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A Short Review on Onion Bulb Dormancy Metabolism

Khalid Mahmud Khokhar*

Horticulture Research Institute, National Agricultural Research Centre, Pakistan

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***Corresponding author:** Khalid Mahmud Khokhar, Vegetable Crops Research Programme, Horticulture Research Institute, National Agricultural Research Centre, Park Road, Islamabad, 44000, Pakistan

Abstract

After completion of the rest period, the onion enters its period of dormancy. It has been postulated that after removal from the ground or immediately after harvest, onions are in a state of natural dormancy, controlled by the various endogenous hormones. Storage regime affects the onion dormancy and biochemical changes in onion. These biochemical changes include the change in water content, the concentrations of flavor-related compounds, organic acids, carbohydrate content, phenolics and endogenous growth-related compounds. The increase in ethylene production at the end of dormancy suggests a role in dormancy termination, or it could be related to other events associated with early sprout growth.

Keywords: Onion; Dormancy; Sprouting; Plant growth regulators

Introduction

Onion bulbs have high water content and display an active life after harvesting. Onions are characterized by three major periods: rest, dormancy, and re-growth (sprouting). After harvest, onions go through a rest period for 4-6 weeks, and during this rest period, they do not respond to rapid environmental change and there is no visible cellular activity [1]. The activity of endogenous hormones (cytokinins, gibberellins, and auxin) is very low, and inhibitor activity is high. After completion of the rest period, the onion enters its period of dormancy. It has been postulated that after removal from the ground or immediately after harvest, onions are in a state of natural dormancy, controlled by the various endogenous hormones, and also varying with the genetic makeup of the particular cultivar [2].

Dormancy

During dormancy, onion bulbs respond to environmental changes. The effect of this environmental change is slower in the early stage of dormancy and more rapid in the later stage until dormancy is finally lost. The duration of dormancy varies from several weeks to months depending on the cultivar, and the methods used in the determination of dormancy and sprouting [3-6]. Even though the onion bulb is in its dormant stage, the source-to-sink transition takes place at a greatly reduced level that keeps the bulb metabolically active, but the change is unnoticeable [7]. Storage regime affects the onion dormancy and biochemical changes in onion. These biochemical changes include the change in water content, the concentrations of flavor-related compounds, organic acids, carbohydrate content, phenolics and endogenous growth-related compounds [8-13]. It was found that during storage both carbohydrates and nitrogen compounds from the outer thickened leaf base were decomposed into available forms, translocated to the inner thickened leaf base and accumulated there in succession [14].

Sprouting

Sprouting is physiological phenomenon that comes after dormancy breakage, and it is a major problem during the storage of onion. The timing of rooting and subsequent sprouting was investigated and concluded that roots appeared first, followed by sprouts [15]. The reason for sprouting has been investigated by a number of scientists with respect to the growth inhibitors [15] and temperature [16,17]. Sprouting is accompanied by many physiological changes, including increases in reducing sugar content, respiration, water loss, and change in plant growth

regulators [18]. Sprouting begins with the reallocation of water and metabolites from scales to a base plate. The sprouts originate from this base plate [19] and this reallocation of phyto-nutrients is responsible for the formation of new cells and cell elongation. Before harvest and during sprout growth, there is an increase in mitotic activity in onion meristem, and significantly less activity is found during dormancy [20]. It has been reported that, at the same temperature, rooted bulbs sprout earlier than non-rooted ones [16]. It has been postulated that the root supplies specific organic substances, called cytokinins, which have been utilized for onion sprout growth. Cytokinins play a role in sprouting by stimulating cell division. Removal of the primordial roots gives less chance for the accumulation of cytokinins, and ultimately inhibits sprouting [21].

Plant Growth Regulators

The role of endogenous growth regulators is well documented in diverse physiological processes, but there are many contradictory reports on the effects of both endogenous and exogenous substances. During over-winter storage in temperate climates, a gradual change in the relative composition of PGRs occurs as the concentrations of growth inhibitors decreases and the concentrations of growth promoters increases. PGR activity in Rijnsberger (long-storing) and Lancastrian (short-storing) bulbs showed peaks in the concentration of gibberellins (GAs), cytokinins and auxins, with the higher concentrations of auxins persisting as sprouting continued [12,13]. However, the application of exogenous GAs and auxin failed to stimulate sprouting [12]. Abscisic acid (ABA) has been identified as part of the inhibitory complex present in onion bulbs [22]. Other studies have related a reduction in ABA concentration to loss of dormancy in onion [23-25].

Many researchers investigated the correlation between sprouting and changes in endogenous growth substances (auxin, GAs, cytokinins, and ABA) levels in onion bulbs or its related species. The role of a growth substance for regulation of onion bulb dormancy was studied and correlated to the gradual emergence of bulb from dormancy with changes in auxin, GAs, and inhibitor level [12].

Onion growth was divided in to three stages as

a. completely dormant bulbs,

b. bulbs showing signs of sprouting when dissected, and

c. bulbs with well-developed and actively growing leaves [12].

Maximum GA activity was found in stage c, whereas high auxin activity was found in stage b. Studies also revealed that different hormone treatments on stored onion were not effective in increasing the number of sprouting bulbs or in increasing time of sprout emergence, but the root development was affected by GA and 1-Napthaleneacetic Acid (NAA). GA treatment stimulated formation of long, fine roots, whereas with the NAA treatments roots were much shorter and thicker than those of control bulbs. High GA activity during sprouting was the result of sprout elongation and by the failure of application of gibberellic acid (GA3); it has been shown that GA cannot stimulate sprouting in the bulb. Bioassay data indicated that more auxin was detected in the early stages of sprouting than in fully sprouted bulbs and suggested an auxin-inhibitor interaction might be more probable than GA action in controlling the early stages of the dormancy breakage in onions [12].

Considering the interaction of GA in bulb development, it was reported that response of GA for the promotion of total stem elongation was higher with respect to the control, whereas no effect was found in peroxidase activity [26]. In case of sugars, glucose and fructose contents were enhanced under GA3 application, whereas sucrose was more sensitive to PGR exposure and had the highest changes (increase of 43% with respect to control). The reason for the increase in the phytochemicals is because of the activity of enzymes, such as ascorbate peroxidase, glutathione reductase, catalase, peroxidase, and others, which protect plants from a variety of stresses as well as metabolization of the complex molecules to small molecules. It was reported that the enzymes were enhanced with the application of growth regulators [27].

Abscisic acid (ABA) was detected as a growth inhibitor and naturally occurring phytohormone synthesized in chloroplasts from a carotenoid precursor [13]. The ABA in plant cells is synthesized in the leaves and translocated to the bulb throughout the growth period [28]. Premature defoliation of onion plants results in an increased bulb sprouting during storage. One of the reasons behind the increase in sprouting during storage may be because of the reduction in the accumulation of ABA in the bulb from senesced leaves. It was reported that endogenous ABA was found in all onion tissues and treatment with ABA induced earlier senescence of the plants, reduced bulb dimensions, and prolonged the dormant period of the resulting bulbs, whereas plant injections of ABA in combination with indole-3-acetic acid (IAA) or GA slightly reduced the inhibition imposed by ABA [13]. Decrease in ABA concentration correlated well with sprout growth during the initial stage or until 50% sprouting and after that there was no correlation found between ABA and sprout growth [29]. In fact, in the latter stage the increase in ABA is thought to be due to synthesis of ABA by the growing sprouts.

Physiological sensitivity of onion towards ethylene is very low compared with some other vegetables [30]. There are conflicting reports on how ethylene affects onion storage life. The observation that onion bulbs produced ethylene in much greater amounts (actual amounts not specified) at the end of dormancy than at the beginning suggests that ethylene may have a role in sprouting [31] and its concentration is very low during dormancy and initial

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sprout growth [32]. The increase in ethylene production at the end of dormancy suggests a role in dormancy termination, or it could be related to other events associated with early sprout growth. However, it was reported that in onion 'Rouge Amposta', the average rate of endogenous ethylene production depended upon the age of onion and the cultivar type [17].

The wounded bulb produced 5-fold as much ethylene as the intact bulb and the wounded bulb was more vulnerable to early sprouting and deterioration by microbial and fungal attack [31]. A relatively low concentration of endogenous ethylene was somehow involved in the regulation of dormancy, but that a relatively high concentration of exogenous ethylene could interfere with dormancy if the supply was continuous [32]. During pre-harvest treatment, ethephon significantly suppressed sprouting but not rooting, as compared with the use of ethylene [33]. The effect of exogenous ethylene on dormant (immediately after harvest and curing) and non-dormant bulbs (stored at 5-6 °C and with relative humidity of 70% for 6 months without visible signs of sprouting) was studied [34]. In the case of the dormant bulbs, an increase in ethylene concentration in the form of an ethephon treatment decreased the time for sprouting, but the non-dormant bulbs showed no significant change in sprouting time. In commercial onion stores, the continuous application of ethylene retarded sprout growth during cold storage [35]. The combined effect of ethylene and 1-MCP on onion with respect to sprouting and respiration before and after curing treatment was studied [36,37]. Onion 'Sherpa' was treated with a combination of ethylene (10 µL L-1) and 1-MCP (1 µL L-1) for 24 hours before and after curing, and then stored at 1 and 6°C. There was an effective reduction in sprout growth observed at 6°C as compared with 1°C because the low temperature inhibits endogenous ethylene production and controls sprouting [37]. Concentration, treatment duration, stages, and maturity of the crop also play important roles for the application of 1-MCP [38]. Treatment with ethylene and 1-MCP combination after curing of onions resulted in shorter sprout growth in onion bulb as compared with untreated onions as control bulbs and those treated with ethylene and 1-MCP before curing [36].

Conclusion

Even though the onion bulb is in its dormant stage, the source-to-sink transition takes place at a greatly reduced level that keeps the bulb metabolically active, but the change is unnoticeable. Onion bulbs produced ethylene in much greater amounts at the end of dormancy than at the beginning suggests that ethylene may have a role in sprouting and its concentration is very low during dormancy and initial sprout growth.

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