

Facility Cultivation Techniques of ‘Kaorino’ Strawberry

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Abstract Strawberry ‘Kaorino’ is one of the perfect early-maturing strawberry varieties with high quality and high yield due to its anthracnose resistance, early maturity and good quality. The variety has become more and more popular with the promotion over the last few years, but there are great differences from other varieties in cultivation. Based on its varietal characteristics and cultivation performance in production over the last few years, we summarized the seedling cultivation techniques, planting management techniques, main disease control techniques and harvesting and storage techniques, aiming to provide reference for better promotion and application of ‘Kaorino’.

Key words Strawberry; Cultivation; Pest and disease control

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‘Kaorino’, also known as Suizhu, was cultivated by the Agricultural Research Institute of Mie Prefecture in Japan. It was registered as a new variety in 2010. In 2017, the strawberry production base of Nanjing Golden Manor Agricultural Products Co., Ltd. introduced ‘Kaorino’, and after more than five years of experimental demonstration and promotion planting, good performance has been achieved.

‘Kaorino’ has extremely strong growth potential, with a plant height of up to 40 cm, a crown diameter of 35–45 cm, and an inflorescence length of up to 28 cm^[1]. The leaves are light green, and the stolons sprout early and rarely. The root system is sensitive to water and fertilizers. ‘Kaorino’ has good early maturity, strong continuous flowering ability, shallow dormancy, and less light demand. It can mature 10 to 15 d earlier than ‘Hongyan’ strawberry, and compared with ‘Hongyan’, ‘Kaorino’ has 1–2 more harvests of fruits in the whole growing season. It has 15 to 20 top inflorescences. The fruit has a thin layer of orange red skin, and the flesh is white to light yellow. In the early stage, the hardness is relatively high, but after spring, the fruit tends to be soft and the hardness greatly decreases. The fruit is conical in shape and prone to deformities and hollowing when growing too fast or too strong. The fruit is relatively large, with an average single fruit weight of 25–35 g, and the largest fruit can reach over 130 g. It has a high sugar content, rich and sweet aroma, soluble solids up to 12%–14%, and low sourness^[2].

Compared with main cultivated varieties such as ‘Hongyan’, ‘Kaorino’ has the characteristics of strong resistance to anthracnose, vigorous growth, early flower bud differentiation, and good early maturity. It is greatly different from other varieties in cultivation. If conventional cultivation and management models are adopted, great difficulties will arise, and improper management can easily lead to problems such as poor coloring, decreased flavor, and declined quality. This paper aimed to improve the

planting level of ‘Kaorino’ by providing relevant cultivation and management techniques.

Seedling Cultivation Techniques

Selection of mother seedlings

It is advisable to choose robust plants free of pests or diseases with well-developed roots, or tissue culture virus-free plantlets, as mother seedlings for breeding.

Seedling raising in fields

Selection of seedling land It is advisable to choose plots with flat terrain, fertile loose breathable soil, clean and pollution-free water sources, and convenient drainage and irrigation as the fields for raising seedlings. The fields should not have been planted with strawberry, eggplant and other vegetables that are prone to continuous cropping diseases.

Soil preparation According to the condition of the seedling fields, 15 000–30 000 kg of decomposed organic fertilizer and 300–450 kg of composite fertilizer (15–15–15) are applied per hectare. Due to the relatively tall plants of ‘Kaorino’, it is necessary to increase the width and height of ridges appropriately. Ridgers or manual methods should be adopted to form ridges in fields with a width of 1.2–1.5 m and a height of 20–30 cm, and the furrows formed between ridges are 20–40 cm in width.

Propagation of mother seedlings The mother seedlings should be planted in mid-to-late March to early April, with a distance of 25–30 cm from the ridge edge and a spacing of 40–50 cm. They can be densely planted appropriately. When the seedling ridges are narrow, it is advisable to raise seedlings in one row, and when the seedling ridges are wide, seedlings can be raised in two rows.

Cultivation of plantlets After the mother seedlings have sprouted stolons, they should be regularly sorted to ensure even extension. When there are many stolons, thin and weak stolons can be appropriately removed to ensure ventilation and transparency. After the formation of new plantlets, the vines should be pressed with the soil, with a suitable rate of 525 000–600 000 plants/hm². When the number of new plantlets is sufficient, the mother seedlings are cut off.

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Fertility and water management According to the soil conditions, drip irrigation and other methods should be adopted, and water management should mainly focus on "wet but not waterlogging, dry but not drought". Drainage should be carried out in a timely manner after rain, and water should be replenished in a timely manner during drought. When stolons grow, it is necessary to combine fertilizers and water, and apply for multiple times with a small amount per time. In mid to late July, the application of N fertilizer should be reduced properly, but cannot be stopped, and the application of P and K fertilizers should be increased.

Seedling raising in high racks

Seedling racks It is recommended to use seedling racks with a height of 0.7 – 1.3 m and a slot width of 20 – 40 cm and a slot depth of 20 – 40 cm. H-shaped and A-shaped racks can be used.

Seedling substrates The seedling substrates are required to have good water holding capacity and air permeability and a pH of 5.5 – 6.8. It is recommended to mix peat, vermiculite and organic fertilizer at a ratio of 4 : 1 : 0.5, or peat, coconut chaff, vermiculite and organic fertilizer at a ratio of 4 : 1 : 1 : 1 evenly, or use a specialized substrate for strawberry seedling cultivation.

Mother seedling cultivation The mother seedlings should be planted in cultivation slots from mid-to-late March to early April with a spacing of 20 – 25 cm. When the cultivation slots are narrow (≤ 20 cm), single row planting should be carried out. When the cultivation slots are wide (> 20 cm), seedlings can be planted in two rows in a staggered manner and can be densely planted appropriately.

New plant cultivation After a certain number of new plants are produced, they are cultivated in substrate seedling trays or 10 cm plastic nutrient bowls using methods such as cuttage.

Before cutting of new plants, it is necessary to use systemic absorption chemicals and biological agents combined with growth promoting regulators for soaking treatment. Available aystemic chemical agents include 325 g/L difenoconazole · azoxystrobin water dispersible granules, 25% pyraclostrobin suspending agent, 25% azoxystrobin suspending agent, 10% difenoconazole water dispersible granules, 30% metalaxyl-M water aqua, 50% fludioxonil wettable powder, 10% imidacloprid wettable powder, 1.8% avermectin suspension, *etc.* Available biological agents include *Bacillus subtilis*, *Trichoderma*, *Trichoderma harzianum*, *etc.* Available growth promoting regulators include humic acids, amino acids, seaweed extract, chitin, rooting powder, *etc.* The soaking time for seedlings should not be too long, and the concentration of agents should not be too high. Biological agents should be avoided as much as possible in combination with agrochemicals. After cutting is completed, it is necessary to perform irrigation in a timely manner to keep the substrate moist, preferably once in the morning and once in the evening.

In the first week after cutting, a high temperature and humidity should be kept. In specific, the temperature can be 28 – 30 °C during the day and 15 – 20 °C at night, and the suitable humidity is in the range of 80% – 90%. After the new plantlets survive,

they should be ventilated and the substrate humidity should be between 60% and 70%. At 30 d after cutting, water control begins. With the temperature ranging from 22 to 25 °C during the day and from 15 to 18 °C at night, the humidity is controlled in the range of 60% – 70%. If the room temperature is too high, a suspended microspray atomizing system will be turned on to cool down the substrate, preventing restriction on root growth due to overheating of the substrate^[4]. Before cutting, a shading net with a shading rate of 70% is covered on the seedlings. At 10 d after cutting, light is provided appropriately in the morning and evening, and the exposure time is gradually extended afterward. After 20 d, the shading net is removed to provide light all day. Early surviving seedlings should be moved to the openings of sheds or ventilation openings to prevent overgrowth. After survival, water-soluble fertilizers are applied every 7 – 10 d. The supply of N fertilizer should be reduced or even stopped in early August, and temperature difference should be appropriately increased between day and night to promote flower bud differentiation.

Temperature and humidity management

For seedling raising in open fields, moderate soil drought should be maintained, and drainage should be carried out timely after rain. When the temperature is too high, old leaves should be promptly removed or simple shading measures should be taken for ventilation and cooling.

The temperature for seedling raising in rain shelters should be controlled as much as possible, and it is advisable to control the temperature between 24 and 28 °C during the day after summer. When the temperature is higher than 28 °C, sunshades, wet curtains or fans should be opened for ventilation and cooling.

Seedling level

'Kaorino' seedlings are divided into first-class seedlings and second-class seedlings according to their growth conditions. Standards for first-class seedlings: four leaves with one heart or more, growing neatly, with a rhizome thickness of 1.0 – 1.2 cm, a seedling age of 40 – 90 d, normal color, and intact roots and leaves. Standards for second-class seedlings: Three leaves with one heart or more, growing neatly, with a rhizome thickness of 0.8 – 1.0 cm, a seedling age of 40 – 90 d, normal color, and intact roots and leaves.

Management Techniques for Planting in Greenhouses

Preparation before planting

Soil disinfection treatment In greenhouses for continuous cropping, it is required to timely remove previous crops and field debris after strawberry harvest. In early to mid June, 7 500 – 15 000 kg of crop straw and livestock manure compost, or 15 000 – 22 500 kg of mushroom residue or rice husk, 1 500 – 2 250 kg of rapeseed cake, and chemical disinfectants such as 300 – 450 kg of dazomet or 600 – 1 200 kg of lime nitrogen or 150 – 300 kg of microbes for high-temperature greenhouse closure are added per hectare. The soil is watered thoroughly, and the greenhouses are sealed with

film at a high temperature for 30 to 45 d. Water is replenished timely when there is insufficient water. When there are many cloudy and rainy days, the duration of greenhouse closure should be appropriately extended.

Substrate disinfection treatment During substrate cultivation, reused substrates must be disinfected. Previous crop plants should be timely removed, and if the substrate is insufficient, peat or specialized cultivation substrate will be used to make up for it. First, 150 – 225 kg of dazomet or 300 – 600 kg of lime nitrogen is spread evenly on the surface of ridges per hectare, and mixed with soil timely and covered with plastic film. The greenhouses are sealed for 30 to 45 d. After disinfection, the pH was adjusted between 5.5 and 6.5 using ferrous sulfate or sulfur.

Soil preparation and ridging

When planting in fields, it is necessary to consider the soil conditions and appropriately reduce the application of chemical fertilizers. To one hectare of land, 1 200 – 1 800 kg of commercial microbial fertilizer, 15 – 20 kg of ternary compound fertilizer (15 – 15 – 15, potassium sulfate type), and 375 – 525 kg of superphosphate (slightly alkaline soil) or calcium magnesium phosphate (acidic soil) are applied as the base fertilizer (70% – 80% of the fertilizer dosage for conventional strawberry varieties). Ridgers are used to form ridges with following advisable sizes: a ridge height ≥ 30 cm (higher than general varieties due to longer flower and fruit stems), a ridge surface width of 50 – 60 cm, a ridge bottom width of 70 – 80 cm, and a furrow ridge of 30 – 40 cm. The base fertilizer should be properly controlled in substrate cultivation.

Field planting

Healthy seedlings that have completed flower bud differentiation are selected and planted appropriately early. It is advisable to plant them in Nanjing from late August to early September. Each ridge is planted with two rows of plants, with a row spacing of 20 – 25 cm, a plant spacing of 20 – 25 cm, and a row edge spacing of 8 – 12 cm (to prevent flowers and fruits from extending into furrows and causing human trampling losses). When adopting ultra-high ridge cultivation or rack cultivation, the row edge spacing should not be less than 5 cm. The plants are planted with the arched back towards ridges and furrow. After planting, facilities such as sunshade and atomization cooling instruments must be covered on greenhouses in a timely manner, and the sunshade time should not exceed 2 weeks.

Management after planting

Fertilizer and water management Chlorine-containing compound fertilizers should not be used for fertilization. Meanwhile, the fertilizer and water application of this variety should pay attention to the following points:

After planting, irrigation is carried out in a timely manner to ensure that the soil/substrate is moist until the plants survive. Topdressing is mainly based on "a small amount each time, multiple times, combining fertilizers with water".

Before covering with plastic film, it is not advisable to carry

out topdressing for field cultivation. For ultra-high ridge cultivation or substrate cultivation, the application of N fertilizer should be reduced, while the application of P and K fertilizers should be increased, or fertilizers such as phosphorus and potassium fertilizers containing humic acid, water-soluble fertilizers containing amino acids (amino acid content $\geq 10\%$) and other fertilizers can be applied with drip irrigation.

In the early stages of flowering and fruiting, it is advisable to appropriately reduce the amount of N fertilizer, increase the application of P and K fertilizers, and combine them with foliar fertilizers such as Ga, Mg and B, but still based on the NO_3^- content in the leaves not less than 500 ppm.

When the temperature warms up in early February, it is necessary to increase the application of P, K, Ga and other fertilizers based on fruit hardness and flavor, along with water-soluble fertilizers containing amino acids. When there is a strong growth trend in early March, it is necessary to control the supply of N fertilizer and water, and spray prohexadione calcium and other fertilizers to control the growth.

Within two months after planting in substrate cultivation, the substrate EC value should be controlled within 0.5 ms/cm. From November to December, the substrate EC value should be controlled between 0.6 and 0.7 ms/cm. From mid December to early March, the substrate EC value should be controlled between 0.8 and 0.9 ms/cm. After mid to late March, it is advisable to reduce the substrate EC to 0.6 – 0.7 ms/cm.

Film covering When the budding rate of plants reaches 50% – 60%, it is advisable to cover them with silver black or white black plastic film. After covering the film, the film is immediately broken to release the seedlings.

When the average temperature ranged from 15 to 17 °C or the nighttime temperature is below 10 °C (usually in late October to early November), the greenhouses should be covered with plastic film.

Temperature and humidity management From the initial stage of heat preservation to the fruit expansion stage, appropriate temperature management should be carried out. It is advisable to maintain a temperature of 24 – 26 °C during the day and 6 – 10 °C at night, to prevent a too-high or too-low temperature in greenhouses as much as possible. During the harvest period, the temperature should be maintained between 18 and 22 °C during the day, and not lower than 5 °C at night.

Flower and fruit management Dead leaves, old leaves, diseased leaves, stolons and lateral branches should be timely removed. Old leaves are removed during the recovering stage after planting while leaving 3 – 5 leaves. Also, old leaves are removed before and after covering the film, before and after the first crop, and before and after the second crop, while leaving 8 – 12 leaves. It is advisable to remove old leaves 4 – 5 times during the production season.

Before flowering, plants are pollinated using bees, with 15 boxes of bees per hectare. It is recommended to use scoliids, *Apis*

mellifera, bumblebees, *etc.* It is necessary to timely eliminate weak flowers and abnormal fruits and leave about 10 fruits in the top inflorescence and about 6 fruits in the side inflorescence for each crop.

White gauze nets should be laid on both sides of cultivation ridges to hold the fruit.

Main Pest Control Techniques

Prevention and control principles

Targeting at green ecology and high-quality and efficient production, following the plant protection policy of "prevention first, comprehensive prevention and control" and the principles of "necessary for production, effective prevention and control, safety first, and minimum risk", pesticides are used scientifically and reasonably^[4].

Main pests and diseases

The main diseases include verticillium wilt, root rot, gray mold, as well as anthracnose and powdery mildew. The main pests include aphids, *Tetranychus urticae* Koch, and *Spodoptera litura* Fabricius.

Prevention and control methods

Scientific cultivation and ecological prevention and control

① Reasonable dense planting: Reasonable dense planting should be carried out at a rate of 75 000 – 82 500 plants/hm². Old leaves and diseased leaves and fruit should be promptly cleaned, and high-grade secondary flowers and fruits should be removed. Organic fertilizers should be added, and attention should be paid to the balance between fertilizers and water. The integrated drip irrigation method of water and fertilizers should be adopted. ② Suitable temperature and humidity control: Suitable temperature and light conditions for strawberry growth should be created, and attention should be paid to temperature and humidity control inside greenhouses. It is necessary to open windows appropriately for ventilation to reduce humidity. ③ Disease control by closing greenhouses: The greenhouses should be closed to control diseases. When there is a large-scale outbreak of gray mold or powdery mildew in greenhouses, closing the greenhouses at noon on a sunny day can be chosen to raise the temperature above 35 °C for 2 h, continuously 2 – 3 times^[5]. ④ Control with natural enemies: Natural enemies such as *Phytoseiulus persimilis* (≥ 3 000 mites/bottle), *Neoseiulus barkeri* (≥ 25 000 mites/bottle), and *Amblyseius cucumeris* (Oudemans) (≥ 25 000 heads/bottle), can be adopted to control the number of pests^[6]. ⑤ Installation of insect prevention nets: Insect prevention nets can be installed. They can be installed at the ventilation openings of greenhouses to prevent pests from migrating into the greenhouses and damaging strawberries.

Physical and chemical trapping and control ① Color avoidance: Silver gray dual-color film can be selected as a mulching film for covering. ② Smell avoidance: Plants such as scallions and garlic can be planted between strawberry rows. ③ Color board trapping and killing: Farmers can purchase special yellow and blue boards, of which yellow boards mainly sticks to kill aphids,

while blue boards mainly sticks to kill thrips. ④ Trapping and killing pests with sugar and vinegar spray: Overwintering adults can be lured and killed with sugar and vinegar liquor. ⑤ Luring and killing pests with insect-killing lamps: Spectral insect-killing lamps can be used to lure and kill phototactic pests. ⑥ Luring and killing pests with sex attractants: *S. litura* sexual attractants can be used to attract and kill *S. litura*.

Pesticide formulation control ① Verticillium wilt and root rot: During the fallow period, 99% sulfur fluoride gas preparation 50 g/m² or 98% dazomet granules 35 g/m² or 20% allyl isothiocyanate emulsion in water (EW) 45 L/hm² are used for fumigation of closed greenhouses. After planting, in the early stage of growth, biological agents such as 3×10^9 cfu/g *Bacillus methylotrophicus* 9912 wettable powder (1 g/m²) are diluted and used for root irrigation. Similarly, 1×10^8 cfu/g Jinggongmycin *Paenibacillus polymyxa* wettable powder 1 000 times dilution, 2×10^{11} cfu/g *B. subtilis* wettable powder 1 000 times dilution and 2×10^8 cfu/g *Trichoderma* wettable powder 300 times dilution^[7] can be used for root irrigation. Chemical agents such as 15% phenamacril suspending agent 600 times dilution and 30% phenamacril · difenoconazole suspending agent 1 000 – 2 000 times dilution are used for root irrigation.

② Gray mold (*Botrytis*): Biological agents, if selected, such as 2×10^{11} cfu/g *B. subtilis* wettable powder 500 times dilution, 1×10^{10} cfu/g *Bacillus amyloliquefaciens* QST713 suspending agent 150 times dilution, 2×10^8 cfu/g *Trichoderma* wettable powder 300 times dilution and 16% polyoxin B soluble granule 300 g/hm², can be sprayed twice or three times before flowering and during the fruiting period after flowering^[8]. Chemical agents such as 42.4% pyraclostrobin · fluxapyroxad suspending agent 1 500 – 2 000 times dilution, 62% cyprodinil · fludioxonil water dispersible granules 1 000 – 1 500 times dilution, 50% boscalid water dispersible granules 1 000 – 1 500 times dilution^[8] and 40% pyrimethanil suspending agent 1 000 times dilution can be sprayed.

③ Powdery mildew: Biological agents, if selected, such as 1×10^{11} cfu/g *B. subtilis* wettable powder 500 times dilution, 1×10^9 cfu/g *B. amyloliquefaciens* AT-332 wettable powder 400 times dilution, and 2% oligosaccharin aqueous solution 300 times dilution, can be sprayed evenly and thoroughly. The disease center and the back of the leaves should be sprayed, with an interval of 7 to 10 d, for 2 to 3 times of continuous control. Sulfur fumigation can also be carried out after the greenhouses are closed at dusk. Chemical agents, such as 12.5% tetraconazole water emulsion 1 500 – 2 500 times dilution, 300 g/L kresoxim-methyl · boscalid suspending agent 1 000 – 2 000 times dilution and 25% ethirimol suspending agent 1 000 times dilution, should be sprayed on both the back and surface of leaves.

④ Anthracnose: Biological agents, such as 5% d-limonene 500 times dilution, should be sprayed once a week in the early stages of the disease, 2 – 3 times continuously. Chemical agents, 40% dithianon · pyraclostrobin water dispersible granule 1 000

times dilution, 250 g/L azoxystrobin suspending agent 1 200 times dilution, 500 g/L fluazinam suspending agent 1 500 times dilution and 50% prochloraz wettable powder 1 500 – 2 000 times dilution, can be sprayed for control of anthracnose.

⑤ Aphids: For aphid control, 2% matrine water aqua 1 500 times dilution, or 10% imidacloprid wettable powder 2 000 times dilution, 10% flonicamid water dispersible granule 1 000 – 1 500 times dilution and 30% pymetrozine · clothianidin suspending agent 2 000 times dilution can be sprayed.

⑥ Thrips: Thrips are controlled by spraying 16% acetamiprid · novaluron emulsifiable concentrates 1 500 – 2 000 times dilution, 25% spinetoram water dispersible granule 1 000 – 1 500 times, etc.

⑦ Red spiders: Red spiders are controlled by spraying 0.1% *Veratrum nigrum* rhizome extract soluble solution 350 times dilution, 0.5% ivermectin emulsifiable concentrates 500 – 1 000 times dilution, 43% bifenazate suspending agent 1 500 times dilution and 110 g/L etoxazole suspending agent 1 500 times dilution in the early stage of mites, while focusing on the back of leaves.

Attention should be paid to the use of cross rotation of pesticides to reduce the occurrence of drug resistance. Prohibited (restricted) pesticides mustn't be used, and the application of pesticides should strictly follow pesticide safety intervals.

Harvesting, Storage and Transportation Techniques

Harvesting

When the maturity of fruit reaches 8 – 9 (2 – 3 circles of seeds on the shaded side of 'Kaorino' fruit do not turn red), harvesting is carried out. The fruit should be graded according to their size and placed in corresponding sponge mats, which are then neatly placed in harvesting baskets.

Storage and transportation

Short-distance (<50 km) or short-term (≤24 h) sales can

be carried by using simple containers. For long-distance (>50 km) or long-term (>24 h) sales, fixed storage devices should be used and the fruit should be pre-cooled for transportation in a timely manner. The fruit should be stored in an environment at 0 – 1 °C with a relative humidity of 90% – 95%. During transportation, cold chain transport vehicles should be used to control the temperature within 2 – 6 °C^[9].

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