Table Grape Production in The Subtropics and Prospects For Nepal

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Abstract

Common grapevine (Vitis Vinifera L.) originated in moderate temperate climates, however, its commercial production is extended to subtropical and tropical climates around the world. Grape cultivation in Nepal started during the Rana regime (>70 years ago) yet there is no expansion of commercial crop production in the country. The western terai region is a prospective area for commercial table (fresh) grape production in Nepal, however, production constraints for this agro-ecological domain require further investigation. Diseases associated with the high rainfall during berry maturity are considered the major problems in the terai and mid-hills. Forcing budburst to shift harvesting time to before the monsoon (June-July) could be considered a plausible strategy for successful viticulture in comparatively warmer and drier subtropical climatic zones of western Nepal. Effective implementation of this strategy will require focus on selection of early maturing disease resistant cultivars and vineyard management practices to achieve earlier and uniform budburst leading to synchronised flowering and crop harvesting.

Keywords: *budburst, dormancy, hydrogen cyanamide and subtropical viticulture*

Introduction

Grape is one of the most widely cultivated fruit crops in the world. Its domestication has long been claimed from the wild population of *V. vinifera* ssp. *sylvstris* (Levadoux, 1956). The hot and dry summers followed by moderately cool winters characterised as the 'Mediterranean' type of climate is the traditional grape growing environment, with the majority (~70%) of commonly grown cultivars (cvs.) originating from the western Mediterranean region (Arroyo-Garcia *et al*., 2006). Over time, various cultivars have been developed, with specialisation to 'table grapes' for fresh consumption and 'wine grapes' for fermentation.

Grape cultivars are also successfully grown in the warmer climates of the tropics and subtropics (Figure 1). Expansion of table grape production in warmer climates is increasing through dynamic vine management and the use of growth regulators. Major tropical climate grape producing countries are India, Brazil, Venezuela, Peru, Colombia, and Thailand. Important or sizeable subtropical climate table grape industries are in southern Brazil, Uruguay, northern Australia, northern India, South Africa, Mexico, Namibia, Israel and Egypt(Souza Leao, 2014). India is the ninth largest grape producing country (FAO, 2015) accounting for more than 90% of its total tropical production (Chadha, 2008).

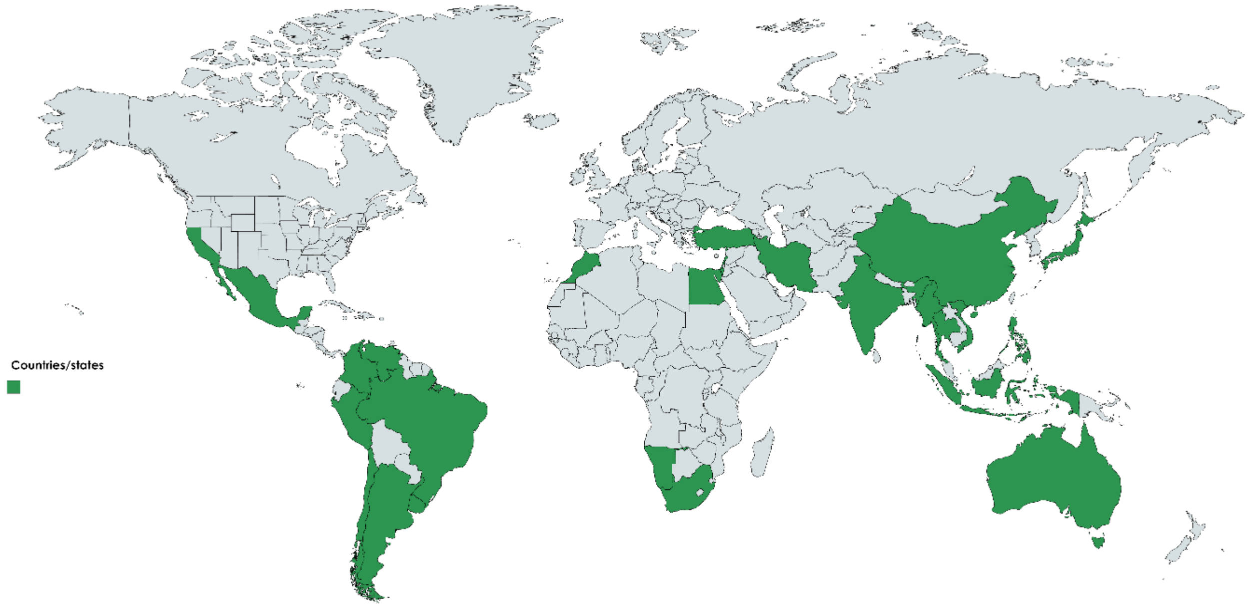

Figure 1 Major table grape growing countries/states in tropics and subtropics.

[Sources: map: https://mapchart.net/ and data: FAO, 2015]

Tonietto and Carbonneau (2004) used a multicriteria climatic classification in suggesting five classes of grape production in tropics and subtropics: tropical dry, tropical wet, tropical alternatively dry/wet, subtropical alternatively dry/wet and dominantly subtropical wet. Shikhamany (2006) used three classifications in India: subtropical, hot tropical and mild tropical grape growing agro-climatic zones.

Grapevine growth is accelerated in warmer climates, and thus the phenological stages are of shorter duration. Traditionally annual growth starts after sprouting of winter dormant buds, but in a mild tropical climate the vine grows continuously without a definite bud rest period, hence vines begin sprouting following pruning (Midmore, 2015). In traditional/Mediterranean climates, budburst starts in spring and is followed by a period of 8 to 12 weeks to flowering (Mullins *et al*., 1992), whereas in subtropical climates (e.g. Queensland, Australia) the flowering period occurs6 to 7 weeks after budburst. A difference of 4^{o}C in mean monthly temperature during vine growth reduced the period from budburst to anthesis from more than 12 weeks in a cool climate to less than 8 weeks in a hot climate (Watt *et al.*, 2008). There is thus the possibility of two or more crops in a year in warmer climates, but challenges lie in growth synchronization i.e. uniform budburst, controlling vigour and vegetative growth, and inconsistent yielding across the years (Lavee, 2000, Dahal *et al.,* 2014; Souza Leao, 2014). The problem of poor and uneven budburst is of special concern in the subtropics compared to temperate regions.

This article explores the prospect for subtropical viticulture in Nepal, but is preceded by a brief discussion of grapevine physiology under traditional and sub/tropical climates. Management practices required to grow grapevine under climate extremes are suggested.

Production Techniques in the Subtropics

Shifts of production from traditional climates towards the subtropics have been accompanied by innovative management techniques. The timing of key management operations (e.g. pruning) are usually determined by temperature and rainfall patterns of different regions of subtropics. In the subtropics, temperature does not limit the growth of the vine. Combinations of pruning, use of plant growth regulators and harvesting practices alter the vine growth cycle. In hot and dry tropical regions, double pruning with double harvest is possible, as buds are apt to sprout at any time of the year. In wet tropical regions, where double pruning is undertaken to manage the vigorous vegetative growth, a single harvest with double pruning is the general practice and the second harvest is not practical as it coincides with rainy season (Souza Leao, 2014). In subtropical regions with a hot, dry summer followed by monsoon and a short-mild winter, a single pruning during the mild endo-dormant stage and a single harvest are the accepted practice i.e. similar to practices in temperate areas (Possingham, 2004).

Grapevine phenology in a subtropical climate

A good understanding of grapevine phenology throughout the growing season for a particular climate is vital for vineyard management and provides a mechanism to adapt crop to changing climates (Wolkovich *et al.,* 2017). Eichhorn and Lorenz growth stage notation (E-L system) modified by Coombe and Dry (2004) is commonly used to identify major growth stages and involves descriptions of 47 stages (Figure 2). Annual growth starts after the swelling of the winter bud (stage 1) and is immediately followed by shoot growth, inflorescence emergence, flowering and fruit set. The annual growth cycle ends with the onset of dormancy or leaf fall after harvesting (stage 47).

The reproductive cycle of the grapevine both in subtropical and temperate climates consists of a biennial process (two seasons) from inflorescence initiation to berry maturity. The current season includes induction, initiation and differentiation of the inflorescence leading to dormancy. In the following season, inflorescence development and flower maturation lead to budburst, followed by flowering to berry ripening (Carmona *et al.,* 2008).The potential berry yield of a vine is largely determined over a period of approximately 15 months and 18 months before berry harvest in subtropical and temperate climates, respectively (Figure 3). In the subtropical climate, the suboptimal chilling due to a brief dormancy condition after leaf fall leads to poor budburst with subsequent yield penalties. Vine management practices that break dormancy and cause synchrony in subsequent growth are vital to subtropical grape production.

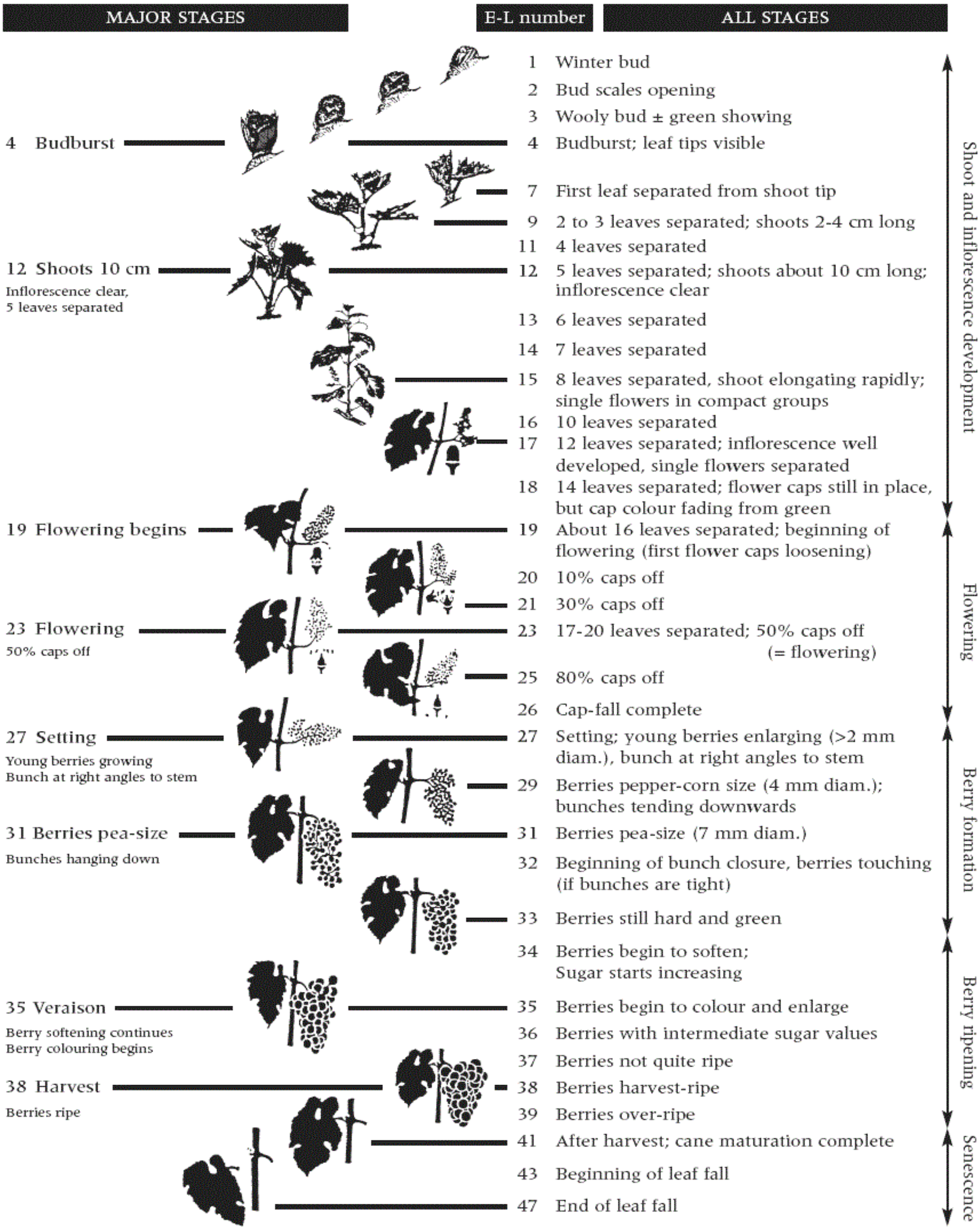

Figure 2 Modified E-L system (revised from Coombe, 1995) for identifying major and intermediate grapevine growth stages (Coombe and Dry, 2004) [Reproduced with the permission of Winetitles, Australia].

Varieties for the subtropical climate

The grapevine is probably the most widely grown temperate fruit crop in the tropics and subtropics. Although few grape cultivars are successfully grown in temperate to subtropics (one example is cv. Thompson Seedless), cultivars suitable for subtropics should have loose clusters, be resistant to fungal diseases and adaptive to high temperature conditions (Possingham, 2004). For table grapes, berries with superior flavour, seedless, crisp, sweet and thin skins are preferred. Popular warm-climate-grown early maturity table grape cvs. are Flame Seedless, Perlette, Himrod, Beauty Seedless and Superior Seedless. High table grape productivity (average of 30 t/ha as reported by Shikhamany, (2006)) has been achieved in north-western India (lat. 28^{o}-32^{o}N) which has a similar agro-climate to the south-western part of Nepal, and there is opportunity to acquire these skills and technologies for viticulture in Nepal.

Regulation of budburst in subtropical viticulture

The key regulators of bud dormancy are temperature, especially accumulated chilling time, and photoperiod (Carmona *et al*, 2008; Fennell and Hoover, 1991). Requirement of chilling hours may not be obligatory for breaking dormancy in sultana under the semi-arid, hot summer climate of Australia (Antcliff and May, 1961) or varies with varieties (Londo and Johnson, 2014). Due to suboptimal chilling temperature and a brief winter in subtropical climates, the application of a dormancy breaking chemical (e.g. hydrogen cyanamide) following the pruning in winter is vital to induce and synchronise budburst (Figure 3).

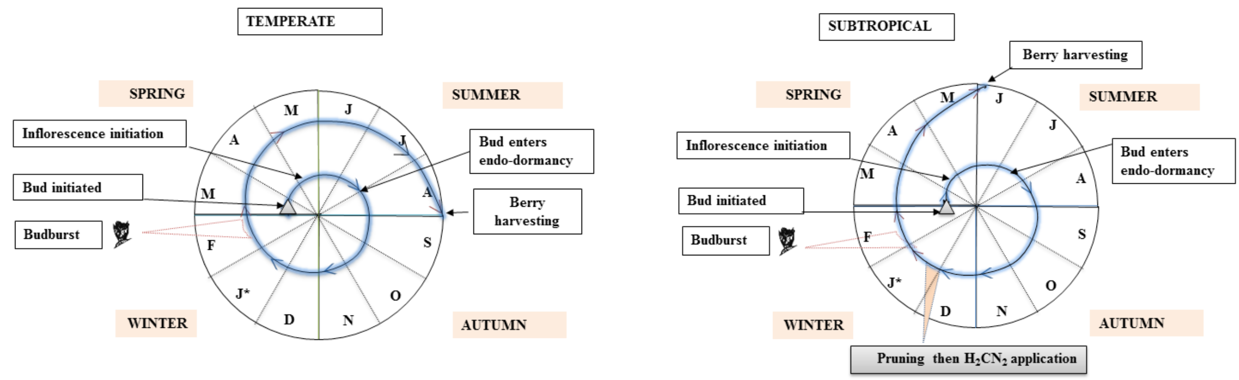

Figure 3 Reproductive cycle and key phenological growth stages in temperate and subtropical climate grown grapevine in the northern hemisphere (J*-January) [Revised to northern hemisphere from Considine, 2014]

Use of bud breaking chemicals

The response of grapevine to bud breaking agents is unique. Hydrogen cyanamide (HC) which was developed for breaking dormancy in grapevines (Shulman *et al.*, 1983) is most efficient whereas other standard dormancy breaking agents such as Dinitro-ortho-cresol (DNOC) and thiourea have only a weak or nil effect on grapevine bud opening (Nir and Lavee, 1993). Dormex® (a.i. HC) is used for the purposes of releasing buds from dormancy as well as enhancing a more uniform and rapid bud opening (Halaly *et al.*, 2008). HC appears to stimulate respiratory and oxidative stress through the perturbation in the activity of the cytochrome pathway in the mitochondria that leads to break of bud dormancy (Vergara *et al*., 2012). However, the mechanism of action and interaction between respiration, cell cycle regulation and oxidative signalling has not been completely elucidated.

Hydrogen cyanamide application is effective and commonly used in subtropical viticulture. However, the concentration of HC varies with application time (days after pruning or days before natural budburst) and genotypes. General recommended doses of HC for table grape varieties is 2% v/v a.i. with a non-ionic surfactant and by using a coarse droplet spray with nozzle pressure <40 psi. The effectiveness of HC 2% is considered as a near lethal dosage (Fuchigami and Nee, 1987) for temperate woody perennials, but Siller-Cepeda *et al.* (1994) did not observe any negative impact on grapevine growth and yield at 29^{o} north in Mexico when treated with up to 8% a.i. of HC at pruning or 5, 10 or 15 days after pruning. Dokoozlian (1998) suggested that the doses of HC could be increased or reduced depending on the ratio between the exposure of chilling temperature (<7°C) and chill-negating temperatures (hours >20°C).

Hydrogen cyanamide effectiveness on budburst depends on stage and depth of dormancy that also influence on berry maturity (McColl, 1986). In a subtropical climate of the Jordan Valley, HC treated buds sprouted 4-26 days earlier than the control, and advanced flowering by 4-13 days and significantly improved berry qualities over those of the control (Muhtaseb, 2008). A recent study in Western Australia showed that timely application of HC advances the budburst by about 20 days as compared to the control in cv. Crimson Seedless cuttings where late application had a negligible or negative effect on budburst response (Velappan *et al*., 2014). HC applied 8-10 weeks before natural budburst advanced fruit maturity by 14-18 days. However, HC application 4-6 weeks before natural budburst had little or no effect on time of berry maturity for cv. Muscat Hamburgbut significantly increased crop yield in a subtropical climate of Australia (George *et al*., 1988).Similar findings have been reported for cv. Perlette (Oar *et al.*, 1999). It is suggested that late application especially at high concentration damage to the buds and a delay in their opening.

Pruning and hydrogen cyanamide application

When and how much of the previous season's growth is to be removed during the winter (dormant) pruning in grapevine to contribute on bud opening and to maintain crop load, has to be determined. Dormant buds are more responsive to the pruning stimulus in tropics than in sub-tropics. Winter pruning combined with HC treatment is very important in regions with low and often inadequate winter chilling to regulate budburst (Lavee and May, 1997; Lombard *et al.,* 2006). Application of HC at inflorescence development stage may advance fruit maturity by 2-3 weeks but yield may be decreased because of increased floral abscission and reduced cluster number (McColl, 1986; Shulman *et al*., 1985) and smaller cluster weight (Or *et al.*, 1999). HC applied 1-2 weeks after pruning delayed budburst by 5 days for cv. Flame Seedless than if sprayed at pruning time (Siller-cepada *et al.,* 1994). Muhtseb (2008) also reported that HC applied as early as at the pruning time in a subtropical climate of Jordan Valley enhanced budburst and maturity than that with a later application. All buds in dormant shoots sprouted within 35 days in Hermosillo Valley, Mexico (Siller-cepada et al., 1994) and 46 days after pruning in Jordan Valley (Muhtaseb, 2008). Early sprouted buds may suffer from frost damage resulting in subsequent penalties in yield. Thus, the combination of pruning and HC application with reference to natural budburst time should be studied for effective budburst, berry maturity time and yield of the variety in a specific growing environment.

Other important consideration

Induced temporary stresses (e.g. restricted irrigation) and/or forced defoliation (e.g. sodium chlorate) before onset of winter are important practices to increase and synchronise budburst in a subtropical climate (Halaly *et al*., 2008; Lavee and May, 1997).Thinning of unfruitful shoots after flowering and trimming of shoots after harvesting (summer pruning) are also important operations to reduce the number of sites prone to fungal infection in subtropical climate grown grapevine.

Prospects of Table Grapes in Nepal

Background

Grape cultivation in Nepal is believed to have been started within the Rana regime (>70 years ago). After 7 decades, the estimated area under grape cultivation is 20 ha (including vines in home garden) with estimated total fresh production of 76 tonnes per annum in Nepal (Aatreya*et al.*, 2015). Small vineyards on government research stations/ farms were established in temperate and warm temperate climates from 1968 AD. However, viticulture has not been prioritized and there is effectively no commercial table grape production in Nepal. Monsoon associated diseases are believed to be the major limitations to production in the terai and mid-hills (Shrestha, 1998). Technology development and a variety evaluation project were initiated in the eastern terai part (wet subtropical) of Nepal during the late 1980's (Shrestha, 1996). Varieties were heavily infected by diseases and research priorities shifted during the early 1990's from the eastern terai to the western terai, i.e. the Regional Agriculture Research Station (RARS), Banke, an area with a comparatively drier subtropical climate.

Currently vineyards are established in three research farms/centres; one in the temperate region (Marpha farm, Mustang; lat. 28°44'N, alt. 2677 masl), and one in the warm temperate region (Central horticulture centre, Kathmandu; lat. 27°4'N, alt. 1289 masl) under the Ministry of Agriculture and serve as resource centres for propagules, and one in Khajura, Banke (lat. 28°06'N, alt. 149 masl) under the Nepal Agriculture Research Council developed as a warm climate research centre. Cultivars such as Thompson Seedless and Perlette gave earliest production of the nine cultivars tested in the western terai (Joshi, 1998), but were heavily infected by anthracnose diseases during the rainy season (Shrestha, 1996). The centre horticulture farm, Kathmandu identified Stuben, Muskut Berry, Kyoho and Black Olympia as promising cultivars but the quality of the first two cultivars were not preferred, while the latter two varieties suffered various disease issues (Sakuma, 1995). Current activities of grapevine in resource centres (Marpha farm, Mustang and central horticulture center, Kathmandu) are limited to small scale propagation and evaluation of varieties from a narrow germplasm pool. Resource centres have been producing and distributing 2000-4000 cuttings of cultivars (Perlette, Beauty Seedless, Himrod and Stuben) every year for home garden and small-scale orchard usein mid-hill districts. Due to inadequate vineyard management, much of the germplasm collected in resource centres become unproductive (RARS, 2012).

Markets for table grapes

Worldwide, table grape consumption is increasing, as part of a trend towards 'convenience' fruit (small fruit that can be consumed without preparation). Table grapes enjoy modest popularity among fruit consumers in Nepal. Table grape demand in Nepal is largely met by supply from India. Nepal imported 10,845 tonnes of table grapes during 2012, which was only 1,439 tonnes in 2009 (http://faostat3.fao.org/browse/T/TP/E), about 7 fold increase in import within four years. With increasing population pressure in urban areas and enhanced purchasing capacity it is anticipated that Nepal will have increasing demand for table grapes for the domestic market and export opportunities.

Climates for subtropical viticulture

Nepal has a diversity of agro-climatic zones in which viticulture could be practiced. In a vineyard suitability analysis evaluating slope, aspect, soil, land cover and physiography, Acharya and Yang (2015) estimated 6.6% area of Nepal is highly suitable for vineyard. Dry temperate hilly areas, e.g. Mustang (28°8"N 83°6"E) experience dry summers, low rainfall and cool winters suitable for grape production, but the physiography and poor road facilities limited the expansion of fresh grapes production in large scale.

Considering the production capacity, mechanization and proximity to market, the subtropical climate of the western terai has potential to expand commercial viticulture. In this area, winters are short, mild and foggy, and summers are hot and dry. A long term (1981-2010 AD) weather data recorded at the regional meteorological station, Nepalgunj (28°05"N, 81°62"E), Banke (a town in the western terai of Nepal) shows a 11.6°C monthly minimum temperature for February. Similarly, mean monthly temperatures for May and June were 31°C and 31.5°C (http://www.dhm.gov.np). Santibanez *et al.* (2014) reported total degree days required from budburst to berry harvesting was 1150 and 2050 degree days for early cv. Perlette and late cv. Crimson Seedless of table grapes, respectively. In 2011, the average daily minimum temperature started to rise i.e. >10°C from early February which is higher than the commonly accepted base temperatures (10°C) for grapevine growth. Based on one year's weather data, there were 2047 degree days (10°C base) from 19th February to 16th June, i.e. over the period of 117 days. In general, early season cultivars are ready to harvest with sufficient sugar level within 110±10 days after budburst in a subtropical climate. Harvesting is possible within 100 days after budburst for the cv. Flame Seedless in a subtropical climate of Australia. Monsoon rain in the western terai of Nepal arrives during the second fortnight of June and continues until September, with an annual rainfall of 800-1200 mm of which 65-75% is within July-September. There is potential to synchronise completion of the grape harvest to within a few weeks before the onset of the rainy season, if forced budburst takes place during the third week of February. Prophylactic sprays of fungicides are equally important to maintain photosynthesis and vegetative growth during periods of monsoon rain to prevent the infection of mature leaves.

Conclusions and Recommendations

Heavy rainfall coinciding with the fruit harvest period is considered a major constraint for production of table grapes in Nepal. The western terai of Nepal which experiences a dry climatic window is considered as a potential production zone for table grapes, however the window for production is short. Therefore, successful production would require vine growth management practices to ensure harvest occurs well before the monsoon rain.We recommendi) establishment of vineyards in cultivating early maturity cvs. such as Perlette, Flame Seedless, Beauty Seedless and Superior Seedless, ii) vineyard management trials testing the use of HC and timing of pruning for artificial induction of bud dormancy release, and iii) use of machinery for effective spray of plant growth regulators (e.g. gibberellins and HC) and pesticides for the development of a table grape industry. We also suggest that future research aims at vine protection strategies during heavy rainfall periods, use of defoliants to induce leaf fall before onset of winter and controlled irrigation for the control of vine vigor and growth. Grapevines are perennial with a long reproductive cycle, hence a multidisciplinary team of viticulturists and pathologists are required to develop productive subtropical table production technologies for Nepal.

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