Postharvest Plant Protection

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Sustainable and organic plant production uses natural products and natural self-regulation processes occurring in the ecosystem. The awareness is growing and the demands of consumers are higher and higher.

Keywords: physical methods ; postharvest plant protection

1. Introduction

Currently, the main objective of plant protection in the European Union and in the world is to implement innovative and safe methods of limiting the development of pests in cultivations [1][2] and in the storage of agricultural and horticultural raw materials. This is related to the implementation of the concept of sustainable agriculture promoting the production of high-quality food in a socially responsible manner, rational use of natural resources and reduction of chemical plant protection product application [3][4][5][6][7]. It is also advisable to integrate various plant protection methods taking into account the requirements of environmental protection and human health [8][9]. The use of chemical plant protection products must be by the Code of Good Plant Protection Practice [10]. Too frequent and careless application of pesticides at various stages of production and during the storage of agricultural and horticultural raw materials contributes not only to the occurrence of resistant pest races, but also to environmental pollution and residue formation in the produced at then stored raw materials [11]. The goal of plant protection is not only to destroy harmful organisms or limit their activity but also to forecast the time they appear and the possible extent to which they might spread. Among the direct and indirect methods of plant protection, there are agrotechnical, biological, breeding, mechanical, quarantine, chemical, and physical methods [1][9]. Physical methods directly destroy harmful organisms, aim to retard their development or prevent them from spreading in the field and in the crop storage.

One solution, instead of chemical methods, is to use various proven physical agents as an alternative to pesticides or use of known methods for new applications [12]. The physical method of plant protection consists in treating the harmful organism with physical factors such as temperature, radiation, light, controlled atmosphere, special packaging, pressure, various sounds and in recent years, also with effective and more and more frequently used thanks to greater availability and lower costs factors such as ozone and low-temperature plasma [13][14].

2. Selected Physical Methods of Plant Protection Useful in Storage

2.1. Checked Solutions

2.1.1. Temperature

The physical method utilizing low and high temperatures is primarily applied to control pests and pathogens. It is used for substrate decontamination, seed treatment, disinfection, or disinfestation, as well as for reducing the number of pathogenic microorganisms during fruit and vegetable storage [15][16]. It is also used for thermotherapy of plants infected with viruses.

The selection of appropriate temperature range for thermotherapy should allow the treated plant to survive and at the same time inactivate the virus, resulting in the production of virus-free plants [17]. Both high temperature, e.g., 37–40 °C, for control of Grapevine leafroll-associated virus 1 (GLRaV-1) and Grapevine rupestris stem pitting-associated virus (GRSPaV), a difficult to eradicate virus, from grapevine “Agiorgitiko” [17], as well as low temperature, approx. 5 °C, in chrysanthemum production free from *Chrysanthemum stunt* viroid (CSVd) are applied [18].

The use of low temperature is one of the most frequently used physical factors in the postharvest strategy of counteracting pathogen growth and the occurrence of fruit and vegetable pests [19]. Ventilation with cold air of low humidity, e.g., in warehouses or the freezing of agricultural and horticultural raw materials, often does not destroy pathogens and pests, but inhibits their spread, development and feeding. This process also reduces or even prevents the production of mycotoxins [20]. Therefore, such postharvest treatments are necessary to minimize pests occurrence and reduce the risk of contamination of fresh fruits and vegetables with pathogens [21]. Low temperature has been also successfully utilized to reduce pests of the ethnographic collections of the National Museum of the American Indian [22].

The use of high temperature in greenhouses and foil tunnels (even above 90 °C) provides very good results in the control of crop pests and pathogens [9][23], as well as in seed disinfection. However, it should be noted that it is dangerous for soil microflora, therefore it is recommended to use temperatures up to 60 °C, at which most pathogens die, and the antagonistic microflora is able to regenerate [9]. Water at a temperature of 43–44 °C is used to immerse planting material (e.g., seedlings, tubers, rhizomes, and bulbs) of various plants in order to destroy fungi, nematodes, and mites [13]. There are also known thermal seed disinfection methods at various time points against 74 viruses, rickettsiae, mycoplasmas, and fungi. Research showed that soaking soybean seeds of the cultivar MFS-561 in hot water at a temperature of 60 °C for 2 min significantly reduced contamination with pathogenic fungi [24]. High air or water temperature is used for thermal weed control, it is especially recommended for young weeds [25].

2.1.2. Physical Radiation or Something

Radiation is one of the non-traditional techniques of reducing pathogenic microorganisms and pests in food products, while maintaining nutritional value, without changing the quality attributes (flavor, odor, and color) [26]. Irradiation techniques can alter food chemical composition and nutritional value, but these changes are usually minor and depend on food composition, irradiation dose and factors such as temperature and the presence or absence of oxygen in the radiation environment [26]. We distinguish various forms of radiant energy, emitted in various ways, which belong to the spectrum of electromagnetic radiation, and these include radio waves, microwaves, infrared radiation, visible light, ultraviolet light (UV), X-rays, and gamma rays [9]. There are two types of radiation in the electromagnetic spectrum: ionizing (X-rays and gamma rays) and non-ionizing radiation (radio waves, microwaves, infrared radiation, and visible and UV light [27]. Non-ionizing radiation, as a method of preserving horticultural and agricultural raw materials, is of little interest, in contrast to ionizing radiation [26]. Only a few studies have confirmed the use of different UV radiation wavelengths in reducing the occurrence of numerous pest species in greenhouse cultivations [28].

Currently, the use of ionizing radiation, i.e., radiation whose energy is sufficiently high to displace electrons from atoms and molecules and convert them into electric charges, called ions, is common in food processing [29]. Ionization occurs during radiation, which has a destructive effect on tissues of harmful microorganisms. The application of ionizing radiation, such as gamma radiation, in the protection of food products has many advantages (low energy requirements, similar changes in chemical composition as in other preservation methods), but also many barriers related to determining appropriate doses that cause death of pests, application costs and lack of information on food-induced radioactivity [30]. Gamma radiation is increasingly used to limit ornamental plants' 100 pathogen infections such as gray mold (*Botrytis cinerea*) on chrysanthemums [31]. The size of a given pest population can be significantly reduced when the appropriate dose is selected. Radiation also effectively destroys young larvae, eggs, and pupae. The study of Abbas et al. [32] showed that a dose of 400 Gray (Gy) for 1–24 h is sufficient to stop the hatching of larvae from the eggs of Indian meal moth *Plodia interpunctella* Hübner (Lepidoptera: Pyralidae), 300 Gy for 15 days to prevent the larvae from reaching adulthood, and 650 Gray (Gy) for 5 days to control population growth of this pest. Irradiation can be performed during product packaging for transport, storing unpackaged seeds in piles, seed accumulation at transhipment ports [32][33]. The radiation method is used to control pests and sterilize males by short-term irradiation, as performed in case of a fly of the order Callitroga—a dangerous parasite of farm animals in the USA in the 1950s [34].

Light traps to combat pests, with lamps emitting light of different spectrum, are based on the assumption that light has a strong influence on insect activity [35]. The effectiveness of a light trap can be improved by placing it in dark or dimly lit areas or places where pests gather [36]. The light is used to attract male moths of such pests as *Autographa gamma*, *Agrotis ipsilon,* and Tortricidae. Special devices with a light bulb inside are used for this purpose. There is a light source in the form of a light bulb inside this device. Thanks to this, it is possible to determine the number of harmful insects in a given cultivation and optimal date of plant protection treatments [37].

2.1.3. Controlled Atmosphere

Controlled atmosphere is increasingly used to limit the number of harmful organisms in storage facilities. For this purpose, special cold stores are built, in which it is possible to manage the atmosphere with specific parameters [38]. Such conditions are unfavorable for harmful organisms, and thus reduce their abundance [39]. Oxygen level (ULO) in the refrigerated room, where fruits and vegetables are stored, is significantly reduced (down to 5%), which limits the number of pests [40] and maintains carbon dioxide content at a constant level. Conditions unfavorable to harmful organisms reduce their number, thereby facilitating crop storage [39][41][42].

2.1.4. Special Packaging

Packaging materials differ in insect penetration resistance, although some insect species can penetrate most flexible films, foils, paper, and combinations. Polycarbonate foil is the most resistant polymer foil; polyester and polyester-urethane films are also resistant to penetration by insects [43]. The packaging is often made of many layers joined together, which increases the degree of protection against insects. Such a package usually includes paper, polyethylene foil, aluminum foil, polycarbonate, polyester, and polypropylene [9]. When using special packaging, it is important to select the right materials, taking account marketing requirements, including distribution and consumer needs, environmental issues and waste management [44].

2.1.5. Pressure

Reduced pressure is also applied to eliminate pests. Such a solution can be used in specially adapted rooms, from which air is sucked out and plant products are stored. This enables long-term storage of fruits and vegetables, and the lack of air eliminates pests [45].

2.1.6. Various Sounds

Sounds are often used to deter birds from causing damage to crops. Propane-butane-fueled cannons or special devices with a loudspeaker are used for this purpose, most often emitting the sound of frightened birds [46]. This method is very effective and willingly used by fruit growers [47].

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