Research on the Construction and Promotion Application of Green Production Technology System for Curly Leaf Vegetable

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Abstract: *Curly leaf vegetables are a nutritious kind of cruciferous vegetables that can also earn money. It has about 2.5 times the amount of vitamin C as kiwifruit and is very easy to use. In the Yangtze River Basin, it can be grown twice a year, the harvesting period is about eight months long, and the output value will be 20,000-30,000 yuan per 667 square meters. Based on production experience and research, the main technologies for the green production of curly leaf vegetables in this paper are intensive seedling cultivation, balanced fertilization, integrated water and fertilizer management, green prevention and control of diseases and pests, standardised harvesting and preservation, and a system of local production technical standards suitable for Hubei Province and similar ecological areas has been established to promote the green, efficient and sustainable development of the leafy vegetable industry.*

Keywords: *Curly leaf vegetable, Green production, Standardization, Hubei Province, Cultivation technology, Disease and pest control, Harvesting and processing*

1. Introduction

Curly leaf vegetables are a new type of healthy food rich in vitamins C and folic acid, various minerals, have antioxidant properties, are easy to store and transport, and meet the demand for healthy food in modern society. Hubei Province is in the middle and lower reaches of the Yangtze River, has a mild climate and is suitable for growing curly-leaf vegetables in spring and autumn, so it has good development prospects. However, due to all sorts of reasons, the current scale of cultivation is still relatively small; there is a lack of popularised technology, poor standardisation, and insufficient training in green production techniques for farmers. Therefore, it is necessary to build and promote a green production technology system for curly leaf vegetables to strengthen the overall strength of the industry and advance rural revitalization. According to the latest planting methods and technical summaries, this paper will systematically explore the technical routes for green production of curly leaf vegetables to provide technical support for the industrial development of curly leaf vegetables in Hubei Province and the surrounding area.

2. Biological Characteristics and Industrial Value of Curly Leaf Vegetable

2.1 Biological characteristics

Curly leaf vegetable is a kind of Brassica oleracea in the Brassicaceae family. It has a curled and wrinkled leaf shape, is a dark green colour, and is crisp and tender to the touch. Curly leaf vegetables are cool-temperate plants that like a cool and mild climate, and the best range for photosynthesis is 15-25 °C. It is easily damaged by high temperatures; if the temperature is more than 30 °C, the growth will be slow and lignification will increase. This crop has a relatively good cold tolerance, and mature plants can withstand a short period of about -5 °C. It can be grown outside in the winter in the Yangtze River Basin to extend the growing season. Curly leaf vegetables can be grown in all kinds of soil, but sandy loam soil with a pH of 6.0-7.5 that is rich in organic matter and well-drained is the most suitable. It has a shallow root system and is mainly composed of fibrous roots, so its absorption capacity is relatively small; therefore, it needs to be watered and fertilised regularly. Curly leaf vegetables are long-day plants that are not sensitive to photoperiod in their vegetative stage, so they can be grown in both spring and autumn, and the production schedule is relatively flexible.

2.2 Industrial Area

Curly leaf vegetables have a different kind of nutrition. It is rich in Vitamin C, folic acid, dietary fibre and minerals such as potassium, calcium and iron. Among them, leafy vegetables have a relatively high amount of vitamin C and are good antioxidants that can help boost the immune system; thus, they meet the demand of modern consumers for functional foods. Curly leaf vegetables can be eaten raw in salads and hot pot dishes, as well as stir-fried; they are also suitable as raw materials for other processing, such as quick-freezing and dehydration, so many products with good market demand can be developed. Curly leaf vegetables have a short growing period and a high number of harvests per year, and their yield per unit area is higher than that of other leafy green vegetables. It has good storage and transportation conditions, so there will be less post-harvest loss and an extended supply chain. At present, in suitable planting areas such as Hubei Province, a large-scale production system for curly leaf vegetables has begun to be established; now, it is an important way to improve the structure of the vegetable industry and increase land-use efficiency, and it has also shown good results in improving the quality and efficiency of crop production and raising farmers' incomes[1].

3. Green Production Technology System

3.1 Intensive Seedling Culture Technology

Seedling culture is the first step in the production process of curly-leaf vegetables. Green seedling cultivation is good for the environment and can help the seedlings grow well.

3.1.1 Seedling Culture for the Autumn Crop

Sowing will be carried out in late July and mid-August 1972 of 72-cell or 105-cell plug trays. A good Substrate should be loose-grained, water-retaining and free from pest eggs and pathogens. Sow the seeds and cover them with 1-2cm of soil; otherwise, the seeds will not germinate or may be easily damaged by wind and rain. The first two problems in the seedling stage are a lack of water and cold. Add some water in the morning and evening, then top-dress with 0.2 per cent balanced water-soluble fertiliser. The two main diseases to be controlled are damping-off and downy mildew; therefore, it is recommended that a preventive treatment of 70% carbendazim wettable powder at an 800-fold dilution be carried out. Flea beetles are pests, so 20% acetamiprid will be added at a dilution of 1500. In order to reduce the amount of chemical pesticides used, we will employ physical control methods, such as insect screens and yellow sticky traps.

3.1.2 Seedling Cultivation of Early Spring Crops

Sowing will be carried out in December, and a multi-layer insulation system, heating cables, thermal blankets, etc., will be used to raise the temperature inside the greenhouse to 20-25 °C. After production, the plastic film needs to be removed promptly so that air can circulate; otherwise, there will be a problem of high temperature and high humidity. The temperature of the watering water should be about 10-20 °C, and it needs to be warm. Downy mildew is the first disease to be prevented, so a preventative measure of 500 times the dilution of 64% oxadiazyl-mancozeb will be taken. Most of the seedlings do not require chemical treatment at this time; we will only change the environment.

3.2 Scientific Fertilizer Technology

In the green production model, the fertilisation strategy for curly leaf vegetables is to build upon the foundation of organic fertilisers, add chemical fertilisers for supplementation, coordinate the regulation of trace elements, and thus achieve the goals of high yield and good quality for the crop, as well as continuous improvement in soil fertility. Based on the nutrient uptake characteristics of curly leaf vegetables, a large amount of nitrogen is required at all times during their growth, and they are also prone to deficiencies in phosphorus, potassium, boron, zinc, etc. Boron deficiency usually causes leaf curliness and deformation, as well as central necrosis of the leaves; zinc deficiency interferes with the development of the apical meristem. Therefore, in addition to the general fertilisers, some extra nutrients and vitamins are also required.

3.2.1 Basal Fertilizer Application

Prepare the land, add 400-600kg of well-rotted chicken manure per 667m², and also add 30-50kg of compound fertilizer ($N:P_2O_5:K_2O$ = 16:16:16). Organic fertilisers are slow-release fertilisers that can

increase the aggregation of soil and improve the water-holding capacity of the soil. Curly leaf vegetables are deficient in boron and zinc, are more susceptible to physiological disorders, so add 0.75-1.0 kg of granular boron fertilizer and 0.25-0.5 kg of zinc fertilizer to the basal fertilizer. Add 50 kg of superphosphate every two years to supply calcium for the leaves and help them be more tender and disease-resistant.

3.2.2 Topdressing Strategy

2-3 new leaves have appeared after transplantation, so 10-15 kg of urea will be added per 667 m^2 to promote the rapid growth of vegetative organs. At different times during the main growth period of the crop, based on changes in the health and leaf colour of the plants, a small amount of balanced water-soluble fertilizer ($N:P_2O_5:K_2O$ = 20:20:20) needs to be added; otherwise, too much nitrogen will cause the leaves to be soft and tender, and disease resistance will decrease. Functional fertilisers that are based on amino acids and humic acid can be used as foliar sprays in the middle and later stages to improve the stress tolerance of the leaves.

3.2.3 How to Improve Efficiency

Now that we have fully introduced the integrated water-fertiliser management technology, soluble fertilisers will be supplied to the root zone according to the demand of the drip-irrigation system, and the supply of water and nutrients will be coordinated in space and time. The utilisation efficiency of fertilisers will be relatively high, less nitrogen and phosphorus will be lost due to surface runoff and leaching, and thus non-point source pollution will be reduced. At the same time, soil tests and individualised fertiliser application should be conducted concurrently to adjust the fertiliser plan according to the baseline nutrient content of the soil and improve the precision, reduction and green development of fertiliser management for curly leaf vegetables[2].

3.3 Rational Irrigation and Water Management

Curly leaf vegetables have shallow roots and do not need much water; therefore, their growth and development will be more easily affected by changes in soil moisture. Although some moisture is required for the growth of crops, too much water will harm the roots; therefore, a water-management system should be established to effectively combine water-saving irrigation and field drainage, meet the water supply and demand of the field, and regulate the environment in the root zone.

3.3.1 Irrigation Strategy and Fine Water Control

According to the Water-Demand Characteristics at different stages of growth, various irrigation methods are employed. The root system has not developed normally in the seedling stage, so the relative water content of the topsoil should be kept at 70% - 80% to promote root expansion and healthy growth of the seedlings. After transplantation and seedling establishment, the crop will be in a period of rapid vegetative growth, so transpiration and soil evaporation will be relatively high. At this time, after each irrigation, the relative water content of the soil should be 65% - 75%; if the topsoil is slightly dry (about every 3-5 days), additional irrigation should be carried out promptly to avoid drought stress that can lead to leaf aging and an increase in cellulose content. Drip irrigation and micro-sprinkler irrigation are no longer used; the old way of flood irrigation has been replaced. Drip irrigation is near the roots, so there will be little surface runoff and deep percolation. Micro-sprinkler irrigation can increase the relative humidity and reduce the air temperature in hot and humid environments or greenhouses. Both ways can reduce the humidity of the air and prevent many diseases of the leaves.

3.3.2 Drainage and Waterlogging Reduction and Soil Aeration Assurance

Curly leaf vegetables are very sensitive to waterlogging stress. If there is too much water in the soil, the roots will not be able to get oxygen; harmful substances will accumulate due to anaerobic respiration, and thus the roots will be damaged and wilt. Areas that are often in a state of rain, have a high water table, need to be deeply ploughed, and should meet a high standard. The high point of the ridge should be 20-25cm, the width of the ridge surface is 80-100cm, and the furrow width is 30-40cm. A three-ditch drainage system will be built to cover the field ditches, middle ditches and surrounding ditches; thus, after it rains, the field will not be flooded and the problem of subsurface waterlogging will be solved. A soil-moisture meter or a simple tensiometer can be used to know when to water and avoid both underwatering and overwatering. According to the management model of "controlling surface moisture and supplementing subsurface water, integrating drainage and irrigation", the dynamic balance of water, air and heat in the root zone will be achieved, and thus a good water-and-ecology

environment will be created for the high-quality, high-yield production of curly-leaf vegetables.

3.4 Field General Management

Rational Planting Density and Regulation of Population Structure: Given the spread of plants and the light-use nature of curly leaf vegetables, a wide-ridge and narrow-furrow planting method will be adopted. The ridge width is 1.2 m, the row spacing is 0.50 m, and the plant spacing is 0.35-0.40 m (for the spring crop, as the temperature will rise rapidly and the period of vegetative growth will be short, the spacing can be reduced to 0.30-0.35 m), and there will be 2,700-3,200 plants per 667 m². The density of this arrangement can meet the nutritional demands of all the plants and form a reasonable population leaf area index to help with canopy ventilation and light distribution, reduce humidity among the plants, limit the spread of disease, and save land resources.

3.4.1 Soil Cultivation and Ecological Weed Control

Plant the seedlings and then, before closing the canopy, lightly hoe and loosen the soil twice to a depth of 3-5 cm to break up the compacted soil, improve aeration in the rhizosphere, and remove germinated weeds at the same time. Do not damage the roots of the trees when carrying out the loosening work. The two kinds of weed control are hand-pulling and inter-row cultivation; chemical herbicides must not be used. When the plants have grown well and their leaves have closed the canopy completely, a dense canopy can shade the soil surface to prevent weed seeds from germinating and growing; therefore, it can be said that "weeds are suppressed by crop canopies", and labour and chemicals do not need to be employed.

3.4.2 Green Prevention and Control Technology System for Diseases and Pests

In line with the plant protection policy of "prevention first and integrated control", a green prevention and control system has been established in agricultural production that integrates all kinds of physical and biological control methods, as well as chemical control. The Goal of crop protection is to reduce the number of pathogens and pests on crops by means of crop rotation, field sanitation and ridge cultivation. Physical Control: Put out yellow sticky traps outside to collect and kill aphids and whiteflies; set up sex pheromone traps to attract and kill adult diamondback moths; and use insect-proof nets to prevent the pests from entering. Biocontrol is the use of microorganisms, other plants and so on, such as *Bacillus thuringiensis* and azadirachtin. The two main causes of black embryo disease are soft rot and downy mildew, so at the beginning of the disease, low-toxicity fungicides such as 70% carbendazim or 64% oxadixyl·mancozeb are used alternately. Diamondback moths, aphids and whiteflies are pests that can be controlled by the very effective and low-risk insecticides 3% emamectin benzoate and 60 g/L spinetoram. All chemical control measures should be in line with the pre-harvest interval, and application records need to be kept to ensure that pesticide residues in the products meet the green food standards; thus, yield, quality and ecological safety will all be considered.

3.5 Standardised Harvesting and Preservation Technology

The time of collection and how the collected goods are processed will directly affect the demand in the market, the storage life and consumer prices. Leaves have some special physiological characteristics; generally, they have a high water content, respire actively in the leaves, are very susceptible to water loss and wilting after harvest, so all-round standardisation technical processes that include timely harvesting, rapid pre-cooling, precise storage and cold chain circulation should be employed to extend the shelf life and maintain the nutritional value of the product.

3.5.1 Harvest Standards and Methods

In the first step of harvest, when there are 10-12 outer functional leaves on the plant, two or three central tender leaves are picked; the length of the leaf is set to 10-12 cm, and eight to ten strong outer leaves are left to continue photosynthesis and regeneration of the plant. Every two or three days, there will be a few fruit harvests, and the total quantity of fruit produced by the trees will increase. The first harvest is generally carried out in late February and early March during the spring, and at this time, the total leaf length of the harvested plants is about 10-15 cm. Keep the whole petioles and tender leaves, then bundle them with the attached leaves or package them whole; this will improve the uniformity of the commercial appearance and raise the market price significantly. Harvesting should be done in the morning when there is dew on the leaves; it is convenient to pick at this time, and then the leaves can be washed to prevent spoilage.

3.5.2 Postharvest Handling and Pre-cooling Process

Within 2 hours of picking, the fruit should be transported to the processing area and sorted promptly to remove diseased leaves, yellow leaves, mechanically damaged leaves and other foreign materials. Sort them out and then use forced-air pre-cooling or vacuum pre-cooling to reduce the core temperature of the leaves to 4-5 °C in 2-4 hours, quickly dissipate the field heat, and thus reduce respiration and ethylene emission. After pre-cooling, various types of packaging will be chosen according to the demands of all sales channels; polyethylene fresh-keeping bags with micro-perforations or directional breathable containers are suitable for e-commerce and supermarket sales, and their net weight will be about 250-500g per bag. Ethylene absorbers or humidity-control pads can be put inside the bags, and for bulk wholesale, corrugated cartons lined with cling film are used, weighing 5-10kg per carton[3].

3.5.3 Storage and Cold Chain Circulation

Packaged curly leaf vegetables need to be stored in a cold room for now, and the storage temperature should be 4-5 °C and the relative humidity should be 90-95%. Therefore, the rate of leaf water loss has decreased significantly, the degradation of chlorophyll and oxidation of vitamin C have slowed down; thus, the shelf life has been extended to 30 days, and the acceptable product rate is still above 90%. In a controlled atmosphere, if the concentration of O_2 is 2-5% and that of CO_2 is between 3-6%, the storage life will be extended to 40-45 days. Store it in a cold room and transport it by refrigerated truck during the entire trip; the temperature change should be no more than 1 °C, so an unbroken cold chain needs to be maintained from the production base to the end consumer. The technical system mentioned above can support the traditional wholesale channel and guarantee the quality of long-distance and multi-node distribution on e-commerce platforms; thus, logistics losses will be reduced, and both the market supply capacity and the brand premium of curly leaf vegetables will be improved.

4. Recommendations for Local Planting Standards in Hubei Province

4.1 Standardisation of Cultivation Seasons

It has been decided that the sowing time for the autumn crop will be from July 25 to August 15. At this time, shade nets and ventilators will be set up over the seedlings to reduce the temperature in the seedbed and prevent heat damage to the young plants. In December, the spring crop will be planted, and by mid- to late-January, it will be transplanted to a greenhouse or covered with plastic-film mulch, and insulating blankets or small arched tunnels will be employed to provide cold protection. Adjust the time of sowing and transplanting more accurately to avoid a serious cold wave, and ensure that the plants can grow normally in good light and at a suitable temperature.

4.2 Soil and Environmental Conditions

The Area should have a pH of 6.0-7.5, an organic matter content of 2.0% or more, and be a sandy loam or light loam soil. The ground should be level, and there needs to be good water supply and drainage; the fields should be far from industrial and mining areas and sources of pollution. The quality of the irrigation water should meet the requirements for farmland irrigation water quality in GB 5084, and the heavy metal content in the soil should not exceed the risk screening values in GB 15618; tests will be carried out every two years. The previous crop should be a non-cruciferous vegetable, and the rotation cycle should be no less than three years.

4.3 Specifications for Pesticide and Fertilizer Application

Strictly comply with the requirements of Standards NY/T 393 and NY/T 394. Do not use very poisonous and high-residue pesticides; microbial agents, botanical pesticides and bio-organic fertilisers will be distributed first. Chemical pesticides should be used no more than twice during the growing season and need not be repeated. A record of fertiliser use should be kept, and the proportion of commercial organic fertiliser in the total nitrogen supply shall not be less than 50%.

4.4 Production Record and Traceability System

Growers should keep electronic or paper field records that detail the time of sowing and transplanting, sources and quantities of inputs (fertilizers, pesticides, seedlings), field agronomic

operations, harvest batches, test results, sales destinations, etc., to ensure full traceability of all links in the production process. The archive period shall be no shorter than two years. QR code traceability labels will be added to enable consumers to scan and view the production origin and test results of the products, so more people will be more confident in our products.

4.5 Technical Training and Demonstration Extension

With the help of agricultural cooperatives, leading enterprises and grassroots agricultural technology extension agencies, a number of core demonstration bases for the green production of curly leaf vegetables will be built, and each base will be no smaller than 3.3 hectares per county and equipped with unified technical signs and field operation procedures. Organise standardised technical training at least twice a year, combine the form of theoretical lectures with field observations and on-site guidance, pay more attention to the training of new agricultural business entities and large-scale growers. At the same time, a simple operating guide will also be released to help people use the technology correctly.

5. Recommendations and Prospects for Industrial Promotion

5.1 Policy Support

It is recommended that the provincial department of agriculture and rural affairs add curly-leaf vegetables to the list of local specialty vegetables, provide special financial support for increasing seed subsidies, subsidies for green disease and pest control, construction of water-saving irrigation facilities, etc., and establish transparent and standardised procedures for the distribution of subsidies. At the same time, we will also learn how to add curly leaf vegetables to the list of local specialty agricultural products in the insurance catalog and cover natural risks and fluctuations in market prices to stabilise farmers' income. Strengthen the coordination of the departments of agriculture, finance and commerce at the local government level to build a linkage mechanism and jointly promote the healthy development of the curly leaf vegetable industry.

5.2 Scientific and Technological Support

Strengthen cooperation with agricultural research institutions and universities to carry out breeding research on disease resistance in black embryo disease and soft rot of curly leaf vegetables, explore cultivation modes that are suitable for mechanisation, and integrate intelligent water and fertiliser management technology. Joint Innovation Platforms for Industry, Universities and Research Institutions will be established to spread the results of scientific research at all levels. Develop some simple harvesting equipment to reduce labour dependence in the future. At the same time, with the development of the Internet of Things, an intelligent monitoring and decision-making system for the growing environment should be built to achieve accurate management and remote technical guidance, thus increasing the proportion of scientific research and development.

5.3 Market Construction

In addition to the new sales business, a deep-processing product chain for curly leaf vegetables should also be established, such as quick-frozen curly leaf vegetables, dehydrated vegetable powder, blended fruit and vegetable juice, functional health food, etc., and special channels such as catering, aviation and military supplies should also be opened. Establish a regional public brand on the platforms of e-commerce and live-streaming sales to increase brand premium. At the same time, curly leaf vegetables need to be added to the school nutrition meal list and a community fresh-produce supply chain should be built to create multiple market channels.

6. Conclusion

The goal of the green production technology system for curly leaf vegetables is to increase the density of seedling cultivation, achieve balanced fertilisation, water-saving irrigation, control green diseases and pests, standardise harvesting, and all have the aim of good ecological and economic performance. Promoting the development of this technology in Hubei Province will help increase the scale of production and improve the quality of curly leaf vegetables, expand market competitiveness,

promote the green, standardised and branded development of the leafy vegetable industry, and provide strong support for rural revitalization and sustainable agricultural development.

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References

[1] Li J M. Why Can Curly Leaf Vegetable Become the "Hermès" of Vegetables?. Changjiang Vegetables, 2025(1): 63-65.
[2] Li X C. The Hottest Vegetable Item This Winter - Yafei Wanlianqing Curly Leaf Vegetable. Changjiang Vegetables, 2025(3): 65-67.
[3] Chen F. Optimization of High-yield Cultivation Techniques for Leafy Vegetables in Intelligent Greenhouses. Rural Science and Technology, 2024, 15(22): 106-109.