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Root distribution, partitioning of dry matter and nutrient uptake in 'Thompson Seedless' grapes (*Vitis vinifera*) grafted on different rootstocks

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ABSTRACT

A study was conducted during 2004-05 on the root distribution pattern of 4 grape rootstocks, namely 'Dog Ridge', 'Salt Creek', '1613- C' and 'St. George' grafted Thompson Seedless (*Vitis vinifera* L.). The soil is heavy black cotton soil (vertisols) with *p*H of > 8.0. Roots of different thickness, viz < 2 mm, 2–5 mm, 5–10 mm, and >10 mm, were examined at a depth of 0–30, 31–60 and 61 – 90 cm from the surface. Dog Ridge putforth maximum root length in < 2 mm category at 0–30 cm distance from the trunk, while at 30–60 cm distance, 'Salt Creek' recorded maximum root length in < 2 mm category. The total root length of 2–5 mm category was higher at 31–60 cm distance both in 'Dog Ridge' and 'St. George'. The total root length of 5–10 mm category was highest in 'Dog Ridge', followed by 'Salt Creek' and 'St. George'. The spread of thicker roots of >10 mm till 60 cm distance, beyond which there was no spread in all the rootstocks. At 0–30 cm depth, 'Dog Ridge' put forth greater root mass, followed by 'Salt Creek' and 'St. George'. But, highest root mass was recorded in all the rootstocks at 30–60 cm depth. The food material (dry matter) is stored in different parts of grapevine after back pruning. Considering the major vine part, ie trunk, the dry matter accumulation was highest in 'Thompson Seedless' grafted on 'Dog Ridge' (69.48%), while 'St. George' was last in the order (43.79%). Canes of 'Salt Creek' grafted vines produced highest dry matter (73.57%) while primary arms and trunk on 'Dog Ridge' grafted vines recorded highest dry matter of 72.64 and 69.48% respectively. However less dry matter was recorded in roots of '1613-C'grafted vines. The nitrogen accumulation in trunk of 'Salt Creek' rootstock was higher (1.45%). Similarly, the phosphorous was accumulated more (0.25%) in canes of 'St. George'. Potash was accumulated more in canes as compared to other parts in 'St. George' and it was moderate in 'Dog Ridge' rootstock. Considering the parameters studied in the present investigation, among the rootstock, 'Thompson Seedless' grafted on 'Dog Ridge' rootstock seems to be better as compared to other rootstocks.

Key words: Dry matter, Grape, Nutrients, Root distribution, Rootstock, 'Thompson Seedless'

In past, all commercial varieties of grapes (*Vitis vinifera* L.) in India were grown on their own roots, as most of the soils were free from soil-borne problems, like nematodes, Phylloxera and salts (Satisha and Prakash 2006). However, with the continuous prevalence of drought in the grape-growing regions and build-up of soluble salts in the soil, these factors became major hindrance for grape cultivation in the semi-arid region. This forced the grape growers to use rootstock in grape cultivation. Since the rootstock plays an important role in combating the abiotic stresses, the introduction of rootstock in grape cultivation became mandatory in the Indian viticulture. It has been shown that both grape yield and quality is dependant on the health status of root (Morlat and Jaquet 1993). The rootstocks are used in grape production where soil chemistry is such that the vines on their root will not grow properly (Williams and Smith 1991). The grapevines are grown on a variety of soils around the world, but the information on the effect of different soil factors on the growth of the vine is scanty. There is only limited information available on rooting pattern of field grown grapevine (Richards 1983).

In addition to these factors, the functioning of roots also depends on grapevine cultivars or rootstock (Perry *et al.* 1983, Nagarajaih 1987, Morano and Kliewer 1994). Studies on the different grapevine cultivars have shown that the soil environment can influence the root distribution (Nagarajaih 1987, Southey 1992, Van Hysteen 1988). It has been pointed out that edaphic conditions determine the root distribution in soil profile while the genetic factors determine root density (Southey and Archer 1988; Williams and Smith 1991) and hence the different rootstock may have different root distribution.

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The difference in the rooting pattern of different rootstocks may affect both water and mineral nutrition uptake by the vine. This in turn would affect the water and mineral nutrient status of the vine (Williams and Smith 1991). Increase in the vine density is related to the root density in the soil profile (Archer 1987, Archer and Strauss 1985). Various workers demonstrated that the uptake of minerals differs among the grape cultivars and rootstocks (Downton 1977 and Erdei *et al*. 1985). The soil water gets depleted in the narrower planting due to the more roots densities (Archer and Strauss 1985).

Considering this, the present study was carried out to determine partitioning of dry matter, root distribution and nutrient concentration in grape variety 'Thompson Seedless' grafted on different rootstocks.

MATERIALS AND METHODS

The study was conducted at the experimental farm of National Research Centre for Grapes, Pune during 2004 – 05 under field condition. The grape rootstocks 'Dog Ridge', 'Salt Creek', '1613 C' and 'St. George' were planted during 1997 with 3.0 m between the rows and 1.8 m between the vines. The experimental site is situated in mid-west Maharashtra at an altitude of 559 m above sea level; it lies on 18.32 °N latitude and 73.51°E longitudes. The climate is mild to slightly dry. The soil of this region is black having *p*H 7.75 and EC 0.46 dS/m. However water used for irrigation had EC 1.8 and *p*H 8.3 (Sharma and Upadhyay 2005). The trial was laid out in a randomized block design as a single vine plot. The land in the experimental plot was uniform and leveled. All the cultural practices were followed uniformly for all the rootstock under the field condition. 'Thompson Seedless' was grafted on the above rootstocks during September 1997. All the vines were given the recommended cultural operations, like fertilizers, irrigation and plant protection, etc. The vines were irrigated with drip irrigation system having 3 drippers/vine of 4-litre capacity. Since double pruning and single cropping pattern is followed in the tropical region of the region, 0.6 m × 1.2 m trench was opened at a depth of 10 cm twice in a year to apply well rotten farmyard manure and single super phosphate and the trench was closed back.

For root excavation study, the soil cores were removed at lateral distance of every cubic feet from the trunk manually. Likewise, the roots were excavated up to 150 cm from the trunk and it was followed for 90 cm depth below the ground. The soil was collected in separate container and was washed from the roots in a sieve with 2 mm mesh. At the first top layer the roots of the weeds, if any, were removed. The collected roots were then divided into different category of < 2 mm, 2 – 5 mm, 5 – 10 mm and >10 mm diameter. The observation on fresh weight of roots at each soil layer, root length under each category and the fresh weight of different parts of the vine was recorded. The samples were then kept in the oven for about 3 days at 50°C to record the observations on dry weight. The data on fresh weight and dry weight of individual vine parts (trunk, primary arm, secondary arms and canes) were recorded and the dry matter was calculated. The samples of each part were also analyzed for N, P and K nutrients by Kjeldhal method.

To compare the results, the statistical analysis was carried out as per the procedures of Panse and Sukhatme (1985). The comparison of treatments was carried out using standard errors of mean and critical difference at $P = 0.05$.

RESULTS AND DISCUSSION

Effect of soil depth on average root length (vertical spread)

Four rootstocks were studied for their vertical movement in soil depth. The values for average root length in the soil profile spread horizontally at 30, 60, 90, 120 and 150 cm from the trunk for 'Dog Ridge', 'Salt Creek', '1613 C' and 'St. George' are given in Table 1. Significant differences were recorded for average root length among all the rootstocks studied. Among the different categories of root diameter, the average root length in the category of < 2 mm diameter in first 0–30 cm distance from the trunk was maximum in 'Dog Ridge' (11,952.05 mm), followed by 'Salt Creek' (10,146.10 mm), and 'St. George' (9,067.21 mm) rootstock. However, in the 31–60 cm depth, 'St. George' recorded the highest root length (17,045.59 mm), followed by 'Salt Creek' (15,955.58 mm), 'Dog Ridge' (14,423.11 mm) and '1613-C'(10,315.56 mm). Under the third soil layer of 61–90 cm depth the differences for average root length varied significantly. However, 'Salt Creek' and 'St. George' were at par. In 2–5 mm diameter category, significant differences were recorded among all the rootstocks. 'St. George'

Table 1 Root distribution of different rootstocks (from ground, average root length in cm)

Rootstock	< 2 mm	2–5 mm	5–10 mm	> 10 mm
First layer (0–30 cm)				
'Dog Ridge'	11 952.05	5 887.46	403.86	7.35
'Salt Creek'	10 146.10	2 674.72	242.09	54.18
'1613 C'	8 361.74	1 497.85	283.46	40.88
'St. George'	9 067.21	2 356.80	154.18	38.38
CD ($P = 0.05$)	176.40	20.50	7.85	6.08
Second layer (31–60 cm)				
'Dog Ridge'	14 423.11	7 455.64	654.12	35.10
'Salt Creek'	15 955.58	6 666.63	915.15	240.49
'1613 C'	10 315.56	1 786.06	279.34	84.79
'St. George'	17 045.59	4 909.45	211.74	48.14
CD ($P = 0.05$)	359.78	243.72	19.97	5.72
Third layer (61–90 cm)				
'Dog Ridge'	7 876.47	2 785.10	282.40	0.00
'Salt Creek'	14 815.02	5 571.20	653.37	62.77
'1613 C'	10 869.80	1 321.64	55.11	0.00
'St. George'	14 670.67	2 530.67	79.18	0.00
CD ($P = 0.05$)	205.38	172.65	11.84	8.07

produced maximum average root length in 0–30 cm depth, followed by '1613 C' rootstock, however, '1613 C' had poor root length. In 31–60 cm depth the rootstock 'Dog Ridge' produced maximum root length than all other rootstocks. However, in the 61–90 cm depth, 'Salt Creek' produced maximum root length. Maximum root length was recorded in first two categories of the roots (< 2 mm and 2–5 mm). The root spread was reduced in 5–10 mm diameter category irrespective of the rootstock. In 0–30 cm depth, maximum root length in 5-10 mm diameter was recorded in 'Dog Ridge' however; 'Salt Creek' has produced maximum root length in 60–90 cm depth. In case of roots in >10 mm diameter, 'Salt Creek' performed better than all other rootstocks in all the soil depth. In the first 0–30 cm depth, the differences for root length were at par with '1613 C' and 'St. George'. However, in the 61–90 cm depth, there were no root spread in >10 mm diameter roots except in the 'Salt Creek'.

Among all the rootstocks, 'Dog Ridge' rootstock produced more roots in first 0–30 cm depth, followed by 'Salt Creek' irrespective of root diameter category. In the lower depth of 31–60 cm, the rootstock 'Salt Creek' produced more average root length and 'Dog Ridge' was in second position in respect to the root spread. The maximum average root length was recorded in 31–60 cm soil depth. These results confirm the results obtained by Nagarajaiah (1987). In our study, maximum root length was recorded in 'Dog Ridge' rootstock at 0–30 cm soil depth. 'Salt Creek' rootstock has recorded more root growth than 'Dog Ridge' in 31–90 cm depth. Penetration of roots in the deeper layer in the soil may enable the rootstock vines to absorb water and nutrients more effectively from the deeper layer of soil (Nagarajaiah 1987). Stevens and Nicholas (1994) reported 'Muscat Gordo Blanco' and 'Shiraz' wine grapes could retrieve 90% of roots in the 0–70 cm soil depth. However Wakabayashi *et al.* (1974) reported rooting depth of grapevine up to 200 cm while Seguin (1972) showed that the grapevine have potential to grow much greater soil depth (600 cm) than reported in this study. But Morano and Kliewer (1994) in their studies on root distribution found significant difference among rootstocks for total root number and class of smallest root size. In their study, 'St. George' had a higher root distribution pattern from either '110 R' or 'A × R 1'. 'St. George' also had the largest root number and also there was a significant rootstock soil depth interaction for the roots with diameter classes of 2–5 mm and 5–12 mm indicating the influence of soil characteristics on root distribution.

Effect of soil depth on root mass

The fresh root mass of the different rootstocks recorded at different depth is presented in Table 2. Among all the rootstocks studied, 'Dog Ridge' recorded maximum fresh root weight at 0–30 cm depth, followed by 'Salt Creek' and 'St. George'. The root mass was highest in 31–60 cm soil depth as compared to the earlier depth. Higher root mass was produced in 'Salt Creek', followed by 'Dog Ridge' and 'St. George'. The same trend was noticed in the lower soil depth of 61–90 cm. However, among all the soil depth, maximum root mass was recorded in 'Salt Creek', followed by 'Dog Ridge' and 'St. George' and the least was recorded in '1613 C'. Among the different depths, the maximum root mass was recorded at 31–60 cm soil depth from the ground as compared to the 0–30 cm and the least was recorded in 61–90 cm soil depth (Table 2). The reduction in the root growth in the later depth has resulted in reduced root mass, which might be due to higher clay content at lower depth. Nagarajah (1987) also reported that the reduction in root growth was associated with an increase in the silt and clay content in the soil profile.

Table 2 Layer-wise fresh root weight (g) of different rootstocks

Rootstock	0–30 cm	31–60 cm	61–90 cm
'Dog Ridge'	3 601.20	4 826.27	1 616.75
'Salt Creek'	3 486.22	5 775.39	4 239.23
'1613 C'	1 517.09	1 443.95	830.84
'St. George'	2 818.61	3 610.53	2 473.68
CD (P = 0.05)	40.32	53.38	30.27

Effect of rootstocks on partitioning of dry matter

The partitioning of dry matter in different parts of 'Thompson Seedless' grafted on different rootstocks is presented in Table 3. The dry matter content significantly differed among rootstocks in all the vine parts. The highest dry matter was recorded in 'Dog Ridge' rootstock, followed by 'Salt Creek', '1613 C' and 'St. George'. Highest dry matter content of 73.57% was recorded in the canes of 'Thompson Seedless' grafted on 'Salt Creek' and was followed by 72.64% and 69.48% was recorded in primary arm and trunk of 'Thompson Seedless' grafted on 'Dog Ridge' rootstock. But canes of 'Thompson Seedless' grafted on 'Salt Creek' had highest dry matter content than on other rootstocks. The performance of 'Dog Ridge' rootstock in the Indian viticulture is considered superior to other three rootstock as the vine grafted on this rootstock is called as high capacity vines. Miller and Howell (1998) in their study also reported that high capacity vines produced the greatest quantity of fruits, leaves, shoots and total canopy dry mass. The yield

Table 3 Distribution of dry matter (%) in different parts of 'Thompson Seedless' vines grafted on different rootstocks

Rootstock	Roots	Trunk	Primary arms	Secondary arms	Canes
'Dog Ridge'	48.28	69.48	72.64	54.58	69.69
'Salt Creek'	41.67	57.07	53.68	56.08	73.57
'1613 C'	22.07	60.44	50.72	51.48	36.71
'St.George'	48.42	43.79	40.42	49.24	37.50
CD (P = 0.05)	1.028	1.331	1.150	0.716	1.03

Table 4 Distribution of nitrogen, phosphorous and potash (%) in different parts of 'Thompson Seedless' vines grafted on different rootstocks

Rootstock	Trunk			Primary arm			Secondary arm			Canes		
	N	P	K	N	P	K	N	P	K	N	P	K
'Dog Ridge'	1.20	0.07	0.50	1.17	0.09	0.57	1.23	0.12	0.57	1.51	0.17	0.80
'Salt Creek'	1.45	0.10	0.45	1.40	0.11	0.45	1.40	0.13	0.45	1.96	0.18	0.72
'1613 C'	1.01	0.08	0.55	0.73	0.10	0.45	1.06	0.12	0.55	1.06	0.21	0.9
'St. George'	0.99	0.12	0.60	1.04	0.13	0.50	0.98	0.13	0.52	1.56	0.25	1.02
CD (P = 0.05)	0.01	0.01	NS	0.01	0.01	0.01	0.01	NS	0.02	0.01	0.01	0.01

on 'Dog Ridge' rootstock is also higher than these rootstocks. The fruits are produced by portioning of carbohydrates to berries at the expense of vegetative tissues and an increase in dry matter production/unit leaf area as the sink strength increases Layne and Flore (1995) and Miller and Howell (1996). Among the different rootstocks, 'Dog Ridge' and 'St. George' recorded the maximum dry matter in roots as compared to other rootstocks. 'Dog Ridge' rootstock had also recorded higher dry matter in trunk, primary arms and also in canes. This indicates that the 'Dog Ridge' rootstock has got maximum root mass, which helps in drought tolerance. In case of '1613 C' rootstock, the maximum dry matter of 60.44% was accumulated in trunk, followed by arms and canes as compared to other plant parts. 'St. George' recorded moderate dry matter partitioning in all the plant parts. This indicates that in the present study the rootstock like 'Dog Ridge' may perform better when the soil moisture is the constraint.

Effect of rootstocks on nutrient distribution in vine parts

The distribution of nutrients in different parts of 'Thompson Seedless' grape grafted on different rootstocks is presented in Table 4. The significant differences were recorded in nitrogen accumulation in different plant parts. The maximum nitrogen accumulation was recorded in canes of 'Salt Creek' rootstock, followed by 'St. George' and 'Dog Ridge' rootstock (Table 4). This indicates that the rootstock is very responsive to nitrogen fixation. 'Dog Ridge' rootstock found at second position in nitrogen accumulation in trunk which is considered as the major food storing material. The rootstock 'St. George' and 'Salt Creek' were found least responsive to nitrogen accumulation. Tardaguila *et al.* (1995) also recorded the variable responsive of rootstocks to nitrogen accumulation. Phosphorous content (%) in different plant parts was affected by different rootstocks except secondary arms (Table 4). The maximum accumulation of phosphorous was recorded in canes of 'St. George' rootstock. The same rootstock recorded the maximum phosphorous accumulation in other plant parts. The least accumulation of phosphorous was recorded in 'Dog Ridge'.

Different rootstocks recorded variable potash accumulation in the different plant parts (Table 4). The maximum potash accumulation was recorded in canes of 'St. George' and the least was in '1613 C' rootstock in different plant parts. 'Dog Ridge' rootstock recorded the maximum potash accumulation in primary and secondary arms.

It is evident from the present study that different rootstocks had different root distribution pattern and in turn they influenced the dry matter partitioning, nitrogen, phosphorous and potash accumulation. Among the rootstocks, 'Dog Ridge' recorded the maximum dry matter in roots, which is an indicator of drought tolerance. The nitrogen accumulation was higher in canes of 'Salt Creek' rootstock. Similarly, the phosphorous was accumulated more in canes of 'St. George'. Potash was accumulated more in canes as compared to other parts in 'St. George' and it was moderate in 'Dog Ridge' rootstock. Considering the research results in the present investigation and the general performance of 'Dog Ridge' rootstock in the grower's field, this rootstock is considered as better rootstock than the other rootstocks.

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