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The Influence of Different Ridge Heights on the Expansion of Sweet Potato Tubers and the Rate of Marketable Tubers

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Abstract In sweet potato ridge cultivation, the height of the ridges is often regarded as a crucial factor. However, its effect varies in different regions and soil conditions. The height of the ridge alters the tightness of the soil, the conditions of air permeability and drainage, as well as the gas exchange at the rhizosphere and the fluctuations of water and temperature. These changes subsequently manifest in the growth of the above-ground part, nutrient accumulation, and the distribution to the tubers. The speed of tuber enlargement, the quality of the tubers, and the rate of commercial tubers also vary. Based on the publicly available literature, local technical regulations, and mechanization standards over the past decade, combined with the test results from typical ecological regions, a relatively consistent trend can be observed: appropriately raising the ridge height is beneficial for drainage and ventilation, reducing CO_2 accumulation at the rhizosphere, and promoting the transport of assimilates to the tubers. However, if the ridge height is too high, especially in dry years, water is prone to loss, often resulting in "strong vines but weak tubers", with inconsistent water supply during the tuber enlargement period, and an increased risk of cracking and deformed tubers. Therefore, in production, it is not advisable to simply pursue high ridges. A comprehensive consideration should be given based on soil texture, rainfall or irrigation conditions, the tuber formation habits of the variety, and the harvesting method. In most regions, a height of 25-35 cm is appropriate, and it should be combined with mulching or drip irrigation and stable water supply in the middle and later stages to more securely increase the rate and efficiency of commercial tubers.
Keywords Sweet potato; Ridge height; Tuber enlargement; Rate of commercial tubers; Micro-environment at the rhizosphere

1 Introduction

Sweet potatoes are not only a common fresh food crop in China, but also an important raw material for processing and feeding. However, in recent years, the focus of production has shifted from merely "whether there is enough" to the "quality and specifications" of the products. The industrial sector increasingly values uniform specifications and stable product rates, which has also forced the cultivation approach to shift from solely pursuing yield to taking into account both product quality and mechanization compatibility (Laurie et al., 2015). Relevant experts from the Ministry of Agriculture and Rural Affairs have repeatedly mentioned improving quality and efficiency and mechanization compatibility in their annual technical opinions. In fact, this signals that sweet potato production is entering a stage where details parameters are being compared. The reason why the ridge height has been repeatedly discussed is that, on the one hand, it raises the cultivation layer, improving drainage and ventilation, which is conducive to the formation of tubers (Kivuva et al., 2015); on the other hand, if the ridge is too high, it is prone to magnify the risks of moisture loss and temperature fluctuations, and the shape and product quality of the tubers are affected instead. Therefore, systematically analyzing the effects of different ridge heights on the expansion of tubers and the rate of commercial tubers can not only explain the common phenomenon of "different tuber shapes for the same variety" in the field, but also provide a basis for determining reasonable ridge types under large-scale and mechanized conditions.

Many people consider the ridge height as an operational detail. However, from the perspective of soil, it actually changes the height difference between the ridge surface and the bottom of the furrow first. Once rain falls, how quickly the water drains, how long it takes for the soil to regain air circulation, and whether the root zone gases will be retained, all of these are related to this height. The mechanized operation procedures require that the ridge height be uniform and not less than 25 cm. This is not just a formal requirement; if the ridge is too short, the root activity layer is restricted, and it is more prone to oxygen deficiency after rain, and the stability of machine operation is also poor. The root zone gas environment cannot be ignored either. Studies have found that when the CO_2 level in the root domain increases, the net photosynthetic rate of the leaves and the stomatal conductance will both decrease (Bhattarai et al., 2017); while through ventilation within the ridge, reducing the CO_2 level from 0.5%-1.4% to 0.1%-0.2%, the fresh and dry weight of the root tubers can reach approximately 1.18-1.19 times that of the control (Jin et al., 2020). This indicates that the underground ventilation condition will, in turn, affect the carbon assimilation in the aboveground part and the yield of root tubers. Rather than considering ridge formation as an external form, it is through the interaction of oxygen, CO_2 and water that it influences the source-sink relationship and the efficiency of root tuber expansion.

First, starting from the soil structure, moisture and temperature changes, let's examine how the ridge height affects the formation and subsequent expansion of tubers. Second, based on the existing experimental results and production procedures, summarize the common patterns of yield composition, commercial potato rate, and the occurrence of abnormal and cracked tubers under different ridge height conditions. Third, taking typical ecological areas such as the southeastern paddy soil region as examples, propose feasible ridge height ranges and corresponding management strategies for actual production. The overall approach is not to simply draw conclusions but to follow a "chain of evidence": first, extract the applicable ridge height ranges from the standards and technical opinions, such as 30-35 cm for clay soil, 25-30 cm for sandy loam soil, and a ridge height of no less than 25 cm, etc. Then, use field experiments to verify the advantages of moderate ridge height in terms of yield and mechanical harvesting. Finally, use physiological and ecological research to explain the internal reasons such as improved aeration, energy supply, and the transport of assimilates to the tubers.

2 The Regulatory Mechanism of Ridge Height on Growth Environment

2.1 Effects of different ridge heights on soil physical properties (aeration, looseness)

Raising ridges ultimately means rebuilding the original cultivation layer. The ridge has been raised, and the loose soil layer is often thicker, making the drainage channels of the ridge clearer. Especially in heavy soil, this change is particularly crucial - water cannot be drained out, air cannot enter, and the problem is concentrated here (Colombi et al., 2018). So in the technical opinion, the height of the clay ridge is set at 30-35 cm, while the height of the sandy loam soil is lowered to 25-30 cm. There are actually two orientations behind this: the clay should be raised to promote drainage, while the light sandy soil should prevent rapid water loss.

The local mechanization regulations also specify the indicators more specifically, with requirements ranging from 20-40 cm for different ridge types, and emphasize that operations are more ideal when the moisture content of cultivated land is between 20% and 40%. In other words, if the ridge cannot be broken, loosened, or leveled, it will directly affect the ventilation status and the resistance of the root system. From a physiological perspective, after improved ventilation, ATP metabolism in leaves and tubers becomes more active, and assimilates are transported more smoothly to tubers (Nunes et al., 2016). This is precisely the intrinsic reason why sweet potatoes prefer looseness and fear compaction. Therefore, instead of staring at the height of the ridge in centimeters, it is better to focus on whether a truly “breathing” ridge can be formed in the target soil.

2.2 The impact of ridge height on soil moisture and temperature dynamics

Once the ridge is raised, the water distribution in the field often becomes uneven, forming a state where the soil is wetter in the ditches and drier on the ridges. During rainfall, water tends to flow into the ditches and be drained away, which is beneficial for alleviating waterlogging. However, in areas with water shortage or severe drought, this structure may also cause the ridges to lose moisture more quickly. The mechanized operation procedures repeatedly emphasize that the ridge height and shape should be consistent, which is actually to stabilize this moisture pattern and avoid the situation where "some areas have good moisture while others are relatively dry" on the same piece of land during the expansion period, thereby widening the variation in tuber shape (Li et al., 2019). Besides moisture, the soil temperature also changes.

Research in the Yellow-Huai-Hai region has found that covering with plastic film on the basis of a ridge height of about 30 cm can increase the temperature of the 5-10 cm soil layer by 6.0%-6.4%, and simultaneously increase LAI and tuber yield (23.8%-33.8%), indicating that the water and heat conditions of the ridge can be regulated through "ridge height × covering or drip irrigation". For ridge farming systems with irrigation conditions, there are also studies proposing to control the ridge height to increase the distance between the water level surface and the soil surface, stabilizing the soil moisture content at 10%-15%, and reducing CO_2 accumulation in the root zone, demonstrating the amplification effect of ridge height in water management (Zhang et al., 2021).

2.3 Changes in the rhizosphere microenvironment under ridge cultivation and their effects on root formation

Whether root formation can proceed smoothly is not merely a matter of whether there is sufficient water and nutrients; the condition of the rhizosphere being “well-ventilated” is equally crucial. In the forced aeration experiment, a phenomenon was quite obvious: when the CO_2 level in the root zone of the ridge was high, the net photosynthetic rate of the leaves and the stomatal conductance would decrease (Bhattarai et al., 2017); when the CO_2 was reduced to 0.1%-0.2%, the fresh weight and dry weight of the roots could increase to 1.18-1.19 times that of the control, and further increasing the aeration volume could even increase the dry weight by 19%-26%.

It is not difficult to understand this in the field context. If the ridge body is low and the drainage is slow in fields with heavy rain and clayey soil or after rice cultivation, the accumulation of CO_2 and the risk of hypoxia in the rhizosphere are prone to occur, and the initiation and early expansion of the roots are often hindered; conversely, if the ridge body is moderately raised, the gas renewal is faster after rain, and the microenvironment is more stable. At the same time, the soil becomes looser and has better aeration, which will also increase the ATP supply and aerobic respiration efficiency of the roots, promoting starch synthesis. Two-season field experiments showed that the yield of sandy loam soil with better aeration conditions was 13.94%-32.91% higher than that of loam soil, and the peak of root expansion was more concentrated (Jin et al., 2020). Although the ridge height was not directly compared, this mechanism supports the judgment that ridge cultivation promotes root expansion by improving aeration.

3 The Effect of Ridge Height on the Growth Characteristics of Sweet Potato Aboveground Parts

3.1 Sweet potato stem and vine growth and leaf area changes at different ridge heights

The impact of ridge formation on aboveground growth is often not immediately apparent, but rather changes the environment before affecting the population. When the ridge height is appropriate and the drainage and ventilation conditions are good, the slow seedlings are often faster, the root system is more stable, and the leaf area index is more likely to form an advantage; On the other hand, when encountering waterlogging damage after rain, low ridges often have yellow leaves, weak seedlings, and uneven populations. It is also difficult to make up for the gap that was widened earlier by applying fertilizer later on. In field experiments, in the Huang Huai Hai region, under the condition of about 30 cm ridge formation and film mulching, ridge formation can increase soil temperature and LAI by about 5.6%-6.4% compared to bare land (Liu et al., 2018).

This indicates that the improvement of ridge water and heat directly reflects on leaf area expansion. However, stem length does not necessarily mean high yield. Comparing different ridge heights of 30, 40, and 50 cm abroad, it was found that low ridges are more likely to grow vines, while medium ridge heights are more conducive to increasing root yield, indicating that ridge height can reshape the distribution relationship between nutrient growth and root tuber enlargement (Villordon et al., 2019). So when evaluating ridge height, we cannot only focus on whether the ridge is sealed quickly, but also on whether the assimilates flow smoothly into the “reservoir” of root tubers after the ridge is sealed.

3.2 The impact of ridge height on photosynthetic capacity and material accumulation

Whether photosynthesis is strong or not is not only related to the structure of the canopy, but also affected by the underground environment. In the forced aeration experiment, when the CO_2 level in the root zone rose to 1%-2%, the net photosynthetic rate and leaf conductance dropped to 0.8 and 0.7 times that of the control, respectively

(Bhattarai et al., 2017). This indicates that once the gas in the rhizosphere is restricted, it will affect the aboveground part through stomatal regulation and assimilation rate. In other words, if the ridge height is too low, the drainage is slow, and CO_2 is prone to accumulate, even if the leaves appear vigorous, the photosynthetic efficiency and assimilate output may still be hindered by the underground conditions.

On the contrary, when the ridge height is appropriately raised and the aeration is improved, the net photosynthetic level is more likely to be maintained, and the assimilate supply is more stable. Such differences can often be observed in production: for the same variety and fertilization, the plots with appropriate ridge height have stable leaf color, are less prone to premature aging in the later stage, and can continue to supply carbon during the expansion period; while the plots with poor ridge shape and low ridge height are prone to “root suffocation” after rain, and then fall into the cycle of “rapid growth - premature aging - small tubers” (Villordon et al., 2019). This is consistent with the technical advice that emphasizes preventing waterlogging in the later stage, timely drainage, and promoting expansion.

3.3 Synergistic relationship between aboveground growth and underground root enlargement

For sweet potatoes to achieve high yields, it is not dependent on any single aspect, but rather on whether the “source” and “sink” can cooperate well: continuous leaf output, and the successful transportation of assimilates to the roots and their conversion into starch. Many physiological studies have already pointed out that once soil aeration is improved, the transportation of assimilates to the roots will be more smooth, and the proportion of dry matter in the roots will also increase (Bhattarai et al., 2017). Recent field results have made this point more specific - in treatments with looser soil and better aeration, the yield and economic coefficient of the roots increased by 27.03%-38.74% and 6.30%-13.05% over two years; conversely, the compact treatment resulted in significant reduction in yield. ^13C labeling also showed that under loose conditions, the efficiency of root input was higher (Colombi et al., 2018).

When these phenomena are viewed from the perspective of ridge height, a possible solution can be proposed: when the ridge height is moderate, the topsoil is more loose and oxygen is replenished faster after rain, allowing the assimilates to flow more smoothly between the “stem base - root”; when the ridge height is too low and encountering waterlogging or compaction, the receiving capacity of the root “sink” decreases, and assimilates are retained in the stems and leaves. A common example is “vigorous vines but thin roots”. Therefore, discussing the optimal range of ridge height is essentially about creating structural conditions to maintain the activity of the “sink” end, rather than simply making the ridge higher.

4 The Effect of Ridge Height on the Swelling Process of Sweet Potato Tubers

4.1 Differences in the initiation and expansion stages of root tubers at different ridge heights

The swelling of the root tuber is not achieved overnight, and can be roughly divided into the initiation period and the rapid swelling period. In the previous stage, the key lies in root differentiation, whether it can form root segments that can be transformed into tubers, and have a more obvious response to soil aeration and soil temperature (Villordon et al., 2014); In the period of rapid expansion, the influencing factors turn to whether the water is stable and whether the assimilates can be continuously supplied. The technical opinion mentions that the root tubers begin to swell 30-40 days after planting and are most sensitive to water at this time. It is required to strengthen management and prevent later waterlogging, which actually corresponds to this stage difference.

The role of ridge height in the two stages is not exactly the same: during the start-up period, a moderately high ridge, especially when combined with mulching, is beneficial for heating and ventilation, and the root system is built quickly with low risk of root blockage; But in the rapid expansion period, if the ridge is too high and lacks irrigation, it is easy to lose moisture, slow down the expansion speed, and increase the risk of potato cracking. From the perspective of energy metabolism, soil with good ventilation conditions is more conducive to aerobic respiration and ATP supply of root tubers, laying the foundation for starch synthesis (Colombi et al., 2018). This also explains why the ventilation status during the start-up phase can affect the “potential upper limit” of subsequent expansion.

4.2 The impact of ridge height on the number of block roots, single potato weight, and girdling rate

Among the several indicators determining the rate of commercial potatoes, the number of tubers per plant, the weight of a single potato, and the proportion of large and medium-sized tubers are often the most intuitive. A field experiment in Longyan, Fujian Province found that as the ridge height increased, the number of tubers per plant and the proportion of large and medium-sized tubers also increased simultaneously. However, the weight of a single potato per plant and the total yield did not increase continuously but showed a “first increase then decrease” pattern. This also suggests that the higher the ridge height, the better, but there is an optimal range (Li et al., 2019).

In this experiment, the treatment with a ridge spacing of 80 cm and a ridge height of 30 cm had the highest yield, reaching 42.91 t/hm^2. At the same time, the emergence rate (visible tubers) reached 96.40%. This indicates that an appropriate ridge height is not only conducive to the expansion of block roots but also helps reduce harvest losses. From a mechanism perspective, the weight of a single potato and the girdling rate are closely related to energy supply. Two-season experiments showed that the ATP content was highly significantly positively correlated with yield and the weight of a single potato, and the girdling rate was also significantly correlated with ATP and ADP content (Bhattarai et al., 2017). This means that any structure that improves ventilation and enhances aerobic respiration can play a role through the “ATP - starch synthesis - single potato weight” chain.

4.3 Analysis of the relationship between root morphology formation and furrow height

Whether the product is of good quality depends not only on whether there are potatoes in the field, but also on whether the potato shape is regular and whether the specifications are uniform. The influence of the furrow structure on the formation of the potato shape mainly manifests in two aspects: one is the compactness of the soil and the distribution of pores, which will set “space boundaries” for the expansion of the root; the other is the fluctuation of water levels, which will change the cell turgor pressure and epidermal tension, thereby inducing cracking or deformity of the potato. Some studies have mentioned that excessive irrigation water easily makes the soil compact, and the potato blocks will be squeezed and deformed accordingly. This “over-wet - high resistance - deformity” path is not uncommon (Colombi et al., 2018).

In the engineering ventilation experiment, when the CO_2 level in the root domain was reduced, the root yield increased, and the CO_2 level after rain was also more stable, indicating that good gas exchange helps maintain a uniform underground environment. When comparing 30, 40, and 50 cm furrow heights abroad, it was also found that an increase in furrow height often accompanies an increase in root length and a decrease in root diameter, and at a specific planting angle, the yield of 40 cm furrow height is higher (Villordon et al., 2019). This suggests that the furrow height not only affects the “size” of the potato but also reshapes the “length, thickness” of the morphological scale. Therefore, the formation of the potato shape should be considered in the design stage of the furrow height, rather than passively grading after harvest.

5 The Effect of Ridge Height on Sweet Potato Commodity Potato Rate and Yield Composition

5.1 Characteristics of changes in potato yield under different ridge heights

The high or low rate of commercial potatoes is often related to whether the specifications are concentrated, whether there are any defects in appearance, whether they are damaged during harvesting, and the situation of pests and diseases. Nowadays, many grading methods directly set thresholds based on weight, such as 150-600 g grading, treating A and B grades as commodity potatoes. Essentially, this is measured by “sellable specifications” rather than simply by the total yield. In field management, people often attribute the increase in commodity rate to reasonable planting density, reduction of underground pests and diseases, and special emphasis on later drainage to prevent decay and deformities.

In fact, the impact of ridge height is often more prominent, as it works by changing the risk of deformities and potato cracking, concentration of specifications, and probability of mechanical damage. When the ridge body is moderate, the ventilation conditions are good, the expansion process is more uniform, and the size of the potato chunks is more concentrated; The ridges are relatively low, and after rain, they are prone to lack of oxygen and are prone to compaction, resulting in an increase in slender or curved potatoes (Colombi et al., 2018); However, if the ridge body is too high and the water management is not in place, it will dry and wet intermittently during the swelling period, and it is also prone to potato cracking (Li et al., 2019). From this perspective, in order to increase the potato yield, ridge height should be considered as a front-end structural factor.

5.2 The impact of ridge height on the incidence of abnormal tubers and split tubers

Abnormal tubers and split tubers are often the most direct cause of a decline in product quality. Abnormality is often related to the underground environment, such as oxygen deficiency in the rhizosphere, overly compacted soil, sudden increase in local resistance after excessive moisture, etc.; split tubers often occur when the moisture level fluctuates during the expansion period. A water irrigation experiment found that a sudden increase in soil moisture content would increase local mechanical resistance, inhibit normal root growth, and excessive irrigation could even directly cause tuber deformation (Colombi et al., 2018). This indicates that improper water management can “create abnormalities” in an invisible way. In areas with abundant rainfall, the value of ridge formation is primarily reflected in timely drainage of water and allowing air to enter.

The mechanized operation procedures in Hunan specify a ridge height range of 20-40 cm, and emphasize the construction of waist ditches and perimeter ditches. In fact, the key to preventing abnormality and split tubers lies in the “ridge ditch system”. Another factor that is often overlooked is root zone gas: when the CO_2 content in the root zone reaches 0.5%-1.4%, reducing it to 0.1%-0.2% through ventilation can significantly increase yield (Bhattarai et al., 2017). This also suggests that reducing gas stress can help reduce abnormality caused by growth inhibition. From this, it can be seen that abnormality and split tubers are not accidental, but the result of the combined effect of ridge height and water and gas management.

5.3 Comprehensive evaluation of potato yield, yield per unit area and economic benefits

Even if the yield increases, the economic benefits may not increase simultaneously. The key lies in how much can be sold and how much is lost during the harvesting and transportation process. The mechanized full-process production procedure integrates the row spacing, row height and operation mode. Essentially, it aims to reduce losses in transplanting, management and mechanical harvesting through standardized ridge types. The practices of enterprises and demonstration sites also give similar signals: technologies like mulching and drip irrigation, which simplify the process, can often increase the survival rate, save water and reduce labor, and simultaneously increase the commercial rate by a significant margin. Some demonstration sites achieve an average yield of 3,000-4,000 yuan per mu, with a commercial rate increase of over 10%. That is to say, economic evaluation should not only focus on yield but also take into account the commercial rate and cost structure.

Research on mechanized transplanting in the Huaihai region also shows that mulching and ridge formation not only increase soil temperature and LAI but also lead to simultaneous improvements in yield and income, forming a continuous chain of “planting quality - growth - yield - income” (Liu et al., 2018). Specifically regarding the ridge height, a more reliable approach is to set 2-3 gradients of 25, 30, and 35 cm in the target ecological area. The plots are compared for commercial potato rate, cracked potato rate, machine harvest damage rate, as well as labor and irrigation costs. Finally, the preferred solution is determined by “commercial potato output minus costs” (Li et al., 2019).

6 Case Study: Analysis of the Effects of Different Furrow Heights on Sweet Potato Cultivation in Typical Ecological Zones

6.1 Overview of natural conditions, soil types and cultivation patterns of the case area

This article selects the southeastern paddy soil area as the discussion case, specifically taking the Ya Jin Village in Dali Town, Xinnuo District, Fujian Province as an example. Public data indicates that this experimental field is of medium fertility loam soil, with good drainage and irrigation conditions, and it was previously planted with rice. It is a typical area for re-cropping sweet potatoes after rice. The limiting conditions in this ecological zone are relatively concentrated: heat and water often occur simultaneously. The soil in the paddy field becomes more cohesive during certain periods of moisture, and whether the ridge structure can quickly regain oxygen after rain directly affects the smooth initiation of the tuber (Villordon et al., 2019).

Therefore, when discussing ridge height here, one cannot simply copy the experience from dryland areas, but needs to consider drainage, ventilation and mechanical harvesting on the same weight scale (Figure 1) (Colombi et al., 2018). At the same time, this area has both fresh food and processing uses, and both yield and uniform potato shape with reduced harvesting damage are required, which also determines that ridge height is not only a parameter for regulating the growth environment, but also a structural parameter for serving mechanized operations.

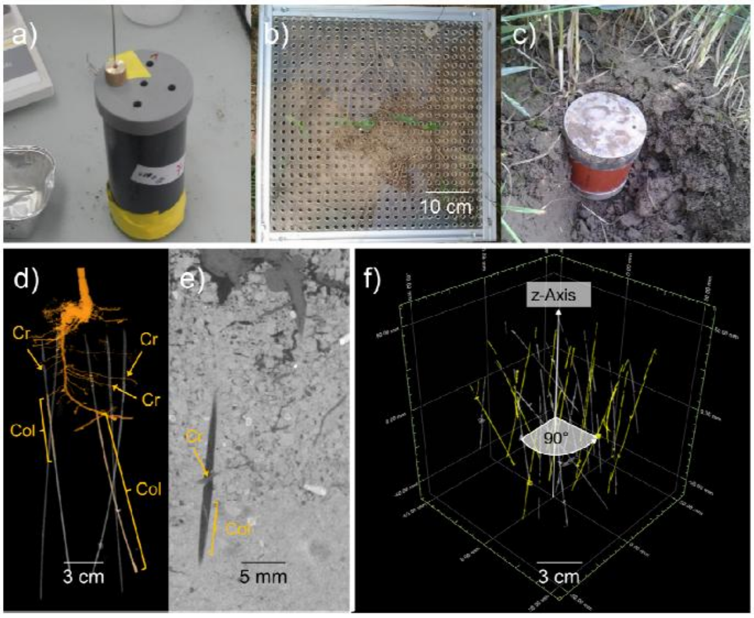

Figure 1 Perforation of compacted soil with steel wire along a 2 by 2 cm grid in a) soil columns and b) in the field. c) Root sampling in the field in 0-10 cm depth. d) Crossing (Cr) and colonisation (Col) of artificial macropores by soybean roots grown in soil columns. e) Vertical cross-sections of reconstructed computed tomography scans of crossing and colonising soybean roots grown in soil columns. f) Artificial macropores of a field sample at their actual position (grey) and after rotation around the central z-axis (yellow) (Adopted from Colombi et al., 2018)

6.2 Yield and quality performance of sweet potato under different furrow heights

This case adopted a two-factor split-plot design, combining furrow spacing and furrow height to examine their effects on the yield of “Longzhu 14” and the performance of small harvesters. The main objective was to identify the furrow type that is more suitable for mechanization. Although the full treatment values were not provided in the public abstract, the trend of the results was quite clear: as the furrow height increased, the number of tubers per plant and the proportion of medium-large tubers increased, while the weight per tuber and total yield showed an initial increase followed by a decrease (Li et al., 2019); when the furrow spacing was appropriately reduced, it was overall beneficial for the improvement of yield-related indicators.

Such “turning-point” changes are actually not unexpected - when the furrow height increases from low to medium, the improvement in drainage and aeration leads to increased yield; further raising the furrow height, if the water supply cannot keep up or the soil becomes too loose causing fluctuations in moisture conditions, the advantage is weakened and even a reduction in yield may occur. One methodological reminder given by this case is: the furrow height experiment should at least have three gradient levels and soil moisture should be monitored simultaneously; otherwise, it is easy to draw simple conclusions such as “higher furrows are definitely better” or “lower furrows are more reliable” (Villordon et al., 2019).

6.3 Insights from the case study on production practices and recommendations for appropriate furrow height

In this experiment, the combination of a 80 cm furrow spacing and a 30 cm furrow height performed the most outstandingly: the yield reached 42.91 t/hm², the number of tubers per plant and the proportion of medium-large tubers were at relatively high levels, the clear tuber rate also reached 96.40%, which was more conducive to the operation of small harvesters. These results at least indicate two points: Firstly, under the condition of post-rice soil, a medium furrow height of about 30 cm can achieve a relative balance between drainage, ventilation and moisture retention and supply, thereby supporting a higher yield (Li et al., 2019); Secondly, the furrow height not only affects growth but also directly influences the emergence rate and damage risk by changing the depth of tuber distribution and the amount of tillage. The study also mentioned that as the furrow height increases, the proportion of medium-large tubers rises, suggesting a more concentrated commercial specification. If combined with research on root zone aeration, when the furrow body re-oxygenates quickly and the CO_2 level is low, photosynthetic output is more stable, the tubers expand more uniformly, and it is easier to form a shape suitable for commercialization (Bhattarai et al., 2017).

7 Our Farm's Practices

Based on the aforementioned literature, our farm implemented large-scale high-ridge sweet potato cultivation technology demonstration in 2015. The fresh tuber yield increased by 30% compared to low-ridge cultivation, with a 10% improvement in tuber marketability, resulting in significantly enhanced economic benefits (Figure 2).

Figure 2 High ridge trials of sweet potatoes at Fanshu Xiaopu Family Farm, Qujiang District, Quzhou City (Left: High-Ridge Cultivation; Right: Commercial Tubers) (Photographed by Shifeng Yang)

8 Discussion

8.1 The physiological and ecological mechanism of sweet potato tuber enlargement influenced by different ridge heights

When looking at the effects of different ridge heights together, it is clear that the role of ridge height is not linear. Higher ridges often show their effects first in terms of ventilation: faster drainage, faster re-oxygenation after rain, lower CO_2 levels in the root zone, more stable photosynthesis in leaves, and easier transport of assimilates to the tubers (Bhattarai et al., 2017); but things are not always positive. If the ridge height is too high, the risk of water loss increases, drought stress occurs, and the enlargement rate decreases, the probability of cracking tubers increases (Li et al., 2019). There is also a frequently overlooked path that comes from mechanization. The more uniform the ridge height and ridge shape, the more stable the machine harvesting and soil removal are, and the lower the loss and damage. Physiologically, improved ventilation can enhance aerobic respiration and ATP supply, promote the distribution of ^14C/^13C assimilates to the tubers, which is the key reason for “optimal ridge height being better”. Molecular research also suggests that tuber development has its own internal program, and ridge height provides a more suitable external environment for this process.

8.2 Comparative analysis of the research results with existing study conclusions

When foreign researchers set the ridge height at 30, 40, or 50 cm for comparison, they often observed similar trends: a medium ridge height is more conducive to root yield, while further increasing the ridge height may lead to an increase in root length while the root diameter becomes thinner, indicating that the ridge structure is quietly changing the scale of the tuber shape (Villordon et al., 2019). The domestic approach places more emphasis on “determining the height based on the soil type”. Northern production opinions distinguish between clay and sandy loam soils, providing recommendations of 30-35 cm and 25-30 cm respectively; Hunan regulations propose a range of 20-40 cm for different ridge types; the mechanized full-process regulations emphasize that the ridge height should be no less than 25 cm and remain consistent. These interval-based expressions are not contradictory to the results of field experiments showing “an initial increase followed by a decrease” - although ridge height does bring benefits, it is not infinitely increaseable, and the marginal effect will decrease or even turn into a negative effect (Li et al., 2019). What needs to be noted is that currently, there are not many studies that directly set the ridge height gradient based on the “commercial tuber rate” as the core indicator; more often, they split it into indicators such as the proportion of large and medium-sized tubers, abnormal rate, cracking rate, or mechanical harvesting damage. In the future, if a unified classification standard can be established and multiple points of verification can be conducted, the relationship between ridge height and commercial rate will be clearer and more easily quantitatively expressed.

8.3 Discussion on the adaptability of ridge height to variety types and ecological conditions

The ridge height is not a universal figure; it is often closely tied to the characteristics of the variety. For varieties with shallow tuber formation and a rounder tuber shape, a shallower soil layer with loose and uniform texture is more necessary; for varieties with deeper tuber formation and a longer tuber shape, a thicker loosened soil layer may be required to avoid spatial limitations during tuber expansion (Villordon et al., 2019). The mechanized operation procedures also emphasize that varieties with a concentrated tuber formation range and strong skin resistance should be selected for mechanized harvesting, which actually reminds us that the ridge height should be considered together with the “tuber depth - skin strength” of the variety. Climate conditions are also important. In rainy areas, a higher ridge height and well-maintained drainage ditches provide a larger safety margin; in arid areas, if the ridge height is blindly raised, the risk of water loss increases, and in this case, covering with plastic film or drip irrigation is more crucial than continuing to raise the ridge height (Li et al., 2019). Research on root zone gases provides more specific judgment criteria - if the field often has stagnant roots after rain and CO_2 accumulation, improving ventilation and ridge height should be prioritized (Bhattarai et al., 2017); if the main problem is water shortage during the tuber expansion period, maintaining moisture conditions at an appropriate ridge height is necessary. In the end, the ridge height should serve the main contradiction in the region rather than being regarded as a uniform answer.

9 Conclusions and Production Application Suggestions

When considering the public literature and various regulations together, several points become quite clear. Firstly, the change in ridge height is not just an alteration in appearance; it will also affect the aeration, moisture, and soil temperature conditions in the rhizosphere. Whether the tubers can start smoothly and whether the subsequent expansion is efficient largely depend on these conditions. From a physiological perspective, this is closely related to ATP supply and the transport of assimilates to the tubers. Secondly, the response of yield and commercial quality to ridge height is not always a linear increase; there is a certain range: if the ridge is too low, it is prone to oxygen deficiency and compaction; if it is too high, it may lead to increased moisture loss, and both extremes may bring risks of deformity or cracked tubers. An appropriate ridge height is more conducive to increasing the number of tubers formed and the proportion of medium and large-sized tubers. Thirdly, in the context of mechanization, ridge height also relates to the emergence effect and damage probability. Whether the ridge shape is consistent is as important as the specific height. Typical cases in rice-after-soil areas show that a medium ridge height of about 30 cm, combined with a reasonable ridge spacing, can not only achieve a higher yield but also be more conducive to machine harvesting, indicating that this height has good adaptability in various situations.

Without aiming for an "absolutely optimal value", by integrating national and local technical opinions as well as mechanization procedures, a relatively reliable range can be determined: In most areas, the ridge height should be set between 25 and 35 cm for better operational feasibility. The specific height also depends on soil and rainfall conditions - in clayey or waterlogged fields, it can be closer to 30-35 cm; for sandy soil or areas with less water, 25-30 cm is more appropriate to avoid rapid water loss. Mechanized production also has minimum requirements, such as a ridge height of no less than 25 cm and a high level of consistency in ridge shape (such as over 95%). The purpose is to ensure smooth machine passage and stable harvesting process. In regions with abundant rainfall or using large ridge double-row farming, the ridge height can be chosen within the range of 33-40 cm, along with side ditches and peripheral ditches. However, it is also necessary to consider moisture conservation measures during droughts to avoid the situation where "the ridge is raised but the yield is reduced due to water loss". Overall, the ridge height is more like an interface connecting environmental control and mechanical operations. Instead of providing a single value, it is better to manage it flexibly using an interval-based approach.

Looking back, there are still several directions for further exploration in related research. First, truly place the rate of marketable potatoes at the core position, uniformly set the grading standards, incorporate weight, appearance defects and mechanical damage into the evaluation, and conduct multi-year and multi-gradient ridge height experiments in different regions to fill the gap of "the insufficient quantification of the relationship between ridge height and marketability rate". Second, introduce root zone gas and water monitoring, not just focusing on the results, but monitoring the process as well, such as the peak CO_2 level after rain, the speed of re-oxygenation of the ridge body, and then analyze these indicators in combination with the occurrence of abnormal and cracked potatoes. The existing forced aeration studies have actually provided a set of reference measurement and interpretation ideas. Third, ridge height should not be studied alone, but should be optimized together with factors such as mulching, drip irrigation, water and fertilizer integration, and planting density. Multiple studies have shown that raised beds with mulching can increase temperature and yield, and drip irrigation can also improve the marketability rate and income. Single-factor experiments without integrated management often cannot be directly applied to production. For the production end, a more feasible approach is to verify different ridge heights through small plots, then use the marketability rate and net income as the basis for decision-making, and finally form a standard ridge type that can be promoted.

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Conflict of Interest Disclosure

The author affirms that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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