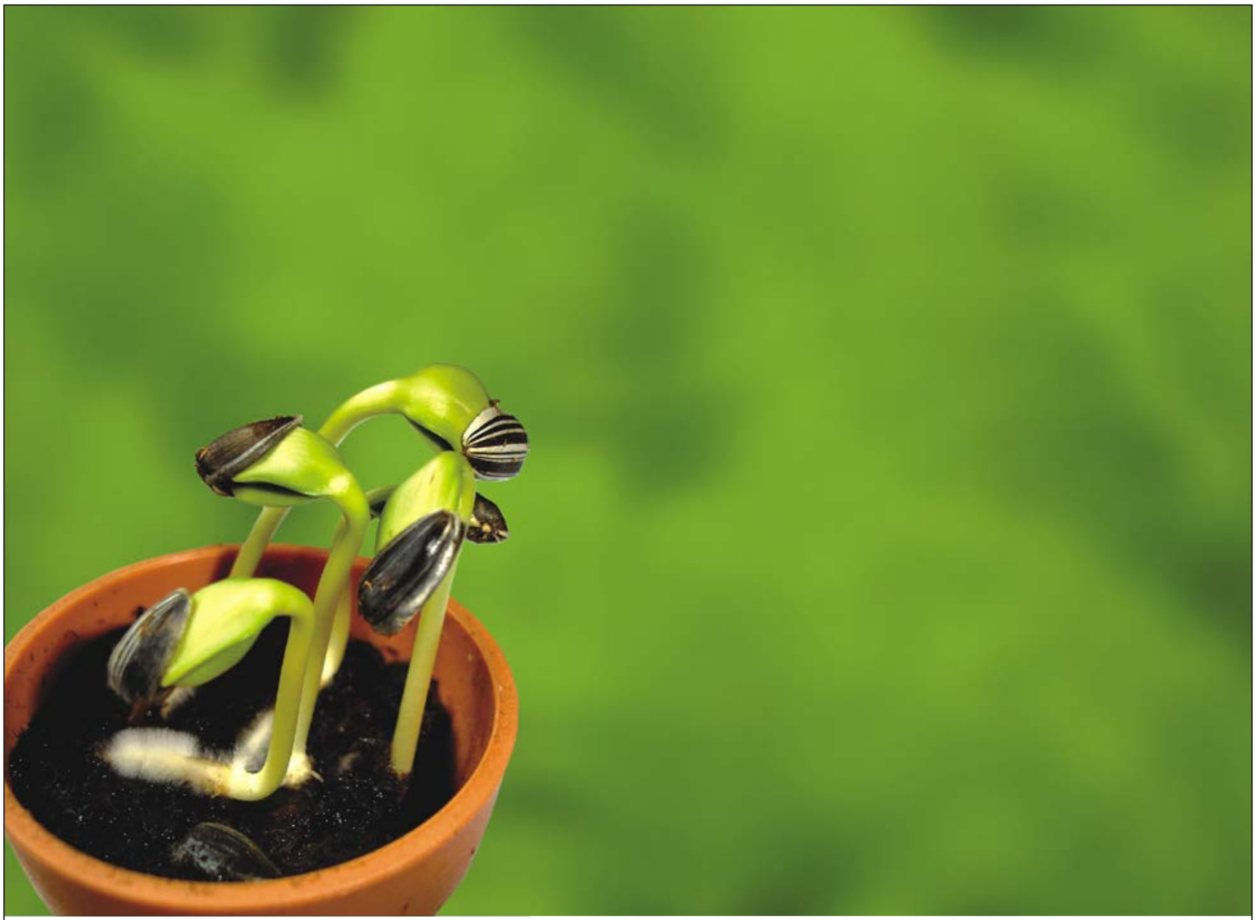

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Influence of Rootstock on Bud Break, Period of Anthesis, Fruit Set, Fruit Ripening, Heat Unit Requirement and Berry Yield of Commercial Grape Varieties

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ABSTRACT

An experiment was conducted to study the impact of commercial grape varieties (Thompson seedless, Flame seedless and Kishmish chorni) and grafted on different root stocks (1103 P, SO_4, Dog ridge) for bud break, period of anthesis, fruit set, fruit ripening, heat unit requirement and fruit yield (kg ha^{-1}). Among varieties, Flame seedless significantly took less number of days for bud break (10.13 days). Among rootstocks, own rooted vines (10.18 days) took less days for bud break and varieties grafted on Dog ridge (12.55 days) took more days for bud. Among varieties, Flame seedless took minimum number of days for anthesis (51.13 days), fruit set (58.82 days), fruit ripening (159.00 days) and heat units (2148 degree days) and among varieties grafted on own root system also took minimum number of days for anthesis (50.48 days), fruit set (57.85 days), fruit ripening (155.00 days) and heat units (2072.23 degree days). Among varieties, Kishmish chorni (11.76 kg/vine) recorded highest yield per vine followed by Thompson seedless (10.55 kg/vine) and Flame seedless (8.42 kg/vine). Among rootstocks, Dogridge produced highest yield of 13.06 kg/vine irrespective of the varieties and lowest yields (7.89 kg/vine) were recorded in case of SO_4 rootstocks, which is lesser than yield obtained from own rooted vines. The interaction between varieties and rootstocks was found to be significant indicating the influence of rootstocks on different varieties.

Key words: Flame Seedless, *Vitis vinifera*, own rooted, significant, interaction

INTRODUCTION

Grape (*Vitis vinifera* L.), an important commercial fruit crop of both temperate and tropical region of the world. The grape is gaining popularity for its high nutritive value, excellent in taste, multipurpose use and better returns (Gowda *et al*., 2008). A constant and steady improvement is observed in worldwide table grape consumption (Celik *et al*., 2005). Recently, hot climate viticulture has gained importance in different tropical regions of the world. The table grape produced from tropical and subtropical conditions, such as in Brazil, Venezuela, India and Thailand, has begun receiving international recognition. Table grapes occupies more than 90% area and there is decline in the productivity of grape growing states viz., Maharashtra, Karnataka and Andhra Pradesh led the way to the utilization of rootstocks in grape cultivation. The grape growing districts in these states experience severe drought conditions during the critical growth stages, such as fruitbud differentiation, shoot maturity and full bloom. The use of drought-tolerant rootstocks would minimize the immediate effects of dry conditions and enable the variety to recover quickly (Satisha *et al*., 2010).

The advantage of grape cultivation is that, either it can be cultivated on their own roots or grafted onto a root stock, which offers benefits such as pest resistance especially to phylloxera *Daktulosphaira vitifoliae* Fitch. However, compatibility between root stock and scion i.e., varieties (Richards, 1983; Vrsic *et al*., 2004) determine adaptation to the soil, resulting in the development of the root system (Morano and Kliewer, 1994), nutrient absorption and vulnerability to drought (Himelrick, 1991; Kocsis *et al*., 1998; Keller *et al*., 2001a, b; Satisha *et al*., 2010). The interactions between root stocks and varieties have an impact on scion phenology, which ultimately affects the productivity of grape vine (Boselli *et al*., 1992; Ferroni and Scalabrelli, 1995; Keller *et al*., 2001a, b). Rootstocks also ensure profitable production by enhancing uniform and early bud burst.

The grape cultivation is being influenced by many factors, the mains ones being: (a) the permanent factors which are constant and do not vary from one-year to the next, that is, the region, the soil, the variety and the rootstock, (b) changeable factors which are related to the annual climate (temperature, precipitation, light and humidity) and establish the rhythm of the vegetative cycle of the plant and c) modifiable factors relating to cultivation practices, such as the fertilizer application, the pruning and the irrigation (Smart, 1985; Bodin and Morlat, 2006).

Understanding the phenology of grape varieties grafted on different rootstock is important for determining the ability of particular region to produce a good crop, within the confines of its climatic regime, *Vitis vinifera* grapevines are a phenologically distinct crop with the most important development stages being budburst, blooming (flowering), setting (fruit set), véraison (color change and beginning maturation) and harvest (grape maturity). The time between these phonological stages varies greatly with grapevine variety, climate and geographical location (Bodin and Morlat, 2006; Webb *et al*., 2007). Timing of these developmental stages is also related to the ability of the vine to yield fruit, with early and fully expressed phenological events usually resulting in larger yields.

In the present study, three rootstocks viz., 1103P, SO_4 and Dog ridge were grafted on three commercial grape varieties such as Thompson Seedless, Flame Seedless and Kishmish Chorni. The resulting effect of rootstock on scion was studies for bud break, fruit set, heat unit requirement and fruit yield (kg ha^{-1}) under semi-arid tropical conditions of South India.

MATERIAL AND METHODS

This study was conducted during 2013-14 in the experimental vineyard of Grape Research Station, Rajendranagar, Hyderabad. The eco-geography of experimental site falls under semi-arid tropical conditions of Southern India. The Research Station is located at 77°85'E longitude and 18°45'N latitude and at an altitude of 542.6 m above mean sea level, with the average annual rainfall of 800 mm. The meteorological data on rainfall, relative humidity, minimum and maximum temperatures and sunshine (h) were obtained from records of meteorological observatory of Acharya N. G. Ranga Agricultural University.

The composite sample was analyzed for its physical and chemical properties. Soil samples were collected from the root zone of the vines at the time of fruit pruning, representing 40 cm soil surface diameter below the emitter and up to 30 cm depth. On average, the soil had a pH of 6.2, an EC of

0.16 dS m^{-1}, organic carbon = 1.8%, available N = 350.0 kg ha^{-1} (medium), available P = 85 kg ha^{-1} (high) and available K = 680 kg ha^{-1} (high). Other elements such as Fe, Mn, Cu and Zn content in the soil were 35.5 mg kg^{-1} (high), 6.50 mg kg^{-1} (medium), 8.20 mg kg^{-1} (high) and 1.8 mg kg^{-1} (medium), respectively. The soils were classified on the basis of rating chart used by soil testing laboratories. The vine yard is being irrigated through drip irrigation system. Two drippers each of 8 L h^{-1} discharge capacity were placed 60 cm apart on either side of the main trunk of the vine. The vine yard is kept weed free by means of manual and mechanical weeding. The backward pruning was done on 1st May 2013 and forward pruning on 12th November 2013. Necessary prophylactic plant protection measures were undertaken to overcome the pests and diseases.

All the vines were pruned twice in an annual growth cycle, which is a common practice in tropical viticulture. The first pruning is done immediately after fruit harvest during the summer months to develop fruitful canes, popularly called "back pruning" and another pruning is done at about 5-6 months after back pruning on the fruitful canes to encourage cluster development. This is popularly known as "forward pruning". Within 24-48 h after forward pruning, 2-3 apical buds on the pruned canes were swabbed with a bud-breaking chemical, hydrogen cyanamide (at 1.5% active ingredient), commercially known as "Dormex", to facilitate quick and uniform bud burst.

The experiment was conducted on a 6 years old orchard, planted at spacing of 10×6 ft and trained on "Y trellis system". There were 12 treatments and replicated four times, in a Factorial Randomized Block Design. One of the factor includes three different varieties of grape (Thompson seedless, Flame seedless and Kishmish chorni) and the other factor includes three different rootstocks (1103 P, SO_4 and Dog ridge) and own rooted vine. The characteristics of the above rootstocks are:

- **1103P:** It is a cross between *Berlandieri Resseguier* No. 2 and *Rupestris* du Lot (St. George). Created by Paulsen, Director of a nursery for American vines in Sicily. It is a vigorous rootstock and adoptable to the clay-lime soils with fresh, humid subsoils. Resistant to drought and excess soil moisture in spring. Moderate tolerant to salinity. It is recommended for very dry conditions. It roots and grafts well
- **SO4:** It is an abbreviation of Selection Oppenheim No. 4. It is a selection of Teleki's Berlandieri-riparia No. 4. The rootstock shows moderate to high vigour and susceptible to Mg deficiency and water berries. It is slightly drought tolerant rootstock. Suited to humid, clay soils, it is not recommended for very dry conditions. Its resistance to active lime is approximately 17-18% and it has a good resistance to nematodes. It accepts up to 0.4 g kg^{-1} salt content. SO4 roots well. It field grafts well and bench grafts satisfactorily. It produces a large amount of propagating wood
- **Dog ridge:** It is a natural hybrid of *Rupestris candicans*. This and similar hybrid vines were grouped together by Planchon as *Vitis champini*. Imparts great vigour to scion. It is tolerant to salinity and well suited for less fertile soil. It is moderately resistant to phylloxera and lime. But the bud/graft take is high on the rooted vines

Data recording for agro-morphological traits: Randomly five healthy plants were selected and subjected to record following agro-morphological traits.

Days taken for bud break: Days taken for bud break were measured after forward pruning. The first sprouted bud with fully expanded leaf was taken as an indicator to measure the days taken to bud break (Satisha *et al*., 2010).

Period of anthesis: Period of anthesis was measured by counting the number of days taken after forward pruning.

Period of fruit set: Period of fruit set was measured by counting the number of days taken after forward pruning.

Period of ripening: Period of fruit ripening was measured by counting the number of days taken after forward pruning.

Heat unit requirement (degree days): The heat units or degree days were calculated from the day of October pruning to harvest by using the following formula described by Rai *et al*. (2002):

$$DD = \frac{(T_{max} + T_{min})}{2} - Tb$$

where, T_{max} and T_{min} are the maximum and minimum temperatures, respectively. Tb is the base temperature below which fruit growth is arrested. The base temperature for grape is taken as 10°C (Brar *et al*., 1992).

The mean daily temperature was calculated from the maximum and minimum temperatures and the base temperature of 10°C was subtracted from this. The remaining temperature thus obtained is called 'Heat Unit' (HU), which is summed up over the period from October pruning to harvest to get heat unit required for maturity of grapes.

Fruit yield (kg/vine): The number of bunches borne on the labeled spurs in each treatment was noted and weighed. The combined weight of these bunches was considered as the total yield per treatment and expressed in kilograms.

Statistical analysis: The data during 2013-14 was recorded for 6 important traits and subjected to statistical analysis using OPSTAT.

RESULTS AND DISCUSSION

The three grape varieties viz., Thompson seedless, Flame seedless and Kishmish chorni grafted on different rootstocks such as 1103P, SO_4 and Dog ridge were studied and results analyzed for days taken for bud burst, period of anthesis, period of fruit set, period of fruit ripening, heat unit requirement and fruit yield (kg ha^{-1}) have been presented and discussed below.

The number of days taken for bud break after winter pruning exhibited significant variation among varieties, rootstocks and for their interaction effect (Table 1). It serves as an index to classify grape varieties as early, medium and late depending upon the number of days taken for bud burst. Among the varieties, Flame seedless considered to be early as it took less number of days for bud break (10.13 days). The Thompson seedless found to be late as it took highest number of days for bud break (12.70 days). Among rootstocks, own rooted vines (10.18 days) took less days for bud break and varieties grafted on Dogridge (12.55 days) took more days for bud break which was on par to SO4 (12.18 days). The interaction among varieties and rootstocks were significant. Flame seedless on own root (8.12 days) was early and Thompson seedless on SO4 (13.55 days) is late to bud break.

Table 1: Effect of different rootstocks on days taken for bud break in commercial varieties of grape

Varieties	Rootstocks 1103P	SO4	Dogridge	Own root	Mean of varieties
Period of anthesis					
Thompson seedless	54.85	53.24	57.55	53.04	54.67
Flame seedless	52.23	53.56	50.68	47.66	51.03
Kishmish chorni	52.54	55.59	57.25	50.50	53.97
Mean of rootstocks	53.21	55.16	54.13	50.40	
CD of rootstocks at 5%	1.52			SEM±	0.52
CD of varieties at 5%	1.32				0.45
Rootstock×variety at 5%	2.64				0.92

SEM±: Standard error of mean

Bud break is a varietal character as, it marks the beginning of seasonal growth and it is strongly influenced by temperature. Bud bursting time is not easily predictable because its relationship with temperature is very complex. The early and increased percentage of bud burst on own roots might be attributed to the increased activity of peroxidase activity (POD) and fewer growth inhibitors in their buds. The least POD activity in vines on Dogridge rootstock might have resulted in late and uneven bud sprouting as reported by Jogaiah *et al.* (2013). Among the rootstocks, Dogridge rootstock found to be late to bud break. A significant effect of rootstocks on bud break of Anab-e-shahi cultivar. For example, the number of days required for bud break was shorter with Gulabi (Isabella) as rootstock and was longer in vines grafted on Dogridge. These results support current findings of delayed bud sprouting on Dogridge rootstock. The changes in peroxidase and polyphenol oxidase (PPO) activity could be an indicator of when endogenous changes occur, as the enzymes might lead to the scavenging of the accumulation of H_2O_2 in the buds and thus release dormancy, resulting in early bud sprouting (Tripathi *et al.*, 2006). Some of the research findings on bud burst were reported on varietal variation was within a wide range in different cultivars which is within the range of the present investigation (Kulwal, 1968; Muthukrishnan, 1969; Shinde and Patil, 1978; Ratnacharyulu, 2010).

Anthesis is an important attribute in grape as the opening of panicles in less possible time is the most desirable and preferred trait. There was significant variation among varieties, rootstocks and their interaction effect (Table 2). Among varieties, Flame seedless took minimum number of days for anthesis (51.03 days) and Thompson seedless took maximum number of days for anthesis (54.67 days). Among the rootstocks, varieties grafted on own root took less period for anthesis (50.40 days) and varieties grafted on Dogridge rootstock took more period for anthesis after pruning (55.16 days). The interaction effect between varieties and rootstock found to be significant and the minimum period was recorded by Flame seedless on own root (47.66 days), maximum period for anthesis was recorded by Thompson seedless on Dogridge (57.55 days), which was on par with Kishmish chorni on Dogridge (57.25 days). The number of days taken for anthesis varies with the genetic base of cultivar and environmental conditions (G×E interaction). Bright warm weather results in early flowering than rainy and cool weather.

The period of anthesis is most useful in assessing the maturity and early harvesting of berries providing ease to harvest fruit in one or two pickings to reduce the cost of picking. Early flowering resulting in early harvesting is required, particularly in North-India, where harvesting often coincides with early monsoon rains resulting in loss of produce due to diseases etc. Among the varieties, the period of anthesis may be due to the prevailing climatic conditions. Several workers (Randhawa and Sharma, 1960; Jawanda *et al.*, 1965; Nalwadi *et al.*, 1972; Garad, 1997) reported a wide range for period of anthesis in different cultivars, which are in accordance with the present findings.

Table 2: Effect of different rootstocks on period of anthesis, fruit set, fruit ripening and heat unit requirement in commercial varieties of grape

	Rootstocks				
Varieties	1103P	SO4	Dogridge	Own root	Mean of varieties
Period of anthesis (days)					
Thompson seedless	54.85	53.24	57.55	53.04	54.67
Flame seedless	52.23	53.56	50.68	47.66	51.03
Kishmish chorni	52.54	55.59	57.25	50.50	53.97
Mean of rootstocks	53.21	55.16	54.13	50.40	
CD of rootstocks at 5%	1.52			SEM±	0.52
CD of varieties at 5%	1.32				0.45
Rootstock×variety at 5%	2.64				0.92
Period of fruit sets (days)					
Thompson seedless	62.24	65.87	69.82	61.01	64.73
Flame seedless	60.68	58.95	61.84	53.81	58.82
Kishmish chorni	61.03	62.11	61.35	58.73	60.81
Mean of rootstocks	61.31	62.31	64.39	57.85	
CD of rootstocks at 5%	1.39			SEM±	0.48
CD of varieties at 5%	1.19				0.41
Rootstock×variety at 5%	2.39				0.83
Period of food ripening (days)					
Thompson seedless	158.00	169.00	168.00	157.00	163.00
Flame seedless	160.00	162.00	163.00	151.00	159.00
Kishmish chorni	164.00	163.00	167.25	157.00	162.81
Mean of rootstocks	160.67	164.67	166.08	155.00	
CD of rootstocks at 5%	1.66			SEM±	0.58
CD of varieties at 5%	1.44				0.50
Rootstock×variety at 5%	2.88				1.00
Heat unit requirement (degree days)					
Thompson seedless	2246.10	2225.80	2310.80	2112.00	2223.60
Flame seedless	2168.00	2206.50	2225.80	1992.70	2148.50
Kishmish chorni	2132.00	2351.90	2330.90	2112.00	2231.70
Mean of rootstocks	2182.23	2261.40	2289.17	2072.23	
CD of rootstocks at 5%	15.67			SEM±	5.44
CD of varieties at 5%	13.57				4.71
Rootstock×variety at 5%	27.15				9.43

SEM±: Standard error of mean

The period of fruit set depends upon period of anthesis. From Table 2, it is evident that Thompson seedless (64.73 days) recorded significantly maximum period to fruit set followed by Kishmish chorni (60.81 days) and minimum period was recorded by Flame seedless (58.82 days). Among the rootstocks, varieties on Dogridge rootstock (64.39 days) followed by SO4 were maximum (62.31 days) and minimum period was recorded by own root (57.85 days). Interaction effect was found to be significant. Flame seedless on own root recorded minimum period for fruit set (53.81 days) and maximum period was recorded by Thompson Seedless on Dogridge rootstock (69.82 days).

The prevalence of cold weather at the time to bloom, the progression of bloom may be delayed the period of fruit set and result in reduced fruit set. The precipitation during flowering can inhibit the pollination and fertilization by dilution of the stigmatic surface, which is to receive pollen from the flowers anthers. Such unfavorable weather condition not only delay the fruit set in grape but also leads to poor fruit set leading poor yield of the vineyard. Hence, management practices such as, use of rootstock may helps to escape aberrant weather in North Indian conditions by cultivating early fruit setting varieties (May, 2004).

The data pertaining to period of fruit ripening has been presented in Table 2. There was significant variation among varieties, rootstocks and their interaction effect. Flame seedless recorded significantly minimum period for fruit ripening (159.00 days) and maximum period was recorded by Thompson seedless (163.00 days), which was on par with Kishmish chorni (162.81 days). Among the rootstocks on different scions, maximum period was taken by Dogridge (166.08 days) followed by SO4 (164.67 days) and 1103 P (160.67 days) and minimum period was recorded by own root (155.00 days). Interaction effect was found to be significant. Flame Seedless on own root (151.00 days) recorded minimum period. The maximum period was recorded with Thompson Seedless on SO4 (169.00 days).

The fruit ripening is influenced by many factors such as climate, variety and crop level. The specific number of heat units (usually expressed as degree-days) are required for berry maturation, which differs significantly among varieties. The seasonal differences contribute for accumulation of degree days which influence the berry ripening in grape. The lower the temperature contributes for slow accumulation of degree days, results in delayed ripening of grape berries. The warm conditions contribute for rapid accumulation of degree days resulting in accelerated rate of grape berry ripening. The effects of elevated temperatures on fruit ripening are temporary and depending upon the degree of heat stress, sugar accumulation and fruit ripening will occur (Dokoozlian, 2000).

The stage of maturity can be judged by heat summation, besides others parameters such as days for bud burst and days for anthesis etc. Hence, heat unit requirement for maturity in different varieties and when grafted on different rootstock has been worked out on the basis of temperature of grape under semi-arid conditions of Hyderabad. There was significant variation among varieties, rootstocks and their interaction effect (Table 2). Among varieties, Flame seedless (2148 degree days) recorded less heat units and more number of heat units were recorded by Kishmish chorni (2231.70 degree days). As, the Flame seedless variety took less heat units, therefore, the bunches on those rootstocks ripened early and can be recommended for growing Hyderabad area. Among the rootstocks, the varieties grafted on Dogridge (2289.17 degree days) recorded highest heat units while, lowest heat units was recorded by varieties cultivated on own root system (2072.23 degree days). There is a significant difference between varieties and rootstocks, Flame seedless on own root (1992.70 degree days) recorded less heat units and more heat units were recorded by Kishmish chorni on SO4 (2351.90 degree days).

Plant growth and development is proportional to the biological time or thermal time, which can be defined as the integral part of the product of the time and temperature above a threshold level. The concept of heat units is simply to predict phonological stages and has been used to forecast the main stages of plant development. Varieties exhibit inherent differences in their heat unit requirement. Each variety has a specific heat summation requirement which however, varies under the influence of place of cultivation and time. This has been observed to be true in the present study. The degree-days were less with Flame seedless among varieties and among rootstocks, Dogridge showed more heat units, this may be due to the variation in the period of ripening. Several workers (Makhija *et al*., 1984; Rameshwar, 1993; Thakur *et al*., 2008) reported a wide range of degree days in different cultivars.

Rootstocks had significant impact on yield of grape wine (Table 3). Among varieties, Kishmish chorni (11.76 kg/vine) recorded highest yield per vine followed by Thompson seedless (10.55 kg/vine) and Flame seedless (8.42 kg/vine). Among rootstocks, Dogridge produced highest yield of 13.06 kg/vine irrespective of the varieties and lowest yields (7.89 kg/vine) were recorded in case of SO4 rootstocks, which is lesser than yield obtained from own rooted vines. The interaction between varieties and rootstocks was found to be significant indicating the influence of rootstocks

Table 3: Effect of different rootstocks on yield in commercial varieties of grape

	Rootstocks and yield (kg/vine)				
Varieties	1103P	SO4	Dogridge	Ownroot	Mean of varieties
Thompson seedless	10.76	8.31	12.80	10.35	10.55
Flame seedless	7.94	5.13	12.41	8.21	8.42
Kishmish chorni	10.80	10.23	13.98	12.11	11.76
Mean of rootstocks	9.83	7.89	13.06	10.22	
CD of rootstocks at 5%	1.99			SEM±	0.68
CD of varieties at 5%	1.73				0.59
Rootstock×variety at 5%	3.42				1.19

SEM: Standard error of mean

on different varieties. On the basis of average yield, it is evident that all the varieties grafted on Dogridge produced higher yields than the other rootstocks. Kishmish chorni yielded significantly highest (13.98 kg/vine) and lowest yield was with Flame seedless grafted on SO4 (5.13 kg/vine). Generally, yield of all varieties on SO4 are less than of varieties on other rootstocks. When own rooted varieties are taken into consideration, Kishmish chorni yielded highest (12.11 kg/vine), while the other two own rooted ones yielded less and are on par with each other. The highest yield per vine was recorded among all the varieties grafted on Dogridge. This may be due to vigour and prevailing climatic conditions. Highly vigorous vines put forth excessive vegetative growth which results in poor fruit setting (Morton, 1979) and fruitfulness due to competition for assimilates or excessive shading effect (Amirdzhanov, 1965). Similarly, Satisha *et al*. (2010) reported that the high vigour rootstocks such as Dogridge and St. George must have influenced the scions to accumulate dry matter in the vegetative portions like the shoot, trunk and canes, while rootstocks such as 110 R, 1103 P and 99 R must have encouraged accumulation in the clusters.

CONCLUSION

From the present investigation, it is evident that among varieties Kishmish churni found to be early maturing based on its requirement for less heat units which enhanced in early bud break, anthesis, fruit set and fruit ripening. Even varieties grafted on own root system were early types. The interaction effect among varieties and root stock is significant which result in identification early type varieties. On the basis of average yield, it is evident that all the varieties grafted on Dogridge produced higher yields than the other rootstocks. Kishmish chorni yielded significantly highest and lowest yield was with Flame seedless grafted on SO4. Generally, yield of all varieties on SO4 are less than of varieties on other rootstocks. When own rooted varieties are taken into consideration, Kishmish chorni yielded highest, while the other two own rooted ones yielded less and are on par with each other. The highest yield per vine was recorded among all the varieties grafted on Dogridge.

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