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Grape Production Injuries and Prevention

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Introduction

Grape acreage and production have been steadily increasing in the US. Ninety percent of grape farms are smaller than 100 acres and about 16,000 of these were vineyards. California accounts for about 90% of the total production in the US (NASS-USDA, 2014).

While acreage in the leading grape producing states has been somewhat steady, the acreage in several eastern and southeastern states has been steadily increasing in recent years. In Virginia, between 1979 and 2007 the number of wineries has gone from six to 130 and grape acreage from 286 to 3,000 (VDACS, 2012). Acreages of Virginia vineyards continues to be primarily comprised of smaller productions with 59% of vineyards at 10 acres or less. The average vineyard size is approximately 15 total acres, while the median size is approximately 7.5 total acres (Virginia Vineyard Association, 2019).

Eastern US grape production is a labor-intensive operation. According to the Virginia Vineyard Association Report (2019), 2 of 3 producers see workforce and labor as a key challenge facing the industry over the near future. Many tasks such as dormant pruning, shoot suckering and crop harvesting are done repetitively by hand and can result in musculoskeletal disorders (MSD) among the workers. As the number of workers in the industry increases, it is reasonable to expect a significant increase in both the number of injuries and treatment cost.

The goal of this publication is to prevent or reduce injuries among vineyard workers by familiarizing them and their supervisors with the operations associated with grape production, common injuries, and steps they can take to prevent injuries with or without the use of assistive technologies.

This publication is organized in three major sections. The first deals with a brief description of different tasks associated with grape production, the purpose, and the tools used. The second section identifies the common injuries associated with each task and the steps the workers can take to prevent such injuries. The final section covers the assistive technologies that are available to reduce the incidence of primary and secondary injuries.

Tasks Associated with Grape Production

Detailed discussion of different tasks associated with grape production is detailed in wine grape production guides (Dami, et al., 2005; NRAES, 2008). Therefore, only a brief description of different tasks associated with grape production and tools used is included in this section.

Dormant Pruning

Dormant pruning (non-growing time) will maintain vine capacity, avoid over-cropping, and maintain the desired training system. Although dormant pruning can be mechanized, the operation is normally done manually in smaller wine grape vineyards of the eastern US. The number of buds retained during pruning depends on the vine's current season capacity as well as the anticipated or desired cropping capacity of the coming season.

The tools commonly used for pruning are loppers, hand pruners and hand saws (Fig. 1). Hand pruners work well for pruning canes (one-year old wood). Loppers and hand saws are used for more mature wood (Brown and Gao, 2004). During pruning, it is

expected that workers will make about 750-1,000 cuts per hour (Roquelaure, et al., 2001). Dormant pruning is typically done late in the winter or early spring before bud burst.

Figure 1. Tools commonly used for pruning. From top to bottom Saw, hand shears, and lopping shears.

Canopy Management

The grapevine canopy consists of growing season shoots, including stems, leaves and fruit clusters. Its architecture is governed in part by the training system used. Canopy management refers to a range of practices used to modify the microclimate of the canopy, specifically around the fruit zone. Appropriate canopy management is critical to achieve optimum grape and wine quality potential. Some of the operations that comprise canopy management are described below.

Shoot Thinning and Suckering

Shoot thinning will reduce shoot density to the desired range of 3 to 5 shoots per foot of canopy (Reynolds and Wolf, 2008). Thinning is generally done when shoots are 3 to 6 inches long, and is more commonly used with cordon-trained vines than with head-trained, cane-pruned vines, as cordon-training results in greater shoot growth from non-count bud locations associated with spur-pruning (Reynolds and Wolf, 2008).

Suckering is similar to shoot thinning but is performed to remove shoots from the crown of the plant, or beneath the soil line (suckers) or from the trunk(s) of the grapevine (water sprouts) (Hellman, 2012). Often, more than one pass through the vineyard may be necessary to complete this effectively (Dami, et al., 2005).

Shoot Positioning

Grapevine shoots are generally phototrophic in their growth habit; however, this varies by species and variety. Shoots of American type grapes (e.g., Vitis labrusca) generally have a procumbent growth habit, whereas shoots of European (V. vinifera) varieties typically exhibit a strongly upright growing habit. These differences in growth habit are often used in the selection of training system. Regardless of whether the shoots are primarily upright or procumbent in growth habit, many shoots will grow horizontally along the trellis and cause shading of other shoots. Shoot positioning is used to redirect shoots into a vertically upright or vertically downward-oriented canopy. While the process untangles the shoots, the shoot positioning (Fig. 2) also creates better air circulation through the canopy and better exposure of fruit clusters (Reynolds and Wolf, 2008). Shoot positioning also maximizes the use of available trellis space by redistributing the shoots for full utilization of trellis space. Positioning is first applied around bloom, before shoot tendrils firmly anchor the shoots, and is repeated once or twice as the shoots continue to elongate.

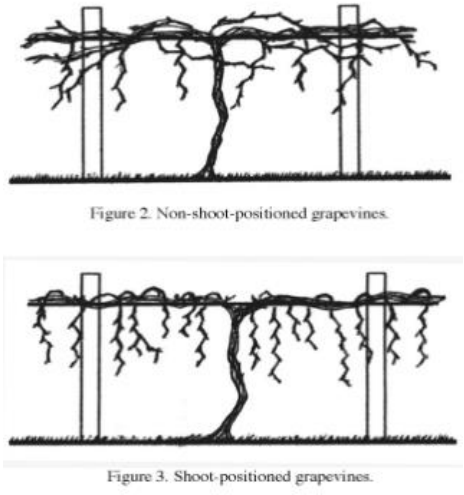

Figure 2. Non-shoot-positioned grapevines.

Figure 3. Shoot-positioned grapevines.

Figure 2. Poorly positioned (top) and properly positioned (bottom) vines (Brown and Gao, 2004)

Depending on the trellis system used, shoots are positioned either upward or downward. This task of positioning the shoots upward or downward is known as tucking or combing, respectively. Vertically divided trellises, such as Scott Henry and the Smart Dyson, will require both combing and tucking (Dami, et al., 2005).

Cluster Thinning

Cluster thinning will reduce crop yield and is typically performed between fruit set (mid-June in Virginia) and the rapid onset of ripening, or veraison (mid-July in Virginia). If cluster thinning too early, vines can compensate by setting more berries and/or increasing berry size, negating the purpose of the thinning. Performed too late (at or after veraison), there is little benefit gained by the remaining crop. Vines that lack adequate capacity (vigor and cropping potential) should be thinned more heavily to promote greater vegetative growth (Dami, et al., 2005).

Selective Leaf Removal

Selective leaf removal will improve air circulation in the canopy, increase fruit exposure and aid the penetration of pesticides into the canopy (Dami, et al., 2005; NC State University, 2007b). Leaf removal, if needed, is typically done on the shady side of the canopy between flowering and well before veraison. Multiple passes may be required to maintain the desired degree of fruit exposure. Tractor-mounted machines are available to shear or blow off a narrow band of leaves from grapevine canopies; however, leaf removal is still manually achieved in many smaller vineyards that cannot afford the capital purchase of specialized equipment. On average, one to three leaves are removed from each shoot (NC State University, 2007b).

Shoot Hedging and Skirting

Shoot hedging is the final operation associated with canopy management and is performed during the growing season to remove shoot tops that would otherwise shade the fruiting zone of vertically shoot-positioned grapevines (Reynolds and Wolf, 2008). Shoot skirting also removes the shoot tips, but is performed with downward growing shoots and is done to avoid pinching and pulling off the shoots with the passage of tractors or other equipment.

Although shoot hedging can be mechanized with tractor-mounted sickle-bars or rotary mowers, many smaller vineyards continue to use hand-tools for this task. When shoots are hedged by hand, workers should keep their arms at the chest height to avoid injuries. Worker height may be adjusted with the use of platforms (NC State University, 2007a).

Weed Control

Weed management is generally necessary to limit the competition from other unwanted plants. This operation generally helps to maintain a healthy vineyard through more effective utilization of soil moisture and nutrients (Dami, et al., 2005). Weeding is particularly important for newly established vineyards because new vines may not be able compete with weeds for water and nutrients.

Weeds can be managed with herbicides, through mechanical means, and by mulching. Many vineyards, including the relatively few that aspire to farm organically, choose to manage weeds mechanically. Cultivators include tractor-mounted implements, as well as the hand-hoe, which is often favored for use around newly planted vines. Powered line trimmers (“Weed-eaters”) are also used for in-row weed management and are associated with potential injuries to the user including loss of hearing, eye injury, and vibration. Proper personal protection equipment (PPEs) such as hearing and eye protection, long pants, boots and/or gators, and vibration-absorbing gloves should be used in conjunction with these tools to avoid injuries.

Harvesting

Hand harvesting of grape involves selecting and cutting grape clusters from the vine canopy and gently placing them in plastic trays (lug) or buckets. The trays hold about 23 pounds of fruit and are moved along the row until full. The trays are stacked on a trailer and transported to a collection site for further processing.

Buckets are sometimes used to collect and carry fruit to half-ton bins. Such systems are favored by some wineries for their ability to be mechanically move and empty bins at the crush pad. In either case, the workers expose themselves to repetitive movements

of cluster removal, loading and handling buckets up to 25 pounds of crop at a time.

Figure 3 illustrates the harvesting cycle followed by the workers. Commonly used harvest tools include a sharp knife with a curved blade or a scissor-like pair of hand shears. Use of appropriate PPEs is highly recommended for preventing injuries during harvest.

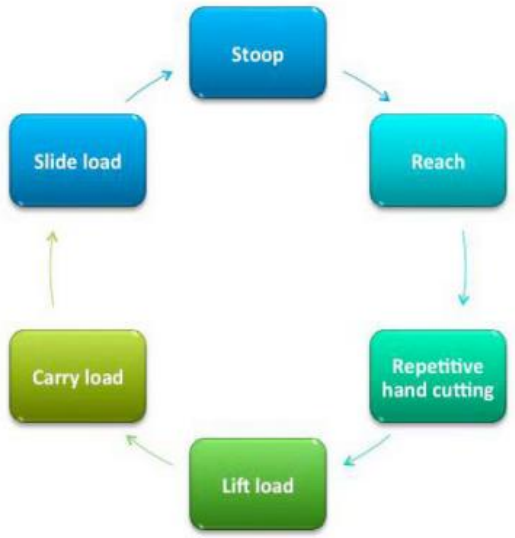

Figure 3. Harvesting cycle for workers (AgSafe, 2011)

Common Primary and Secondary Injuries among Vineyard Workers

Musculoskeletal Disorders

Among work-related injuries experienced by vineyard workers, the most common is the Musculoskeletal Disorders (MSD) resulting from repetitive stressing of body parts (Meyers, et al., 1998). Back injuries, tendinopathies and neuropathies are typical examples of most common MSDs. Risk factors associated with these types of disorders are repeated use of manual cutting tools such as shears, being a female, and being overweight. Most workers are susceptible to this disorder because they do not condition their bodies adequately before engaging in these high-risk tasks. The fact that most vineyards are exempted from the Occupational Health and Safety Administration (OSHA) Regulations as small farms also increase the opportunities for MSDs among the vineyard workers.

Tasks such as pruning and harvesting cause repeated stressing of hands and wrists. For this reason, MSDs are very common during the pruning and harvesting seasons (Youakim, 2006). Similarly, during harvest, lower back, hands, and shoulders are stressed multiple times when trays or buckets filled with grapes are lifted from the ground and carried to the trailer/bin. Low frequency vibrations from machines also cause lower back problems. Musculoskeletal disorders of the hips, knees, legs, ankles, and feet occur when workers stand and walk on uneven or muddy ground, carrying heavy loads, squatting for long periods or standing on hard surfaces. Osteoarthritis is also a common hip problem among vineyard and farm workers (Davis and Kotowki, 2007).

Another reason why MSD problems are so widespread among the vineyard workers is that they do not always seek medical assistance when needed. Many may not report injuries fearing the loss of their jobs. Furthermore, the current OSHA forms used for reporting injuries lack a designated space for reporting MSDs.

Within the farming communities, the reluctance among workers in seeking medical assistance may be attributed to either the cultural and social norms or difficulty in getting medical assistance. Many migrant workers try to treat their illnesses on their own or visit a clinic or hospital only when it is unavoidable. Factors such as distance, lack of health insurance, cost, legal status of the migrant worker, language barrier and lack of familiarity with the health care system may also interfere with seeking medical help when needed (Brumitt, et al., 2011).

Tractor Related Injuries

Tractors are widely used in vineyards to transport fruits and on occasion to perform tasks related to crop maintenance such as pruning, weeding, and harvesting. While tractors are extremely versatile, they are known to cause serious injuries or even fatalities when improperly used. Tractor upsets are common and unless the operators are protected adequately (Fig. 4), they may result in severe injuries or in loss of life. Combined use of seat belts

and roll-over-protection (ROPS) devices while operating a tractor has helped to significantly reduce the number of injuries and fatalities.

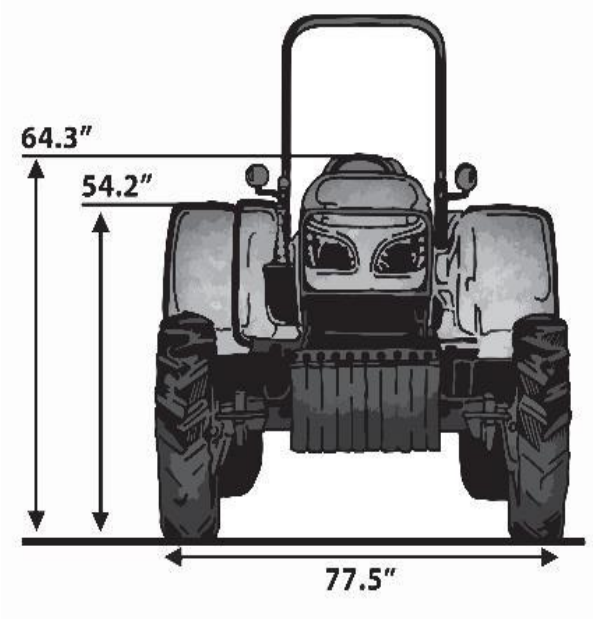

Figure 4. A low-profile tractor with roll over protection structure (ROPS) (http://www.kubota.com/product/M40LOW/M40LowProfile.aspx?tab=lowprofile)

For this reason, by law, all tractors manufactured and sold in the US since 1973 are required to be equipped with seat belts and ROPS. However, the problem is that a large number of tractors manufactured prior to 1973 are still in operation in vineyards and on farms without seat belts and ROPS.

Tractors are designed to be occupied only by one person – the operator. However, tractor operators often take other riders along creating opportunities for accidents and severe injuries.

Tractor operators experience MSDs and stomach problems due to exposure to low frequency vibration. Many tractors lack proper seat suspension systems that can isolate and protect the operator from the low frequency tractor vibration. Other problems that are common among the tractor operators are changes in cervical vertebrae, abnormalities with thoracic and lumbar vertebrae, protruded and herniated disks, and reduced disk height (Kumar, et al., 1999).

Pest Hazards

Ripe grapes attract bees, hornets, and wasps and these stinging insects pose a significant hazard to workers, particularly those who might be allergic to stings, and subject to anaphylaxis. Supervisors should assess the risk prior to engaging in the work, and be properly trained to recognize shock symptoms and be equipped to provide first aid in the event of stings. Increasingly, tick-borne illnesses. Use DEET-containing repellants. Spider mites in vineyards can cause dermatitis, hives, conjunctivitis, or a runny, stuffy nose and asthma. Reaction to different allergens in vineyards may also cause asthma among workers. Those experiencing asthma symptoms should not be permitted to work in the vineyard (Youakim, 2006). Venomous snakes, particularly eastern timber rattler and copperheads, pose limited risk in most vineyards. This risk increases in weedy vineyards or in those that support a population of voles or meadow mice. Proper footwear, including boots, greatly minimizes this risk.

Sunburn

Farm workers are at risk of sunburns when exposed to sun on a daily basis. Overexposure to sun on daily basis for long periods of time may cause skin cancer. The most vulnerable areas of the body are the head, face, ears, and neck. Light skinned workers are more susceptible to sunburns and skin cancer than others. American Cancer Society estimates 800,000 new cancer cases are diagnosed each year. The following steps may help reduce the incidence of sunburns and/or cancer:

1. Whenever possible avoid sun exposure between 10 AM and 3 PM,
2. Wear protective clothing such as long sleeves, long pants, high sock, and gloves,
3. Wear wide brimmed hat, cap flap or flap on the cap, and
4. Use sunscreen with sun protection factor (SPF) rating of 15 or more every two hours.

Pesticides and Herbicides

Pesticides including herbicides are important for managing weeds, diseases, and arthropod pests of grapes. Pesticides may, however, harm workers if they ingest, breath, or absorb the pesticides through direct exposure. Acute exposure to certain

pesticides and herbicides may cause cancer, neurological disorders, or reproductive disorders. Examples of common neurological disorders linked to over-exposure to pesticides and herbicides may include muscular weakness, mood disorders, anxiety, concentration problems, memory disorders, and Parkinson's disease. Some pesticides are known to affect the reproductive system causing sterility, miscarriages, still-born births, delays in growth and development, and fetal abnormalities. Pesticides may also interfere with hormone balance, growth factors, neurotransmitters, and the development of the nervous system (Garrigou, et al., 2011).

Workers must use appropriate PPEs such as gloves, protective coveralls, and masks when applying pesticides and herbicides for protection. A study by Garrigou, et al. (2011) showed that less than 50% of the workers use PPEs required during the application of pesticides. Pesticide labels are required to provide information on Restricted Entry Intervals (REIs) that specifies the minimum amount of time that must pass between the time of application of a pesticide to an area and the time individuals without protective clothing and equipment can go into that area. The REIs, when adhered to, limit the exposure of unprotected workers to the pesticide. In addition to pesticide label requirements for PPE and REIs, the Worker Protection Standards must be followed to provide at least the minimum legal requirements of worker protection on the farm.

Hand and Wrist Injuries

Hand and wrist injuries are very common among vineyard workers. Repetitive operations such as harvesting and pruning are high risk activities that can cause hand and wrist injuries. When pruning, workers make cuts repetitively with pruners continuously for several hours. This repetitive motion creates considerable stress on the hand and the wrist. The same is also true when grape clusters are cut and removed from the vines continuously for long periods of time. The MSDs that are common among the vineyard workers are bursitis, carpal tunnel syndrome, cubital tunnel syndrome, and myalgia (Meyers, et al., 2006).

Carpal tunnel syndrome is a disease caused by the repetitive bending and twisting of hands during pruning and harvesting. This condition causes the tendons in the wrist to swell and compress against the median nerve as shown in Figure 5. Symptoms of carpal tunnel syndrome may include soreness and the swelling of hands and numbness in the fingers especially in the thumb, index and middle finger at night. Treatments for this condition may include rest, exercises and surgery. Carpal tunnel syndrome may also be caused by power tool vibration, gripping tools, carrying heavy loads, and holding a steering wheel.

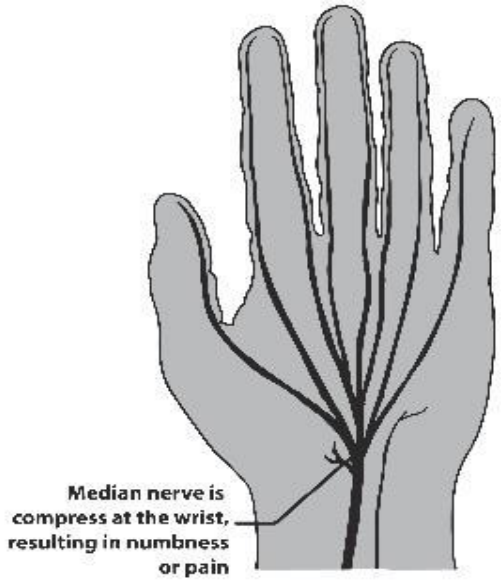

Figure 5. Nerves and parts of the hand and wrist affected by Carpal Tunnel Syndrome

Transient hand paresthesia (tingling, tickling, pricking or burning sensation) is another hand-wrist injury common among the vineyard workers. A study in France (Roquelaure, et al., 2001) concluded that slightly over one-third of the vineyard workers experience this condition. Very few transient hand paresthesia cases, however, are chronic and they generally occur only during the pruning season. The study also concluded that the piece-rate pay system may be the primary contributing factor to this condition. Under such a system, workers try to increase their output and income by working faster and longer hours. Both cause overstressing of their hands and wrists. Incidence of transient hand paresthesia cases may be reduced with the use of

pruners with sharp blades (Roquelaure, et al., 2001) and ergonomically designed handles.

The major contributor to the MSDs in hands and wrists of vineyard workers is the tools they use. Kumar, et al. (2008), studied the ergonomics of vineyard hand tools. They examined how the factors such as handle diameters of tools along the handle, length of the handle, weight of the tool, and angle of the handle with respect to the hand. They concluded that tool handles should be large enough to distribute the force across the palm spanning fingers two through five. They have also observed that the body parts susceptible to injuries may depend largely on the worker's body position and the task they are performing.

Lower Back Disorders

The most common MSD among the vineyard workers is the back problem. Lower back disorders are particularly common during the harvesting season due to frequent bending over and lifting heavy loads (Fathallah, et al., 2008). When the connective tissues support the lumbar spine and the intradiscal fluid is lost, the nucleus' ability to bear weight may be reduced. Then the load may be spread on to the annulus adding more stress on these tissues (Fig. 6). Repetitive forward bending may also cause changes in the reflexive behavior of spines, increasing the risk of low back disorders (Fathallah, et al., 2008).

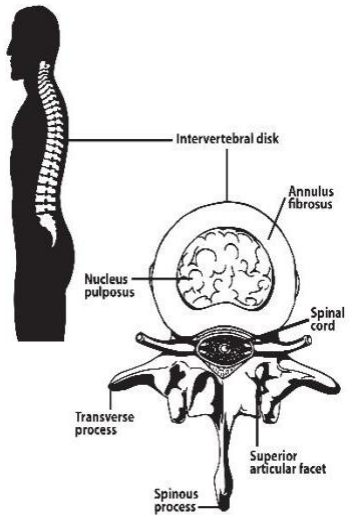

Figure 6. Detailed View of a Human Vertebrae and Disk

Even though stooping postures are known to cause lower back disorders among agricultural workers, vineyard workers favor this posture because of minimum energy requirement compared to others (Fathallah, et al., 2004). Trellises also force workers to stoop and work at levels below the optimum. Working in a stooped position reduces the ability of spinal tissues to manage the internal and external forces adequately causing lower back disorders (Fathallah, et al., 2008). Stooping while lifting the loaded tubs/buckets found to triple the load on the spine compared to lifting while standing in the neutral position (Fathallah et al., 2004).

Preventing Primary and Secondary Injuries in Vineyards

General Prevention

Adoption of safe and healthy work habits should help vineyard workers to prevent or reduce incidence of primary and secondary injuries. Staying in shape with regular exercises is very important for avoiding injuries while doing highly strenuous vineyard jobs (Hermans, et al., 2009). There are several yoga postures that can be incorporated into the daily routine that could open up the back and release tension in muscles, tendons and joints. Stretch exercises (Fig. 7) at the start of each work day and periodically during work may also help prevent MSDs (Hermans, et al., 2009). Proper nutrition, proper meals on time, and staying hydrated throughout the work day are also important for preventing MSDs (Vierra, 2005).

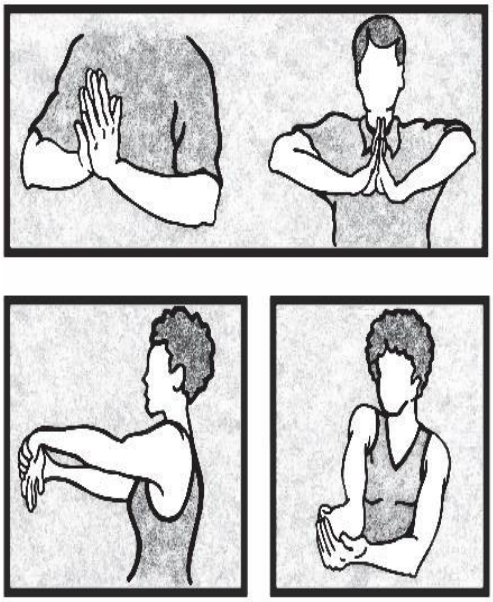

Figure 7. Simple wrist stretch exercises that can help prevent MSDs (Vierra, 2005).

Selecting the right tools for the job that are well maintained is extremely important for reducing the incidence of work-related injuries. Well maintained tools of proper size can reduce both the power requirement for the job and the stress on body parts significantly.

Hand and Wrist Injuries

The risk of hand and wrist injuries may be avoided with good work habits. Other steps for reducing the hand and wrist injuries are assigning different responsibilities to workers on a given work day (example: alternating between harvesting and sorting grapes), taking periodic breaks, working at a slower pace and using ergonomically matched tools (Walters, 1996).

Lower Back Disorders

Depending on how they are trained, grapevine shoots may reach a height of 7 feet or more. The fruit zone may range from 2 to 6 feet above ground level, again depending upon training system. This height may result in many awkward hand, wrist, and back postures while working. Use of a vineyard cart (Fig. 8) may improve posture by letting workers sit while carrying out different operations such as pruning and harvesting. Although the carts are reasonably effective in preventing MSDs, they work satisfactorily only when the ground is relatively flat and firm (Hermans, et al., 2009).

Figure 8. A worker pruning while sitting on a vineyard cart (Hermans, et al., 2009)

Many different types of trellis systems are used in vineyards and they differ in height and in maintenance requirements. Five most commonly used trellis systems (VSP 4x4, Smart-Dyson, Scott-Henry, Vertical Shoot Position and Lyre systems) were evaluated to determine which is more worker friendly (Fathallah, et al., 2004; Kato, et al., 2006). They examined hand and wrist, and torso positions while working. Back flexion and torsion were measured using a lumbar motion monitor which tracked motion in three planes. The torso flexion for each of the trellis systems was significantly different due to differences in their set-ups. For example, some systems required lifting of the arms well above the shoulder to reach the grapes while the others required bending over. These studies concluded that the Vertical Shoot Positioning trellis is better suited than others from the point of view of worker health.

Proper work-bench height when carrying out indoor activities such as fruit sorting or packing is critical to prevent MSDs. This will allow workers to do their work without bending or reaching over (Fig. 9). For men, the ideal height for light work is between 40 and 43 inches and for heavy tasks it is between 36 and 39 inches. The same for women range between 37 to 39 and 33 to 35 inches for light and heavy tasks, respectively. When a task can be performed sitting down, workers should be encouraged to do so on a work bench for safety and comfort (CDC and NIOSH, 2001).

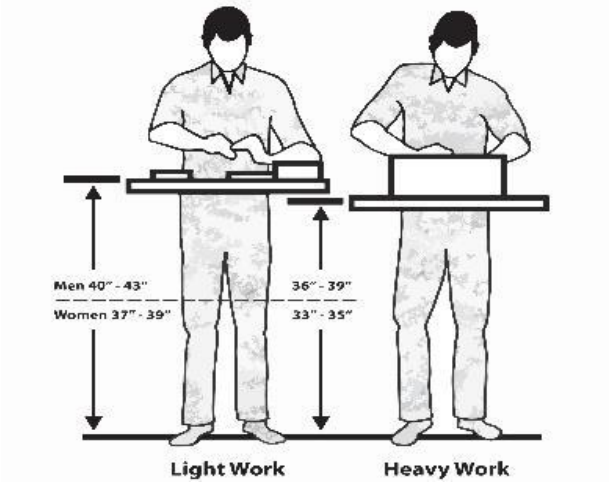

Figure 9. Ideal work bench heights to prevent musculoskeletal disorders (CDC and NIOSH, 2001)

Particularly during harvest season, vineyard workers lift and carry heavy loads on a daily basis exposing themselves to lower back disorders. Ideally, these workers should not be lifting weights heavier than 50 pounds. When lifting weights, one must make sure that the load is equally distributed on each hand to prevent overloading of one side of the body (Hermans, et al., 2009). If at all possible, loads should be kept between hand and shoulder levels. This may not be feasible especially during harvest because filled bins have to be lifted above the head to dump the grapes into the collection trailer (CDC and NIOSH, 2001). For ease in lifting and to prevent back injury during lifting, the load should be kept close to the body. When loads need to be rotated, make sure the body is turned with the load by turning on one's feet instead of twisting the body to protect the lower back (Hermans, et al., 2009). Harvest bins should also have handles to help protect the workers (CDC and NIOSH, 2001). The best handles are those with smooth finger grooves for keeping the wrists in the neutral position. Soft material coating on handles is recommended for protecting the hands and wrists of workers (National Institute for Occupational Health and Safety, 2004).

Administrative Control

Prevention or reduction in the number of work-related injuries may also be possible through the adoption of selected administrative steps. Government regulations similar to the ones developed for protecting workers in other industries can be voluntarily used to protect the vineyard and agricultural workers. For example, an OSHA regulation enacted in 1997 requires any workplace with two or more workers performing the same task and diagnosed with musculoskeletal disorders within 12 months of each other to undergo the following three-step mitigation process:

1. Employers must identify the cause/s of the musculoskeletal disorders.
2. Develop steps to reduce the risk of MSDs among their employees.
3. Train employees on steps they can take to avoid musculoskeletal disorders.

Employers may also create teams of managers, supervisors, and workers to discuss and identify potential MSD risks in the work place. In such a setting, workers with insight to tasks causing MSDs should be encouraged to share the information with the supervisors and/or managers. Administrators can then use this information to take steps to protect the workers. Workers may also help managers to find solutions that workers will adopt instead of creating regulations that workers will ignore because they are either inconvenient or impractical (CDC and NIOSH, 2001). Changes in the health care system may also help prevent musculoskeletal disorders. A survey by Lopez-Cevallos, et al. (2012) revealed that only about 23% of farm workers have health insurance. In addition, only 5% of the respondents spoke English.

Both lack of health insurance and language barrier serve as road blocks for seeking medical help when needed.

Assistive Technologies for Preventing Injuries

Mechanization of Grape Production

Most agricultural operations in the US including the production of certain specialty crops are fully mechanized. Thus far, the progress towards the mechanization of grape production has been limited for two primary reasons: 1) grape growers believe that quality grapes can only be produced manually, and 2) most vineyards are smaller than 100 acres and

this size is not conducive to mechanization. However, high labor requirements and high injury potential of tasks associated with grape production have generated interest in mechanized grape production. This interest has resulted in the development of different mechanical systems for different operations.

One such system is found to be effective for tasks such as pruning, shoot thinning, fruit thinning and leaf thinning. Many producers like the potential to produce high quality grapes economically and with minimum injury risks to workers. Because it is faster, this system can do fruit thinning multiple times during the season improving both yield as well as quality of grapes. Even though considerable savings in labor and cost of production, one can justify justification its use depends primarily on vineyard size. According to Daniel (2010), the vineyard must be at least 300 acres to justify a mechanized grape production system.

A second system well suited for summer and winter pruning, leaf removal, fruit and shoot thinning (Fig.10), and canopy management (Fig. 11) was developed. The quality, quantity, and taste of the grapes produced using this mechanical system was similar to the grapes produced manually. Even though the mechanical systems currently available have resulted in considerable savings in labor, there is room for further improvements so that grape production can be fully mechanized (Morris, 2007).

Figure 10. Korvan vineyard mechanization system shear pruner (Morris, 2007)

Figure 11. Korvan vineyard system: shoot thinner (Morris, 2007)

Pruning

Electric pruners (Fig. 12) are effective in reducing the stress on hands and wrists during dormant pruning and thus the number of MSDs. These battery-operated units weigh four to eight pounds and have the capacity to work continuously for eight to ten hours when fully charged. With the push of a trigger, the pruners can cut wood up to 1.8 inches in diameter with minimum effort. Newenhouse, et al., (2005) concluded that electric pruners have the potential to save labor by about 20% and they cost approximately $1,500.

Figure 12. Electric pruning shears (Newenhouse, et al., 2005)

Harvesting

While most operations associated with grape production are known to cause MSDs, the harvesting operation is found to cause more disorders than other operations. Activities such as frequent bending over,

and lifting and unloading the filled tubs or buckets may all contribute to disorders.

In an effort to reduce the number of MSDs, a smaller tub (24in. x 16in x 8in.) was developed (Fig. 13). Even though this tub is only one inch shorter than the traditional, it reduced both the weight of the filled tub by about 11 pounds and the stress on lower back by bringing the center of gravity of filled tubs closer to the worker body. Results of field tests have shown fewer back injuries with the new design (Tesconi, 2003).

Figure 13. Newly designed smaller tub (left) beside traditional tub (Meyers, et al., 2006)

While it took 26 seconds to fill a tub, the productivity with the new tubs dropped by about 2.5%. Both workers and employers were not happy with this drop because daily income of workers is tied to productivity. However, the vineyards participating in the study switched to the smaller tubs to reduce the number of back injuries (Meyers, et al., 2006).

During harvest, workers move the tub from one location to the next with their legs to avoid frequent bending over. In order to minimize this effort, two new tub designs were attempted. One design included tubs with smooth base for easy sliding on the ground surface. The second included mounting the tub on a wheeled cart (Fig. 14). Even though the design changes associated with the first design was minor, it helped to reduce fatigue and risk of injuries among the workers in a significant way.

Figure 14. Tub mounted on a wheeled cart

The second design worked well on firm dry terrain. However, the mobility problems in wet soils and the high cost did not favor the adoption of the second design (Duraj, et al., 2000).

In an effort to reduce the incidence of MSDs on hands and wrists, there are attempts to redesign the handles of harvesting knives. The new handle designed by Duraj, et al. (2000) was very similar to the traditional one except that the new design has a tapered handle (Fig. 15). The end of the handle closer to the blade is narrower for better control and the opposite end larger for increased power and comfort. A similar study concluded that the ideal knife handle diameter for male and female workers should be 1.34 and 1.26 inches, respectively. To avoid multiple handle sizes, they recommended a standard diameter of 1.3 inches for all hand tools (Sancho-Bru, et al., 2003).

Figure 15. Traditional (left) and ergonomically designed (right) blade

Mechanical Systems

Even though most producers prefer traditional ways of producing grapes, efforts have resulted in several mechanical systems. Researchers at the University of California have been working on a partially mechanized harvesting system. The first system developed included a trailer (Fig. 16) with a hopper to empty the filled harvest bins. The hopper then feeds the grapes onto a conveyor belt for sorting.

Figure 16. The first mechanized system developed at UC Davis (Duraj, et al., 1999)

This design has helped to prevent some of the harmful postures that harvesters experience (Duraj, et al., 1999). This design was further modified by adding a fork to the tractor (Fig. 17) for collecting the filled tubs on the ground and emptying them into a conveyor belt for workers standing on a platform for sorting (Duraj, et al., 2001). A revision of the system made improvements which resulted in a more automated process (Duraj, et al., 2002).

Figure 17. The second mechanical system developed at UC Davis (Duraj, et al., 2001)

Weeding

Manual weeding being a cumbersome activity is identified as a major contributor to musculoskeletal problems. Several alternate weeding systems have been attempted (Fig. 18) to protect the workers. Some have used sheep and goats to do the weeding without damage to the grape vines or fruits (Hirsch, 2006). Unlike the mechanical systems, sheep and goats cause less soil compaction and thus less damage to the root system. For this reason, mechanical weeding systems are not widely used in vineyards. Herbicides can also be used to provide long-term, pre-emergent weed suppression, as well as post-emergent burn-down of existing weed growth.

Figure 18. Tournesol mechanical weeder

Conclusions

Grape production and acreage in Virginia have been increasing steadily. Most vineyards in Virginia are small and they produce grapes manually. Brief descriptions of tasks associated with manual grape production and tools used to perform these tasks have been reviewed. Tasks such as dormant pruning, shoot suckering and crop harvesting are labor intensive operations and they are carried out multiple times throughout the growing season. Doing the same task repeatedly for a long period of time, lifting heavy weights over the head and unloading tubs/buckets frequently, twisting the body multiple times, and working on uneven grounds and at different heights all cause over-stressing of certain parts of the human body numerous times during the crop season. These conditions, in turn, make the vineyard workers susceptible to different types of musculoskeletal disorders. Selected examples of other injuries these workers are exposed to are back

and stomach problems due to exposure to low frequency vibration, sunburns, and other disorders resulting from exposure to sun and herbicides, snake bites and bee stings. Steps can be adopted to protect the workers. These may include following exercise routine before engaging in daily activities, using well maintained and ergonomically designed tools, use of assistive technologies, use of machines, and administrative controls.

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