Gupta RK, Vishwakarma RK, Nambi VE, Kumari L, Yadav DN (2016) Fumigation of grapes (*Vitis vinifera*) with sulphur dioxide (SO_2) to control insect-pest during storage. Pp. 382–386. In: Navarro S, Jayas DS, Alagusundaram K, (Eds.) Proceedings of the 10th International Conference on Controlled Atmosphere and Fumigation in Stored Products (CAF2016), CAF Permanent Committee Secretariat, Winnipeg, Canada.

CAF

Fumigation of grapes (*Vitis vinifera*) with sulphur dioxide (SO_2) to control insect-pest during storage

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ABSTRACT

India is one of the major grape (*Vitis vinifera* L.) producers, and exporters in the world and now the country is exploring new markets for Indian grapes. New Zealand and Australia are the future potential export markets for Indian grapes to high demand and low domestic production in these countries. Phyto-sanitary requirements of New Zealand for the import of grapes are very strict and they considered *Drosophila suzukii* (Matsumura) is as invasion insects in Indian grapes. These flies are present on damaged wine grapes during the harvest period, especially when the damage of berries skin takes place due to cracking, disease, hail injury, and bird damage. Reports indicated presence of *Drosophila suzukii* in temperate regions of India; however, no report showed presence of these flies in grapes producing regions of India. The USA developed a fumigation treatment method (SO_2/CO_2 in combination) of grapes followed by cold disinfestations treatment to manage spiders and *Drosophila suzukii* in fresh table grapes, and Europe Union countries also followed this method. The treatment includes fumigation of grapes with 6% CO_2 and 1% SO_2 for 30 min followed by cold treatment for 6 days or more at –0.5 to 0.5°C pulp temperature. Such treatment of grapes is not in practice in India which limits the export of Indian grape. Controlled release and uniform distribution of SO_2 and CO_2 in fumigation chambers is a technological challenge in India. Higher concentration of SO_2 softens the grape berry, making it unacceptable for export. Development of automated fumigation chamber may reduce the post-harvest spoilage of grapes and standard protocol of fumigation with SO_2 may assist in satisfying the international norms of quality. An automated fumigation chamber for standardization of fumigation protocol for Indian grapes is prepared to meet international standards for export.

Key words: Grapes, CO_2, *Drosophila suzukii*, Fumigation, Fumigation chamber, SO_2

Grapes (*Vitis vinifera* L.) contribute to about 16% of global fruits production and it is preferably consumed as fresh. It is also used for producing raisins, wine and other value added products. India is 9th major grape producer in the world with total production of about 2.48 mT in 2013-14 (DAC, 2015). Tropical regions of India are the major producing areas while Maharashtra and Karnataka contribute to about 95% of total production. In India 71% grape goes for fresh consumption, nearly 27% dried for raisin, 1.5% for wine making, and 0.5% for juice production (APEDA, 2016). Further, a recent survey reported that 8.6% of total grapes produced in India are lost during harvest and post-harvest operations due to mechanical injuries, physiological decay, water loss, glut in season, and inadequate storage infrastructure (Jha et al., 2015). Use of advanced technologies and creating export market demand may reduce such losses.

India exported 0.19 mT grapes to over 40 countries across the Asia, Europe, America and Africa and contributed to about 9.1% of total fruit exports from the country (Sharma and Jain, 2011; APEDA, 2016). However, Indian grape (*Vitis vinifera)* exporters are facing specific problem to export grapes in New Zealand and Australia due to their phytosanitary certification criteria. New Zealand phytosanitary requirements consider *Drosophila suzukii* (Matsumura)

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as an invasion insect and presence of these flies is reported in temperate region of India, viz. Kumaon, Jammu and Kashmir but not in tropical grape growing regions. Thus fumigation of grapes with CO_2 and SO_2 is demand of importing country. However, the system and protocols for fumigation of grapes are not available in India at present. This paper highlights the status of fumigation technologies in India, fumigation needs, system and protocols for export of grapes.

STATUS OF GRAPES MARKET IN INDIA

Growing fruits and vegetables is suitable for small holders than food grains because they are labour intensive, provide recurring income, have high-value markets, offer value addition promise and are a mechanism of risk management against field crop failure (Singh, 2013). However, these crops are highly perishable, require more input, need careful post-harvest handling, suffer from high loss, and have profitability dependent on rapidly changing quality/standards (Singh, 2013). Further, local markets are either absent or too small to absorb high-value and perishable produce in India, which makes it a high-risk business for smallholders and requires good market linkages for their viability.

The post-production processes at the export pack house in India include receipt of raw material at pack house; weighing and acceptance of produce; trimming, sorting and grading; weighing, packing and coding; pre-cooling; palletization; sulphur dioxide padding; storage (cold stores); container loading; and transportation. In contrast, packaging in cardboard crates is preferred at the farm after grading for the produce destined for domestic market.

Grapes are unprocessed fresh produce, therefore, the market linkage and customer demand influence their production and distribution. This has direct impact on grape producers, especially smallholders, as quality standards in post-production system and export make it difficult for smallholders to directly deal with high-value markets, despite being low in price (Collins, 2000). The grape production network for export in India involves several agencies (Table 1). Indian grape exporters follow the GlobalGAP practices (Amekawa, 2009). Some exporting companies organize small growers under GlobalGAP group certification for quality exports by a third party (Singh, 2013). The quality parameters for the export of grapes include size of bunch and berry, colour, weight, shape, firmness, sugar content, acidity, absence of bruises or blemishes; flavour, odour, pesticide/chemical residue, stem colour, pest or chill damage, packing quality, and average check weight (Roy and Thorat, 2008).

RISK ASSOCIATED WITH PESTS

Being a non-climacteric fruit with low physiological activity, the water loss and softening are common in grapes that result in stem browning, berry shatter, wilting, shriveling of berries etc. (Crisosto and Smilanick, 2007). Gray mold due to *Botrytis cinerea* and *Botrytis* rot are responsible for postharvest decay of table grapes (Crisosto et al., 1998).

Import of any fruit and vegetable by a country is associated with risk of invasion of new pest that is not generally found in the importing country. Insects/pests associated with grapes may be categorized into regulated and non-regulated pests. Regulated pests

Table 1 Export grapes production network in India (Singh, 2013)

Farm inputs	Production	Harvesting	Grading and packaging	Export	Super markets
Rootstock (Private) Micro-irrigation (Public and Private) Credit (Banks) Fertilizers Pesticides Machinery Fabricators Extension (Public and Private) NRCG NABARD PACS	Farmers Farm Labours Exporter Certification agencies APEDA Marketing boards Labour contractors	Farmers Agencies Harvest labour Transporters Quality testing staff Labour contractors	Pack house owner Operators Management staff Supervising staff Packing labour Certification Insurance NABARD Credit (Banks) Transporters Labour contractor	Exporters Certification (residue labs) APEDA Sea freight cos. SPS authority Marketing boards NAGGE Banks Insurance	Distributors/ repackers Importers

NRCG: National Research Centre for Grapes, Pune; NABARD:National Bank for Agriculture and Rural Development; SPS: Sanitary and Phytosanitary; NAGGE: National Association of Grape Growers and Exporters; PACS: Primary Agricultural Cooperative Societies.

(pathway dependent) are those pests for which phytosanitary actions would be undertaken on interception/detection. Quarantine pests (new organisms, non-plant pests, vectors of linked quarantine pests, virulent strains) are non-regulated pests and contaminants and their interception/detection lead to rejection by the importing country. Quarantine pests (for a country) are the pests, which may occur (according to information received from the exporting country or from the literature) in the commodity of exporting country (such as grapes) and are not known to occur in or present in importing country but not widespread. In this context *Drosophila suzukii* is a quarantine pest for New Zealand.

The *Drosophila suzukii* is a global pest attacking to various berry crops. It lays eggs in damaged and intact wine grape berries of the most soft-skinned varieties. Ovi-position increases with an increase in sugar content and decrease in acidity levels. Also, ovi-position increases with a decrease of fruit skin penetration force (Lee et al., 2011). Incised berries are more favorable for *D. suzukii* ovi-position as a nutrient substrate. Increased presence of flies on wine grapes (as indicated by egg laying and increased longevity) was observed to the berries that were exposed to incised berries as compared to fully intact berries. The *D. suzukii* flies find their feed on damaged wine grapes during the harvest period, especially when the skins of berries are negatively impacted due to disease, cracking, hail injury, and bird damage. Such an increase of feeding and ovi-position may increase the likelihood of spoilage bacteria vectoring due to *D. suzukii* (Ioriatti et al., 2015). Increased levels of *Acetobacter* spp. due to *D. suzukii* activity alone or in combination with *D. melanogaster* negatively impact the quality of wines with increased production costs.

FUMIGATION WITH SO_2/CO_2

The *Drosophila suzukii* is an emerging pest which has recently spread to USA. In response to the detection, the USA imposed emergency mitigation measures requiring cold treatment or methyl bromide fumigation of grapes exported from the USA to New Zealand in May-June 2010. Cold treatment is another measure that may be suitable in managing the risk of *Drosophila suzukii* infested fruit.

Fumigation is basically, releasing and dispersing a toxic chemical so that it reaches to the target organism in gaseous state and kill the organism. SO_2 is widely used as fumigating agent for table grapes to prevent decay during storage, by either initial fumigation of fruit from the field followed by weekly fumigation of storage rooms or slow release from in-package pads containing sodium metabisulfite (Palou et al., 2010). Cantin et al., 2012) observed that SO_2 fumigation followed by controlled atmosphere storage is a promising strategy for fresh blueberries to reduce decay, extend shelf life, and maintain high nutritional value. Treatment of table grapes with SO_2 reduces the incidence of post-harvest decay; however it may damage the grapes and result in sulfite residues, which are unacceptable to some consumers. Fumigation with SO_2 controls fruit decay organisms in grapes (Snowdon, 1990). Nelson and Richardson (1967) stated that SO_2 is a very effective fumigation for retarding the spread of decay in table grapes caused by *Botrytis vinerea*. Marois et al., (1986) reported that 200 ppm of SO_2 can stop the spread of disease, however, complete control can be obtained with 800 ppm dose with repeated fumigation (three times/week).

Gray mold and botrytis rot are reported to be controlled by fumigation with SO_2 and CO_2 in table grape (Mitcham and Leesch, 2004). Short-term applications of CO_2 showed beneficial effects to many fruits during storage (Herner, 1987). Under high CO_2 storage, the internal amount of succinic acid increases and respiration decreases. Kubo et al. (1990) stated that storage at high CO_2 concentration had little effect on respiration of grapes. However, storage of grapes at 10-15% CO_2 control grey mold growth for 2-4 weeks (Crisosto and Smilanick, 2007). Hribar et al. (1994) observed better fruit quality preservation by initial high CO_2 treatments. Martinez-Romero et al. (2003) observed that grapes stored in non-perforated polypropylene packages at 1°C for 53 day had the highest CO_2 and lowest O_2 contents with reduced weight losses, increased berry and skin firmness and were effective in maintaining skin color. Pretel et al. (2006) reported that a slightly CO_2 enriched atmosphere along with SO_2 fumigation can extend the storage life of late harvested 'Aledo' table grapes without relatively affecting its quality.

Post-harvest fumigation with sulphur dioxide (SO_2) and carbon dioxide (CO_2) have a beneficial effect in preserving quality attribute for table grapes (Mitcham and Leesch, 2004). The USA developed a combination treatment of SO_2/CO_2 fumigation followed by cold dis-infestation treatment as a measure to manage *Drosophila suzukii* in fresh table grapes (Crisosto and Smilanick, 2007). The treatment include fumigation with 6% CO_2 and 1% SO_2 (by volume) for 30 min at a pulp temperature of 15.6°C or greater, followed by cold treatment for 6 day or more at a pulp temperature of -0.5±0.5°C. Various other risk management measures may be suitable to manage the risk of *Drosophila suzukii* in the pathways associated with the import of host fruit into Australia.

DESIGN OF FUMIGATION CHAMBERS

The purpose of a fumigation chamber is to allow fumigations to be carried out efficiently, safely and economically. The basic elements for design and construction should be incorporated in all chambers with variations made to suit individual needs. An effective fumigation chamber must be:

- precisely constructed so as to be gas tight;
- provided with an efficient system for applying and distributing the fumigant;
- provided with an efficient system for removing fumigant at the end of treatment;
- properly sited so as to handle infested goods conveniently; and
- accurately operated to present no hazard to personnel working with or near the chamber.

Common facilities of automated fumigation chambers include:

- Stationary chamber with at least two portions (Treatment area and pretreatment /entry area)
- Gas flushing and controlling system
- Gas evacuating system
- Gas diffusion and distribution system
- Temperature and r.h. controllers
- See through monitoring window
- Auto shut-off controllers.

CHAMBER CONSTRUCTION

Location: The safest location for fumigation chamber is outside the main buildings. The chamber should be approachable for vehicle for loading and unloading materials. If the chamber is to be placed permanently inside a building, it may incorporate a part of the floor, two existing walls and even the ceiling. A generalized plan indicating some of the essential features of an atmospheric fumigation chamber must be prepared.

Material: The most satisfactory type of chamber is likely to give the minimum of trouble from leakage. Small capacity chambers can be constructed with polyurethane panels stuffed with polyurethane foam. For higher capacity chambers, concrete floor, brick walls and flat roof of reinforced concrete are preferred. An impermeable flexible film lining on the inner surface may be provided, if needed. The chamber can be provided with one or two doors, depending on its size and function. Doors sliding on rails are better for installations outside of a building.

Circulation, ventilation and gas evacuation: Proper circulation and post-fumigation venting of the fumigant/air mixture are essential in fumigation chambers. The volume of the chamber governs use of fan systems to achieve adequate circulation or ventilation. Another way is to use blower with a large inlet and outlet. Suitable blast gate or valve operated from outside provide better for circulation of air throughout the chamber by means of ducts or blown out through the exhaust stack.

Exhaust door or port: The exhaust port may be a small door in the wall of the chamber at the opposite end of the chamber from the door. Thus, fresh air comes in the chamber from the open door during venting and unloading. Exhaust port may be slide open or move on hinges as a trapdoor.

Lighting systems: Lighting inside the chamber is necessary since fumigation chambers do not have windows. The lights should be arranged properly so that the loading does not obscure them and they must be adequately protected against damage.

Gas flushing and application equipment: Gaseous-type fumigants are introduced from outside the chamber through tubing with proper flow control valves. The sensors provided inside the chamber detect the concentration of fumigant and once the desired concentration is reached, the flow control valves regulate the flow of fumigant into the chamber. Electronic controls are the need of present era for efficient and precise control of treatment.

Accessories: Provision of a small observation window helps in monitoring the treatment from outside. Digital thermometers, RH sensors, gas sensors should be essentially placed at appropriate locations to control the chamber environment accurately. A control panel placed outside of the chamber should control all sensors.

The present fumigation system being established in India will be controlled electronically and operated from outside of the chamber after loading the grapes into the chamber. The chamber will be constructed inside another structure and only 33% space of outer chamber will be used for fumigation. The fumigation space (inner chamber) is planned to be covered from five sides. One side of the inner chamber will be provided with sliding doors, which will be opened or closed from control panel placed outside of the structure. The workers need not to go inside the chamber after loading the grape pallets into the inner chamber. A computer controlled camera will also be placed inside the chamber to monitor the operations. The workers will go inside the chamber only after completion of fumigation and flushing of the chamber with fresh air and concentration of fumigants is well below the safe limits. All the doors will be controlled automatically from control panel so that the chances of health hazards may be avoided.

CONCLUSION

Development of automated fumigation chamber in India is in nascent stage. However, it is necessary to develop such system so that the post-harvest spoilage of grapes may be reduced and standard protocol of fumigation with CO_2 and SO_2 may be prepared for satisfying the international norms of quality. This will help in opening a new export market for Indian grapes and reduce glut in the season. Thus the farmers and traders may get higher economic value for the grapes. Further, this system will open the venues for fumigation of the perishable commodities in India to improve the quality and standards for export market.

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