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Progress in Quality Control of Lettuce

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Abstract: Lettuce is one of the largest leaf vegetables in the world. It belongs to the genus lettuce of Compositae. It is mostly green, including loose-leaf lettuce, cream lettuce, knot lettuce, etc. It is widely cultivated in most parts of the world. Lettuce is favored by the public because of its low risk of pests and diseases and less pesticide residue. It meets the public's demand for pollution-free vegetables. In recent years, the demand for lettuce is increasing rapidly, and the planting area is also expanding, so the research work on lettuce is also rapidly advancing. With the development of science and technology, the production of lettuce has greatly increased. Although people pay more attention to the quality of lettuce with the increase in economic income, this study reviewed the regulation of lettuce quality from the aspects of the genome, leaf color, temperature, fertilizer, light, and storage methods.

1. Overview of Lettuce Quality

Lettuce [romaine lettuce] is an important vegetable crop and is one of the ten most valuable crops in the United States. Lettuce originated from the Mediterranean coast of Europe and West Asia after wild domesticated. After years of natural selection and artificial cultivation, lettuce has become one of the most important vegetables in our daily life. Lettuce like a cold environment, its growth is greatly affected by temperature, and the growth period is slightly different, the three to four months. The suitable temperature for germination is 18-22℃and hardly germinates when the temperature is higher than 30℃. During plant growth, like in cool climates, 15-20℃ growth is the most suitable, high yield, excellent quality; persistent above 25℃, poor growth, coarse old leaf quality, slightly bitter. Cultivated in rich and moist soil, with high yield and good quality, as shown in Figure 1. The pH value of the soil was 5.8-6.6 Lettuce also contains a range of beneficial secondary plant metabolites, including phenols, ascorbic acid, A-tocopherol, and lignans, and is widely consumed in Europe and North America, so it is advisable to improve taste and increase consumption. Sugar is an important organic matter in plants, and its content accounts for more than 50% of plant dry weight. It exists in a wide range of forms, including soluble sugars such as glucose and sucrose; insoluble sugars such as cellulose, starch, etc. The content of soluble sugar affects the sweetness of lettuce. The sweetness of lettuce is a major factor in consumer preferences.[1, 2] Vitamin C is an essential organic nutrient to maintain the normal physiological metabolism of the human body. Lack of vitamins will affect the healthy growth and development of the human body,

especially when the lack of vc, it will cause the increase of capillary vascular permeability and brittleness, the synthesis of rubber elements is blocked, the body resistance is weakened, even the occurrence of scurvy. vc can block the formation of nitrosamines in the body and eliminate excess free radicals in the body, improve the activity of SOD in the body and the immunity of the body, and play an important role in the prevention of cancer and antiaging. Therefore, soluble sugar and Vc are the key factors affecting the quality of lettuce. The following will review the research on the quality of lettuce in recent years from various perspectives.

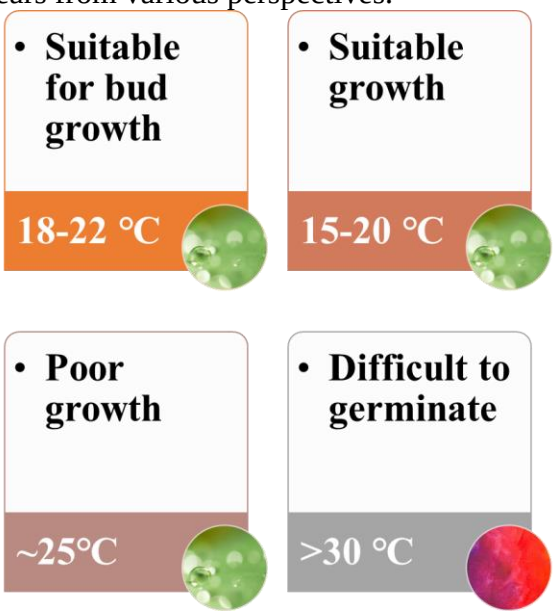

Figure 1: Relationship between plant growth and temperature

2. Genome and Lettuce Quality

The research on improving the quality of lettuce at the genetic level has been vigorously developed. Thanks to the rapid development and application of high-throughput sequencing technology, whole genome sequencing and assembly have been conducted for many species. Using this technology, Reyes-Chin-Wo et al. [3] sequenced and assembled the genome of lettuce. Lettuce is diploid, with 2n=2x=18 chromosomes and a genome size of about 2.5Gb. After the genome of lettuce was determined, Zhang et al. [4]conducted transcriptome sequencing on 240 kinds of lettuce, generating 1.1 million single nucleotide polymorphisms [SNPs], and identified 5311 expressing quantitative trait loci [eQTL] and 4105 genes in the whole genome. Six candidate loci related to leaf color were identified by genome-wide association analysis [GWAS], which regulated the variation of anthocyanins in lettuce leaves. Anthocyanins are the general name of a large class of polyphenolic compounds widely found in plants. They have strong antioxidant and free radical-eliminating effects and can effectively eliminate superoxide anion radicals and hydroxyl radicals. Protect and stabilize vitamin C, and help the absorption and utilization of vitamin C.

The above two research results are essential in the history of lettuce research and lay an important foundation for future research on the genetic level of lettuce. Lettuce like a cool environment, high temperature will lead to early bolting bloom and loss of nutritional value and edible value. In recent years, lettuce production and quality have been severely affected by global warming. High temperature promotes the bolting of lettuce, which will affect the quality of lettuce. Therefore, anti-bolting is of great significance for lettuce production. Han et al.[5] Conducted transcriptome sequencing analysis on lettuce grown under mild and high temperatures and excavated the gene LsSOC1 in lettuce that responds to high temperatures. Knocking out this gene

can significantly delay bolting and is not sensitive to high temperatures. In addition, it was found that LsFT is also a gene related to bolting and high-temperature response. After knocking out the LsFT gene, lettuce was observed to delay bolting and lose its sensitivity to high temperatures. Through these, the genes that affect the bolting of lettuce can be found, and the quality of lettuce can be improved by gene editing and other technologies. On the other hand, overexpression of the ABF3 gene in Arabidopsis thaliana increased drought and low-temperature tolerance of lettuce. VANJILDORJ et al.[6] improved the expression of genes related to stress resistance in lettuce through transgenic methods, to enhance the adaptability of lettuce to adverse environments. Yu Mingsen et al. [5] applied this technology in lettuce and detected the editing of target sites, indicating that they successfully established CRISPR/Cas9 gene editing system in lettuce. The successful application of this technology will lay an important foundation for future research on lettuce gene function and molecular breeding to improve the quality of lettuce.

3. Leaf Color and Lettuce Quality

Because of the different content of chlorophyll and anthocyanins, lettuce can be divided into green and purple, among which green is the main food. In recent years, with the increasing demand of consumers for diversified varieties, purple lettuce has become increasingly popular in raw salads due to its unique leaf color, but its quality and nutritional value have received little attention. The results showed that the contents of soluble sugar, soluble protein, vitamin C, and anthocyanin were significantly different between purple leaf variety and green leaf variety. The results showed that the content of vitamin C was higher in purple, and the soluble content of green leaf lettuce was 112.9% higher than that of purple leaf lettuce. It shows that green-leaf lettuce tastes better than purple-leaf varieties. In general, although green leaf lettuce tastes well, purple leaf lettuce has a higher nutritional value, As shown in Figure 2. The proper combination of different colors of lettuce can provide the best nutrition for the human body.

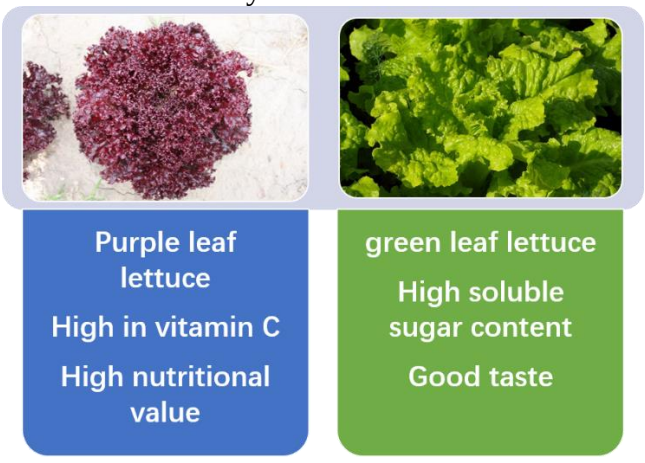

Figure 2: The relationship between color and quality of lettuce

4. Temperature and Lettuce Quality

Lettuce is a cold-loving crop. It is generally believed that the suitable temperature for its growth is 15-20 ℃, and if the temperature exceeds 30℃, the growth will be poor, it is easy to bolt, and the edible quality will be reduced. Further research was conducted to explore the relationship between day and night temperature and lettuce quality. The researchers pointed out that VC content in leaves decreased with the increase in day temperature. VC content in leaves was the highest at 20℃ and the lowest at 30℃. There was no significant difference in soluble sugar content at different day

temperatures. There was no significant difference in the content of VC and soluble sugar in lettuce leaves between 25℃ and 20℃. As the night temperature decreased to 15℃, the contents of VC and soluble sugar increased significantly, which indicated that reducing the night temperature could increase the contents of soluble sugar and VC. In conclusion, when the day temperature is 20℃ and the night temperature is 15℃, the content of VC and soluble protein of lettuce are the highest and the quality is the best, As shown in Figure 3.

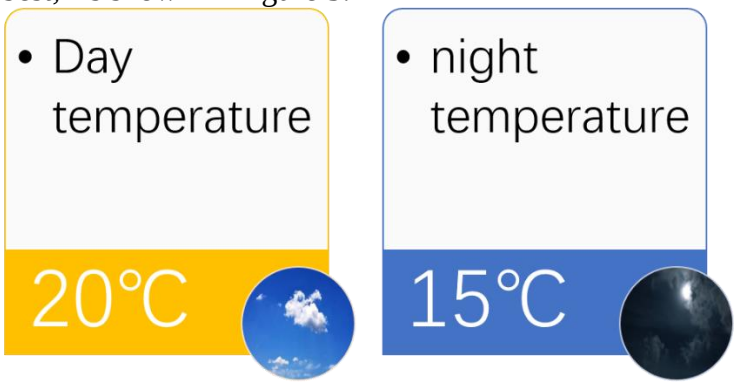

Figure 3: Lettuce is best for day and night temperatures

5. Fertilizer and Lettuce Quality

Fertilizers can promote the growth of plants, and lettuce is no exception, so people use different fertilizers to study the effect of fertilizer on the quality of lettuce. The soil in the protected area has special characteristics, such as high potential fertility and sufficient phosphorus and potassium nutrients. Therefore, the effect of nitrogen application on the quality of lettuce was studied. It was found that the vc content of lettuce decreased with the increase of nitrogen application, and the nitrogen application had little relationship with the soluble sugar content. Studies on potassium fertilizer indicate that the level of K has little effect on the content of vc, and the content of soluble sugar needs to be further studied. As shown in Figure 4. Selenium is an important element in the ecological environment and has multiple biological functions on humans and animals.[7] Selenium and its compounds can protect cells, remove free radicals, and resist mercury, cadmium, arsenic, thallium, lead, and other toxic substances. Residents in areas lacking selenium have a high incidence of cancer, cardiovascular disease, Keshan disease, Kachin-beck disease, and other diseases. Plants are the key intermediate link in the natural selenium cycle, the direct source of selenium intake for humans and animals, and the natural organic chemical plant that converts inorganic selenium into organic selenium. Therefore, plants were cultivated by adding different concentrations of selenium. After adding selenium, the VC content of lettuce in each treatment was significantly increased, among which, the content of VC in lettuce treated with 0.50 mg/L selenium concentration was the highest. The reason is that selenium can promote the absorption of iron in lettuce, which is an important component of the respiratory electron transport protein complex, thus affecting the whole electron transport chain, promoting the metabolism of vc through such a mechanism and increasing the VC content of lettuce. After adding selenium, the content of reduced sugar in lettuce was higher than that of the control. When the concentration reaches 0.50, called L, the reduced sugar content reaches its peak. At the same time, in terms of increasing the selenium content of vegetables, a large number of studies have fully confirmed that the application of exogenous selenium before harvest can significantly improve the selenium content and quality of vegetables. Therefore, the experiment found that the vc content was significantly increased when the concentration of agricultural selenium fertilizer was 1.00mg/L after harvest. For soluble sugar,

the content of soluble sugar increased significantly when the concentration of agricultural selenium fertilizer was 0.50 mg/L. With the development of technology, non-toxic. And then sprayed lettuce with different concentrations of eco-nano selenium. The results showed that spraying eco-nano selenium on lettuce leaves could significantly reduce the content of soluble sugar in leaves. With the decrease in selenium concentration, the VC content of lettuce generally increased first and then decreased, and the VC content reached the peak after 400 times dilution, which was significantly higher than that of the control. Timely and reasonable application of fertilizer in the growing period of plants is a necessary measure to achieve a high yield of vegetables. However, in some areas, farmers simply apply a large amount of fertilizer to achieve a high yield, which not only causes a low fertilizer utilization rate and environmental pollution but also easily leads to serious soil compaction, soil acidification, and other soil quality degradation phenomena. Organic manure occupies an important position in our country's agricultural development history. When applied to the soil, its rich nutrients can improve crop yield, improve crop quality, and prevent soil compaction, enhance soil fertility. Therefore, the use of organic fertilizers is also worth exploring.[8] Different natural organic fertilizers [rapeseed cake, corn stalk, pig manure, chicken manure, pasture, and peat soil] were used to cultivate lettuce, and their effects on the quality of lettuce were explored. It was found that the use of organic fertilizer could reduce the content of vc and soluble sugar in lettuce. Therefore, to improve the quality of lettuce, the use of natural organic fertilizer should be avoided when growing lettuce. The use of base Shiwang ecological organic fertilizer [Jiamusi Sanxing Agricultural Technical Service Co., LTD.]: containing 5% of the total available potassium oxide, water-soluble fulvic acid 18%, total available nitrogen 10%, organic matter 45%, water-soluble magnesium oxide 0.7%, 14% amino acids. It was found that basal Schwann could significantly promote the content of VC and soluble sugar in lettuce at 200 kg/hm^2. Why the two organic fertilizers have different effects on lettuce quality is worth further investigation. The level of supply K has little effect on the content of vc, and the content of soluble sugar needs to be further studied.

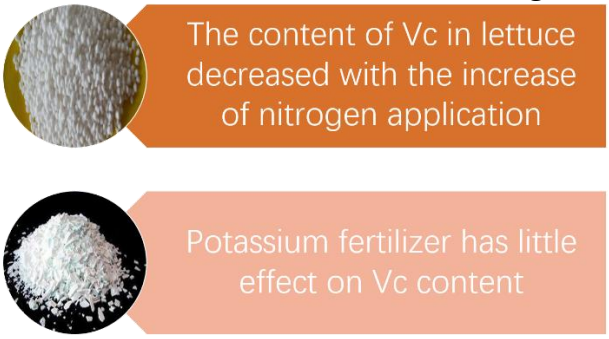

Figure 4: Effect of fertilizer on lettuce.

6. Light and Lettuce Quality

Light is one of the most important environmental factors in plant growth. It is not only the necessary energy for photosynthesis but also the necessary condition for the formation of chlorophyll. At the same time, light also regulates the activity of many enzymes and stomatal openings in the process of carbon assimilation, affecting plant growth, metabolism, and material transport. Higher plants have a complete set of sophisticated light acceptance and light signal transduction systems that detect changes in light intensity, light quality, light direction, and light duration and make adaptive responses. Light has a wide range of regulatory effects on plant morphogenesis, physiological metabolism, growth and development, and product quality [7]. As a cold light source,[8] an LED lamp is a new fourth-generation light source. It has the advantages of pure spectral distribution, rich spectral distribution type, easy spectral energy modulation, low heat,

small size, and long life. It was gradually applied in plant science research and production[9], so it was used to study the effects of different light sources on the quality of lettuce. The results showed that the soluble sugar content of lettuce in the red-light treatment was the highest, followed by the red-blue light treatment. The soluble sugar content of the two treatments was significantly higher than that of the control group, but there was no significant difference between the blue light treatment and the control group. The content of Vc in the red light treatment was low, the control treatment was in the middle, and the content of Vc in the blue light and red blue light treatment was relatively high, most of them were significantly higher than the control group. As shown in Figure 5. That is, blue light treatment can promote the synthesis of Vc in lettuce. At the same time, the quality of lettuce is also related to the light time. Further study found that the soluble sugar content of lettuce increased with the extension of the light time.

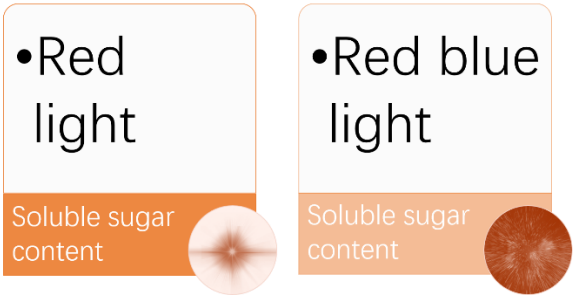

Figure 5: Relationship between light and soluble sugar content.

7. Storage Method and Quality of Lettuce

Lettuce is widely used in fresh food and is the main side dish of all kinds of western fast food. With the improvement of people's consumption level and the acceleration of the pace of life, consumers' demand for cutting lettuce is also increasing. When lettuce is cut and stored, it is prone to Browning and its quality will decrease or its commodity value will be completely lost. Gibberellin [GA] is an important hormone commonly used to regulate plant aging.[10] It has been found that gibberellin can delay the senescence of leaves of many plants, but the effects of exogenous gibberellin on the storage quality of treated lettuce have not been reported. Temperature is a key factor affecting the aging of plant leaves, and proper low-temperature storage can delay the aging process of lettuce leaves. It was found that gibberellin treatment significantly delayed the decrease of soluble sugar content in lettuce leaves during storage. At the same time, packaging during storage will also affect the quality of lettuce. The content of VC in the PE packaging group and MAP packaging group is always higher than that in the control group.

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