clear that at all the stages of investigation i.e. 30, 60 and 90 DAP, the shoot lengths were in the sequence of own-rooted Thompson seedless vines < vines grafted on 110R < vines grafted on Dog Ridge. The internode length, shoot diameter and leaf area measurements at 90 DAP (Table 1) exhibited the same pattern. The days taken for cane maturity were significantly more in vines grafted on Dog Ridge (84.51 days) followed by 110R (79.80 days) and was least in case of own rooted vines (74.59 days).

The data on disease incidence on Thompson seedless grapevines (Table 1) revealed that the powdery mildew incidence in case of vines grafted on Dog ridge (3.19%) was significantly higher than the vines grafted on 110R (1.57%) and own-rooted vines (2.08%). There was no significant difference in anthracnose infection on leaves. However, the anthracnose infection of the canes was the highest in own rooted (2.00%) Thompson seedless followed by vines grafted on 110R (1.20%) and the least in case of the vines grafted on Dog Ridge (0.80%).

The biochemical composition of the leaves at 90DAP (Figure 1) revealed that the total sugars were significantly more in case of own-rooted and 110R grafted vines than the vines grafted on Dog Ridge. Reducing sugars and protein contents were significantly higher in case of the vines grafted on Dog Ridge. The results on phenolic compounds in the leaves (Figure 2) indicated that the total phenols, flavan-3-ols, flavonols and flavonoids contents were

significantly high in the vines grafted on 110R. Own-rooted vines were at second position and the vines grafted on Dog Ridge had the least phenolic contents.

The correlation coefficients (Table 2) between the growth parameters, biochemical composition and disease incidence of the vines revealed that the days taken for sprouting after pruning had no significant impact on further growth, biochemical composition as well as disease incidence of the vines. The vine vigor measured in terms of shoot length, internode length, and leaf area were significantly inter-related and had significant correlation with foliar powdery mildew incidence and anthracnose infection of canes with mixed influence on biochemical composition. Disease incidence of Thompson seedless vines had no significant correlation with biochemical composition of the leaves at 90DAP.

DISCUSSION

The effect of rootstocks on days taken for sprouting were highly significant that are in accordance with the reports of several workers in the past, who established the influence of rootstocks on bud burst. Satisha et al. (2010) reported that Thompson seedless grafted on Dog Ridge take significantly more time to sprout after pruning. Prakash and Reddy (1990) reported the effect of different rootstocks on bud break in the grape cultivar Anab-e-shahi, with a significant effect of rootstocks on bud burst. These results are similar to the current findings of delayed bud sprouting on Dog Ridge rootstock. In contrast, Tangolar and Ergenolu (1989) found that time required for bud break was not significantly affected by rootstocks. Increase in shoot length in grafted vines was in agreement with the finding of Sommer et al. (1993). The increase in shoot length and cane diameter was reported by Satisha et al. (2010) also in Thompson seedless grafted on Dog Ridge. Bica et al. (2000) found that the effect of rootstock was significantly higher on leaf area.

The results on biochemical composition exhibited significant difference due to grafting of Thompson Seedless on Dog Ridge and 110R rootstocks. This might be due to the alterations in the growth pattern of the vines by rootstocks as well as the differences in their uptake of nutrients and water from soil solution, as root development patterns vary with the rootstocks. Most secondary effects of rootstocks are mediated through their influence on vine size and internal canopy shading. Previous research has found a relationship between canopy structure and sunlight exposure and subsequent phenolic contents (Marbrouk and Sinoquet 1998). In addition, a relationship between variations in vine growth and differences in total phenolic levels

(measured as absorbance at 280 nm) has been reported (Lamb et al. 2004, Cortell et al. 2005). Influence of rootstocks on changing pattern of phenolic compounds in Thompson seedless was reported by Satisha et al. (2008) confirms the results of the present investigation.

Rootstocks not only perform a critical function in water and nutrient assimilation (Rom 1996), but also provide increased tolerance to insect pest and diseases of grapes (Ren and Lu 2002). In the present investigation use of Dog Ridge rootstock found increase in foliar powdery mildew disease susceptibility. However, the vines grafted on 110R rootstock exhibited significantly low powdery mildew incidence. Satisha et al. (2008) observed less powdery mildew infection in vines grafted on 110R rootstocks. Variation in the incidence of disease in Thompson seedless grafted onto different rootstocks may have been due to the genetic makeup of the rootstock, which may have indirectly contributed to the synthesis of various secondary metabolites. The results on reduced anthracnose incidence on grafted Thompson Seedless vines were similar to the finding of Ren and Lu (2002) where they reported increased resistance of Florida hybrid grapes to anthracnose disease.

CONCLUSIONS

The rootstock Dog Ridge and 110R were found to alter the growth of the Thompson seedless grapevines as compared to the own-rooted vines. The rootstock Dog Ridge imparted more vigor to the scion followed by 110R. Although the own rooted vines sprouted earlier, they were less vigorous. The results on biochemical composition and powdery mildew and anthracnose disease incidence of vines were also influenced due to use of rootstocks. These traits may have significance in selection of rootstock considering the local soil and climatic conditions.

REFERENCES

- Anonymous. 2008. Crop Profile – Grape, NRC for Grapes, Pune.
- Arnous, A., Makris, D. P. and Kefalas, P. 2001. Effect of principle polyphenolic composition in relation to antioxidant characteristics of aged red wines. *J. Agric. Food Chem.* 49: 5736-5742.
- Bica, D., Gay, G., Morando, A., Soave, E. and Bravdo, B. A. 2000. Effects of rootstock and *Vitis vinifera* genotype on photosynthetic parameters. *Acta. Hort.* 526: 373-379.
- Carbonneau, A. and Casteran, P. 1987. Optimization of vine performance by the lyre training system. In: Lee, T. (ed.) *Proc. 6th Aust. Wine Ind. Tech. Conf.*, Australian Industrial Publishers, Adelaide, Australia, pp. 194-204.

- 213 Cortell, J. M., Halbleib, M., Gallagher, A. V., Righetti, T. L. and Kennedy, J. A. 2005. Influence
214 of vine vigour on grape (*Vitis vinifera* L. cv. Pinot Noir) and wine proanthocyanidins. J. Agric.
215 Food Chem. 53: 5798-5808.
- 216 Hartmann, H. T., Kester, D. E. and Davies, F. T. 1993. Plant pathogen- principles and practices.
217 Prentice Hall, New Delhi, India.
- 218 Hedge, J. E. and Hofreiter, B. T. (1962). In: Whistler, R. L. and Be Miller, J. N. (eds.)
219 Carbohydrate Chemistry, Academic Press, New York: 17.
- 220 Howell, G. S. 1987. Vitis rootstocks. In: Rom, R. C. and Carlson, R. F. (eds.) Rootstocks for
221 food crops. Wiley and Sons, New York, pp. 451-474.
- 222 Keller, M., Kummer, M. and Vasconcelos, M. C. 2001. Soil nitrogen utilization for growth and
223 gas exchange by grapevines in response to nitrogen supply and rootstock Aust. J. Grape Wine
224 Res. 7: 2-11.
- 225 Kim, D., Chun, O. K., Kim, Y. J., Moon, H. and Lee, C. Y. 2003. Quantification of polyphenols
226 and their antioxidants capacity in fresh plums. J. Agric. Food Chem. 51: 6509-6515.
- 227 Lamb, D. W., Weedon, M. M. and Bramley, R. G. V. 2004. Using remote sensing to predict
228 grape phenolics and colour at harvest in a Cabernet Sauvignon vineyard: Timing observations
229 against vine physiology and optimizing image resolution. Aust. J. Grape Wine Res. 10: 46-54.
- 230 Lowery, O. H., Rosebrough, N. J., Farr, A. L. and Randall, R. J. (1951). Protein measurement
231 with folin phenol reagent. J. Biol. Chem. 193:265.
- 232 Mabrouk, H. and Sinoquet, H. 1998. Indices of light microclimate and canopy structure of
233 grapevines determined by 3D digitizing and image analysis. Aust. J. Grape Wine Res. 4: 2-13.
- 234 Mazza, G. 1999. Anthocyanins in grape and grape products. Critical Rev. Food Sci. Nutrition.
235 35:341-371.
- 236 Miller G.L. (1972). Use of dinitrosalicylic acid reagent for determination of reducing sugars.
237 Anal. Chem. 31: 426-428.
- 238 Peros, J. P.; Nguyen, T. H.; Troulet, C.; Michel-Romiti, C. and Notteghem, J. L. (2006).
239 Assessment of powdery mildew resistance of grape and Erysiphe necator pathogenicity using a
240 laboratory assay. Vitis 45: 29-36.
- 241 Pongracz, D. P. 1983. Rootstocks for grapevines. David Philip Publisher, Cape Town.
- 242 Pouget, P. 1987. Usefulness of rootstocks for controlling vine vigour and improving wine
243 quality. Acta. Hort. 206: 109-118.

- 244 Prakash, G. S. and Reddy, N. N. 1990. Effect of different rootstocks on budbreak in grape cv.
245 Anab-e-shahi. *Crop Res.* 3: 51-55.
- 246 Ren, Z. and Lu, J. 2002. Muscadine rootstock increased the resistance of florida hybrid bunch
247 grape cv. 'Blanc Du Bois' to pierce's and anthracnose diseases. *Proc. Fla. State Hort. Soc.* 115:
248 108-110.
- 249 Reynolds, A. G. and Wardle, D. A. 2001. Rootstocks impact vine performance and fruit
250 composition of grapes in British Columbia. *Hort. Technol.* 11: 419-427.
- 251 Richard, D. 1983. The grape root system. *Hort. Rev.* 5: 127-168.
- 252 Rom, C. R. 1996. Coordination of root and shoot growth: roots and rootstocks. In *Tree Fruit*
253 *Physiology*, K. M. Maib (ed.), pp53-58.
- 254 Satisha, J., Prakash, G. S., Murti, G.S.R. and Upreti, K. K. 2005. Response of grape genotypes
255 for water deficit: Root shoot growth and endogenous hormones. *Indian. Pl. Physiol.* 10: 225-230.
- 256 Satisha, J., Doshi, P. and Adsule, P. G. 2008. Influence of rootstocks on changing the pattern of
257 phenolic compounds in Thompson seedless grapes and its relationship to the incidence of
258 powdery mildew. *Turk. J. Agric.* 32: 1-9.
- 259 Satisha, J., Somkuwar, R. G., Sharma, J., Upadhyay, A. K. and Adsule, P. G. 2010. Influence of
260 rootstocks on growth yield and fruit composition of Thompson seedless grapes grown in the
261 Pune region of India. *S. Afr. J. Enol. Vitic.* 31: 1-8.
- 262 Shaulis, N. J. 1982. Responces of grapevines and grapes to spacing of and within canopies. In:
263 Webb, D. (ed.) *Grape and Wine Centennial Symposium Proceedings*, University of California,
264 Davis, pp. 353-360.
- 265 Singleton, V. L. and Rossi, J. A. 1965. Colorimetry of total phenolics with phosphomolybdic-
266 phosphotungstic acid reagent. *Am. J. Enol. Vitic.* 16: 144-158.
- 267 Sommer, K. J., Clingeleffer, P. R. and Olat, N. 1993. Effect of minimal pruning on grapevine
268 canopy development, physiology and cropping level in both cool and warm climates. *Vitic. Enol.*
269 *Sci.* 48: 135-139.
- 270 Tangolar , S. and Ergenolu, F. 1989. The effects of different rootstocks on the levels of mineral
271 elements in the leaves and the carbohydrate contents of the canes of some early maturing grape
272 cultivars. *Doga, Turk Tarim ve Ormancilik Dergisi.* 13: 1267-1283.

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Table 1. Effect of Dog Ridge and 110 R rootstocks on Thompson seedless scion on growth and powdery mildew and anthracnose disease incidence.

Parameters	Vines grafted on Dog Ridge	Vines grafted on 110R	Own-rooted Thompson Seedless	Significance
Days taken for sprouting	13.48 ±1.12 a	12.64 ±0.93 a	10.08 ±0.59 b	**
Shoot length at 30 DAP (cm)	39.71 ±0.74 a	35.03 ±1.27 b	31.44 ±1.66 c	**
Shoot length at 60 DAP (cm)	72.01 ±1.78 a	66.50 ±1.74 b	59.30 ±1.27 c	**
Shoot length at 90 DAP (cm)	104.21 ±2.78 a	93.34 ±2.40 b	85.01 ±2.25 c	**
Internode length (cm)	6.60 ±0.20 a	5.28 ±0.22 b	4.90 ±0.24 c	**
Shoot diameter (mm)	8.98 ±0.25 a	8.00 ±0.16 b	6.71 ±0.12 c	**
Leaf area (cm ²)	8411.14 ±424.29 a	6836.35 ±348.92 b	4727.22 ±252.50 c	**
Days required for cane maturity	84.51 ±0.86 a	79.80 ±0.71 b	74.59 ±1.02 c	**
Foliar powdery mildew incidence (%)	3.19 ±0.62 a	1.57 ±0.41 b	2.08 ±0.65 b	*
Foliar anthracnose incidence (%)	1.30 ±0.54 a	1.14 ±1.22 a	1.96 ±0.55 a	ns
Anthracnose incidence on canes (%)	0.80 ±0.12 c	1.20 ±0.13 b	2.00 ±0.39 a	**

The data are the means of five replicates ±standard deviation. ‘*’, ‘**’ and ‘ns’ represent significance p<0.05, p<0.01 and non-significance, respectively by one-way-ANOVA statistics. Values followed by different letters differ significantly by DMRT at p=0.05.

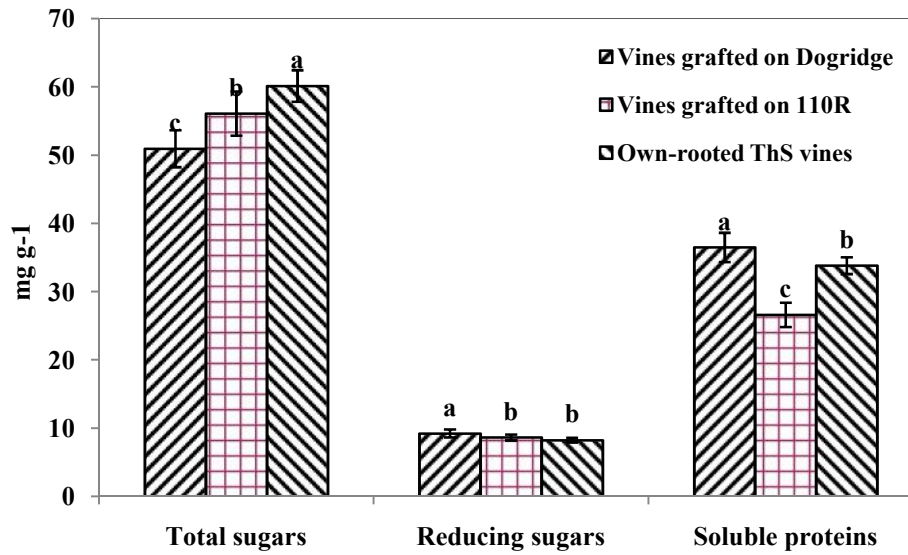
Table 2. Correlation between vine growth, disease incidence and biochemical composition in own-rooted and grafted Thompson Seedless grape.

Parameters	Shoot length	Internode length	Leaf area	Foliar PM	Foliar Anthracnose	Cane Anthracnose	Total phenolics	Reducing sugar	Total sugars	Protein
Days taken for sprouting	-0.19 ^{ns}	-0.13 ^{ns}	-0.29 ^{ns}	-0.19 ^{ns}	0.15 ^{ns}	0.41 ^{ns}	0.10 ^{ns}	-0.05 ^{ns}	0.31 ^{ns}	0.03 ^{ns}
Shoot length	0.89 ^{**}	0.89 ^{**}	0.88 ^{**}	0.70 ^{**}	-0.29 ^{ns}	-0.84 ^{**}	-0.72 ^{**}	0.57 [*]	-0.86 ^{**}	0.26 ^{ns}
Internode length			0.86 ^{**}	0.80 ^{**}	-0.24 ^{ns}	-0.79 ^{**}	-0.83 ^{**}	0.68 ^{**}	-0.74 ^{**}	0.50 [*]
Foliar PM incidence					-0.39 ^{ns}	-0.63 ^{**}	-0.66 ^{**}	0.79 ^{**}	-0.41 ^{ns}	0.47 [*]
Foliar Anthracnose						0.33 ^{ns}	-0.02 ^{ns}	-0.38 ^{ns}	0.05 ^{ns}	0.10 ^{ns}
Cane Anthracnose							0.50 [*]	-0.51 [*]	0.80 ^{**}	-0.08 ^{ns}
Total phenolic								-0.38 ^{ns}	0.69 ^{**}	-0.75 ^{**}
Reducing sugars									-0.19 ^{ns}	0.38 ^{ns}
Total sugars										-0.10 ^{ns}

‘*’, ‘**’ and ‘ns’ represent significance of the correlation coefficients at $p < 0.05$, $p < 0.01$ and non-significance, respectively.

287 Figure 1. Effect of Dogridge and 110 R rootstocks on biochemical composition of Thompson
288 seedless scion as compared to own-rooted vines.

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Figure 2. Effect of Dogridge and 110 R rootstocks on phenolic contents of Thompson seedless leaves as compared to own-rooted vines.

