

Feature Review

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Effects of Continuous Rainy Weather on Pea Pod Set Rate and Preventive Measures

Xingde Wang, Tianxia Guo ✉

Institute of Life Sciences, Jiyang College, Zhejiang A&F University, Zhuji, 311800, Zhejiang, China

✉ Corresponding email: tianxia.guo@jicau.org

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Abstract Pea is one of the important legume crops in my country, but its pod setting rate is easily affected by environmental conditions. In recent years, continuous rainy weather has occurred frequently in some planting areas, resulting in insufficient light, soil moisture and high incidence of diseases, which have led to the obstruction of pea flowering and pod setting and a decrease in yield. This study focuses on the physiological mechanism of pea pod setting, systematically analyzes the specific effects of continuous rainy weather on the pea pod setting rate, including photosynthetic restriction, root inhibition and pollination and fertilization barriers, compares the response differences of different pea varieties to continuous rain, explores the characteristics of highly sensitive and shade-tolerant varieties and their pod setting rate under rainy conditions, and proposes targeted prevention and control strategies and field management measures on this basis. Through case analysis in Yunnan, Gansu, Guizhou and other places, local experience is summarized and the effectiveness of the above measures is verified. This study provides a scientific basis for coping with the decline in pea pod setting rate under abnormal climatic conditions, and hopes to enhance the risk resistance of pea production.

Keywords Pea; Pod setting rate; Prolonged rain; Variety resistance; Prevention and control measures

1 Introduction

Pea (*Pisum sativum* L.) is a leguminous crop with a long history of cultivation in my country, and it occupies an important position in the edible bean industry. According to statistics, my country's edible bean crops are mainly broad beans, peas and mung beans, and the total planting area of the three accounts for more than 90% of the total edible bean area. In recent years, with the promotion of new varieties and new technologies, the yield and total output of edible beans such as peas have increased significantly. In particular, in the past decade, broad beans and peas have gradually shifted from harvesting dry grains to harvesting fresh pods for marketing, which has promoted the development of my country's bean industry (Chen et al., 2021). Peas are not only eaten as fresh vegetables, but also as food and feed. They are an important source of protein for adjusting grain and oil supply and developing animal husbandry. my country's main pea producing areas are distributed in the southwest and northwest, such as Yunnan and Gansu provinces, where the planting area is large. However, the yield of peas is subject to factors such as the number of pods (i.e., pod setting rate) and the number of grains per pod. Among them, improving the pod setting rate is the key to achieving increased production (Yang et al., 2022). In recent years, in actual production, the low pod setting rate of peas in some areas has become a problem that restricts the increase of yield, which has attracted the attention of researchers and growers.

Continuous rain refers to a rainy and low-sun weather process that lasts for many days, generally accompanied by a significant lack of sunshine, long-term high air humidity, and sometimes low temperature. In the middle and lower reaches of the Yangtze River in my country, the "plum rain" in early summer every year is a typical continuous rain phenomenon. Its cause is that the warm and humid air currents in the south and the cold air in the north interact for a long time, forming a stable frontal precipitation belt (Wu et al., 2021). In addition to the plum rain period, continuous rainy weather processes often occur in southwest my country and South China in early spring and autumn. Studies have shown that abnormal atmospheric circulation is an important cause of continuous rain. When the large-scale circulation adjusts slowly and the cold and warm air currents maintain a confrontation

for a long time, local continuous rain is prone to occur (Lee et al., 2023). In recent years, extreme precipitation events have increased under the background of climate change, and the frequency and duration of continuous rainy weather in some areas have shown an upward trend. For example, the Sichuan Basin and Jiangnan region have experienced continuous rain for more than ten days, which has had a serious impact on agricultural production. Continuous rain usually leads to reduced light, near-saturated relative humidity, and may cause low temperature and low light. The combination of these meteorological conditions is extremely unfavorable for crop growth (Bai et al., 2025).

This study will explain the main physiological mechanisms of pea pod setting, including key physiological processes, endogenous hormone regulation and environmental factors, analyze the specific manifestations and causes of reduced pea pod setting rate under continuous rain conditions, and compare the response differences of different pea varieties under continuous rain from three aspects: insufficient light, excessive soil moisture, and increased pathogens. The characteristics and practical application value of highly sensitive and shade-tolerant varieties are clarified, and the indirect agronomic effects of continuous rain, such as outbreaks of pests and diseases, disordered fertilization management rhythm, and poor field ventilation, are discussed. Through typical cases in Qiubei, Yunnan, Dingxi, Gansu, and the central mountainous areas of Guizhou, the practical experience of coping with continuous rain disasters is introduced and analyzed. By revealing the physiological and ecological mechanism of changes in pea pod setting rate under continuous rainy conditions, this study hopes to improve the stable yield capacity of pea and other grain and bean crops, and ensure my country's food security and sustainable agricultural development.

2 Physiological Mechanisms of Pea Pod Setting

2.1 Key physiological processes during pod set stage

The pod setting stage of pea refers to the process in which the ovary develops into pods after the flower organs are fertilized, including continuous links such as flowering, pollination, fertilization, and the development of young pods and seeds. First, pea is a closed-pollinated crop, and its flowers can complete self-pollination before opening; successful pollination and fertilization are necessary conditions for starting pod development. After fertilization occurs, the division and elongation of ovary cells are activated, and the ovary begins to expand rapidly to form young pods, at which time the ovules also develop into seeds. Studies have shown that in most angiosperms, if the ovules are not fertilized, the ovary usually does not develop further, and the plant will actively terminate the organ growth of the flower to avoid wasting resources. The same is true for peas. Unfertilized pea flowers are prone to fall off or stop developing, so the pod setting rate depends largely on the success rate of pollination and fertilization. Secondly, during the young pod formation stage, there is a close exchange of substances and signals between the pods and the seeds inside (Figure 1) (Bal and Østergaard, 2022). Developing seeds can generate growth signals to promote pod development, and pods provide nutrients for seeds and regulate their growth. The two work together to ensure the normal formation of pea fruits. If environmental stress causes any of these links to be blocked, such as pollination and fertilization failure or lack of nutrient support for young pods, it may cause pod development to stagnate or young pods to fall off, thereby reducing the pod setting rate. It can be seen that the pea pod setting stage is a process that is very sensitive to the internal and external environment. It requires not only the coordinated supply of internal hormones and substances, but also relies on suitable external conditions to ensure the smooth progress of pollination, fertilization and young pod development.

2.2 Influence of hormonal regulation on pod formation

Plant hormones play an important regulatory role in the pea pod setting process. Studies have shown that hormones such as auxin (IAA) and gibberellin (GA) accumulate rapidly after pollination and fertilization, which helps ovary expansion and pod growth (Miryeganeh, 2022). Especially in pea and other Fabaceae crops, seeds will produce a large number of auxin signals after fertilization, including a special chlorinated auxin (4-Cl-IAA), which is abundant in pea fruit and seed tissues and is believed to be related to the promotion of pod elongation. Auxin releases the inhibition of growth-related genes through signaling pathways, thereby triggering cell division and elongation, and plays a key role in pod formation (Bal and Østergaard, 2022). In addition to auxin,

gibberellins are also indispensable in pea podding. As early as the pollination stage, exogenous spraying of appropriate amounts of GA can induce unfertilized pea ovaries to develop into seedless pods, reflecting the promoting effect of GA on fruit growth. Under normal pollination conditions, ovule development is also accompanied by the activation of the GA synthesis pathway, so that pods and seeds develop synchronously. In addition, cytokinins contribute to the cell division of the embryo and endosperm, and abscisic acid (ABA) accumulates during the seed maturation stage to promote embryo maturation. The temporal and spatial interactions of these hormones jointly determine the final pod and seed setting (Miryeganeh, 2022). It is worth noting that ethylene is often regarded as an "aging hormone", and its excessive content will promote the shedding of flowers and young pods. Under adverse conditions, the ethylene level in plants may increase, which will have a negative impact on pod setting. Therefore, the formation of pea pods is the result of the balance of multiple hormones: growth hormones (such as IAA, GA, cytokinin, brassinolide, etc.) provide positive signals to maintain pod and seed development; while inhibitory hormones (such as ABA, ethylene) may cause pod failure if they appear too early or in excess. By regulating the balance of hormones, the pod setting rate of peas can be affected to a certain extent. For example, field experiments have found that timely spraying of growth regulators (such as gibberellins or brassinosteroids) can reduce the shedding of flowers and pods and increase the number of pods. Overall, endogenous hormone levels and sensitivity are important internal factors that determine the success or failure of pea pod setting.

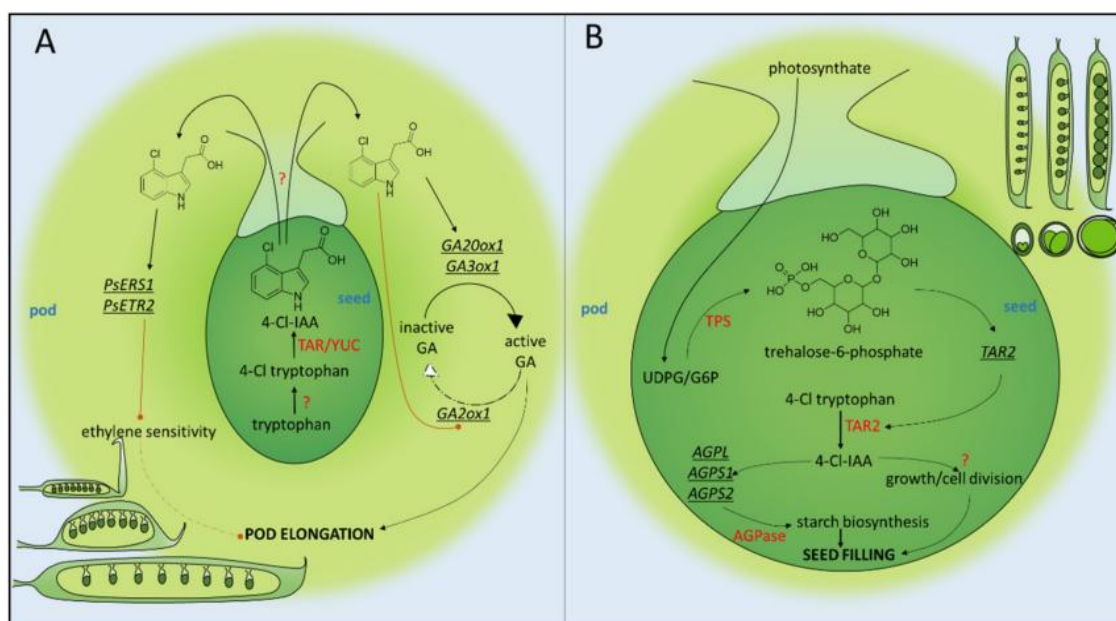


Figure 1 Schematic representation of pod elongation (A) and seed filling (B) stages of pea reproductive development. 4-Cl-IAA, 4-chloroindole-3-acetic acid; TAR, tryptophan aminotransferase related; YUC, yucca; GA, gibberellic acid; GAox, gibberellic acid oxidase; ERS1, ethylene response sensor 1; ETR1, ethylene receptor 1; UDPG, uridine diphosphate glucose; G6P, glucose-6-phosphate; TPS, trehalose phosphate synthase; AGPase, adenosine diphosphate glucose pyrophosphorylase (Adopted from Bal and Østergaard, 2022)

2.3 Integrated effects of environmental factors

The pod setting process of peas is affected by a variety of external environmental factors at the same time, among which light, temperature, moisture and other conditions are particularly critical (Naveed et al., 2024). First, sufficient light ensures the accumulation of photosynthetic products and provides energy and nutrition for pod and seed development. If the flowering and podding period encounters continuous cloudy days, the light intensity and duration will be significantly reduced, which will lead to a decrease in the photosynthetic rate of the plant, and the synthesized organic matter will be insufficient to support the growth of new pods and grains, thereby increasing the risk of young pods falling off (Zhao et al., 2019). The photoperiod will also affect the flowering and podding rhythm of peas. Peas are long-day plants. Under conditions of shortened daylight, flowering may be delayed and

the podding process may be disturbed. Secondly, temperature affects pollen vitality and fertilization. The suitable flowering temperature for peas is generally in the range of 15 °C~25 °C. If continuous rain is accompanied by low temperatures, the activity of flower organs will decrease, which is not conducive to normal pollination and fertilization. Thirdly, soil moisture conditions also play an important role in root function and pod development. When the soil is too wet, the root respiration is restricted and the absorption capacity is reduced, and the plant may experience physiological hypoxia and nutrient absorption disorders. Excessive water can also easily cause root rot and other diseases, weakening the plant's ability to supply pods and leading to a decrease in the pod setting rate. Continuous rain is usually accompanied by air humidity close to saturation, which is conducive to the germination of pathogen spores and infection of floral organs. In particular, moisture-loving diseases such as gray mold are easy to spread during the flowering period, directly infecting flowers and causing rot, which seriously hinders fertilization and pod formation. Therefore, external environmental factors often affect pea pod setting in combination: rainy and low light not only reduce photosynthetic products but also breed diseases, and the dual effects of low temperature and high humidity make the pea reproductive process face multiple stresses. In actual research and production, it is necessary to comprehensively consider these environmental factors and improve the pod setting rate of peas in adverse weather by improving cultivation conditions (such as supplementary light, moisture drainage, etc.).

3 Effects of Continuous Rain on Pod Set Rate

3.1 Light deficiency and limitations on photosynthetic capacity

The first direct impact of continuous rainy weather is severe lack of light. Continuous cloudy days and cloud cover cause a sharp decrease in solar radiation, and the photosynthesis level of pea plants is significantly reduced. The assimilates produced by photosynthesis are the material basis for the growth of pods and seeds. When the supply of photosynthetic products is insufficient, the plant will give priority to its own nutritional growth, and the allocation to reproductive organs will be relatively reduced (Naveed et al., 2024). Experiments have shown that under weak light conditions, plants often change the proportion of photosynthetic product distribution, with more allocated to nutritional organs such as stems and leaves, while the proportion allocated to fruits is reduced, which will directly lead to a decrease in pod setting rate and a decrease in the number of grains per pod. Specifically for peas, the number of sunshine hours during continuous rainy periods is relatively small. If it coincides with the flowering period of peas, the nutrients produced by the plant will not be able to meet the development needs of all young pods. Many surveys have recorded the phenomenon of a large number of pea flowers and pods falling due to rainy weather. Insufficient light can also cause morphological changes in pea plants, such as elongated stems and leaves, thinning leaves, and increased plant height, which indirectly affects pod setting. For example, under low light, the internodes of pea plants elongate and become tall and thin, and they are prone to lodging and shading. The lower part of the plant lacks light, forming a vicious cycle (Zhao et al., 2019). Due to limited light, the lower flower position often blooms but cannot pod, or the small pods that are produced quickly turn yellow and fall off. These factors work together to significantly reduce the pod setting rate of peas under continuous rainy and low-light conditions. Studies have pointed out that under shading stress, the flowering and fruiting of different crops are generally affected. For example, reduced light will delay the flowering of peas by about 9% to 15%, delay the pod setting time, and reduce the number of effective pods. Therefore, insufficient light caused by continuous rain is one of the primary reasons for the decline in the pod setting rate of peas. To address this problem, measures such as supplementary light and reasonable dense planting need to be taken to minimize the limitation of weak light on pea photosynthesis.

3.2 Excessive soil moisture and suppression of root function

Long-term precipitation during continuous rainy periods can lead to excessive soil moisture in the field, and even waterlogging, which seriously affects the normal function of the pea root system. Peas are taproot crops, and their roots are very sensitive to soil aeration. When the soil is close to saturation, the oxygen content in the pores decreases, the root respiration is restricted, and the root absorption of water and mineral nutrients is inhibited (Zaman et al., 2025). Especially in the flowering and pod-setting stage, peas require more water and fertilizer. If the root vitality decreases due to waterlogging stress, the aboveground part of the plant is prone to nutrient

deficiency symptoms and growth stagnation, and cannot provide sufficient nutrition for the pods, resulting in poor development or shedding of young pods. Long-term excessive moisture in the soil can also induce pea root diseases, such as root rot and wilt, which infect the root system and weaken the plant's absorption function, exacerbating physiological drought and nutritional disorders.

The study compared waterlogging-tolerant and waterlogging-intolerant soybean varieties. Under flooding conditions, the root biomass and number of beneficial rhizosphere bacteria of waterlogging-tolerant varieties were significantly higher than those of sensitive varieties, which enabled the former to maintain good nutrient absorption in waterlogging (Schillaci et al., 2023). Similarly, different pea genotypes also have differences in root adaptability under waterlogging stress. Some moisture-tolerant varieties can form more aeration tissue to alleviate the problem of insufficient oxygen. But in general, peas are relatively intolerant to waterlogging, and continuous 14 days of flooding can cause peas to almost fail. The excessive moisture in the soil caused by continuous rain has a huge impact on the pea pod setting rate: impaired root function means that the water and nutrient supply required for the flower pods cannot be guaranteed, and the result is that a large number of flower pods will wither and fall off, and the pod setting rate will drop sharply. In terms of management, measures such as digging ditches to drain waterlogging and adding organic matter to improve soil permeability should be taken to minimize the inhibitory effect of field waterlogging on the pea root system.

3.3 Increased pathogens causing pollination and fertilization issues

High humidity environment provides a breeding ground for the growth and spread of a variety of pathogenic microorganisms. In continuous rainy weather, the pea population is closed and humid, and diseases such as gray mold, sclerotinia, and rust are prone to outbreaks, which directly infect the floral organs and young pods of peas, thereby interfering with the pollination and fertilization process. Gray mold (infection by gray mold) is particularly common under continuous rainy conditions. Gray mold can infect the stems, leaves, flowers, and pods of peas. Its spores are most likely to germinate at a relative humidity of more than 95%. Once they invade the flowers, they will cause petals to rot, and then destroy the pistil and ovule tissues, making it impossible for the flower to complete normal fertilization. Field observations show that a gray mold layer is often seen on pea flowers after continuous rainy days. This is a sign of massive reproduction of gray mold. The affected flowers then wither and fall off, and the pod setting rate is significantly reduced (Long et al., 2022). Sclerotinia disease (such as pea sclerotinia disease) is also prone to spread in humid environments. The ascospores of its pathogen can attach to flowers, causing floral rot and producing white sclerotia. In years with continuous rain, sclerotinia disease often occurs on a large scale, causing peas to "flower without fruit".

Rust, downy mildew, etc. also spread rapidly under high humidity conditions, and severe infection can terminate the reproductive growth of plants prematurely. Continuous rain can also indirectly affect the activities of insect pollinators (although peas are mainly self-pollinated, some insects help to increase the pod setting rate). The attendance rate of pollinating insects on rainy days is reduced, which may cause a decrease in pollination efficiency. However, in comparison, the disease poses a greater threat to pea pod setting, because peas are mainly self-pollinated by closed pollination, and the impact of insect vectors is limited, while the damage of pathogens to the flower is devastating. A monitoring of rapeseed in Hunan showed that continuous rain and low light led to a large outbreak of sclerotinia disease during the flowering period of rapeseed, and the number of pods decreased by more than 30% in severe cases. It can be inferred that flowering diseases caused by continuous rain on peas will also cause significant yield reduction. Therefore, during continuous rainy weather, we must be particularly vigilant against diseases such as gray mold and sclerotium, and take preventive measures on pea flower pods, such as spraying protective fungicides and promptly removing diseased and residual parts, to reduce the interference of pathogens on pollination and fertilization.

4 Varietal Differences in Response to Continuous Rain

4.1 Characteristics of sensitive vs. tolerant cultivars

There are obvious differences in the tolerance of pea varieties to environmental stress. Some varieties have a sharp

drop in pod setting rate under continuous rain conditions, showing high sensitivity; while other varieties are relatively tolerant to low light and high humidity environments, and are called shade-tolerant or humidity-tolerant varieties (Zaman et al., 2025). Highly sensitive varieties often have the characteristics of fast growth and lush plant shape. They have high yields under normal conditions, but are prone to leggy growth and lodging, and serious flower drop when encountering insufficient light. For example, some high-yield pea varieties require sufficient sunlight for normal pollination and pod formation. Once they experience continuous rain, their pod setting rate drops significantly. Shade-tolerant varieties usually have relatively short and strong plants, thick and hard stems, thin leaves, and strong ability to utilize weak light. These varieties can still maintain relatively stable photosynthesis under low light, are not prone to leggy growth and lodging, and are less affected by pod formation in continuous rain. The experiment compared the performance of multiple pea varieties under low light treatment and found that the chlorophyll content of shade-tolerant varieties was less sensitive to changes in light intensity, and the photosynthetic efficiency decreased less, while the photosynthetic rate of sensitive varieties decreased significantly (Wu et al., 2020).

In addition, the flower organs of shade-tolerant peas are also more adaptable to high humidity. Some varieties have smaller corollas and shorter flowering periods, which can reduce the chance of pathogen infection. On the contrary, highly sensitive varieties often have large and long-lasting corollas, and are more susceptible to gray mold and other diseases when it rains during flowering (Su et al., 2023). In addition to tolerance to low light, highly disease-resistant varieties also have an advantage in continuous rain. Even in a humid environment, the flower pods of some pea varieties resistant to gray mold are not easily infected, and the pod setting rate can be maintained. Shade-tolerant and humidity-tolerant varieties usually have: compact plant type, strong resistance to lodging, higher leaf photosynthetic efficiency and the proportion allocated to reproductive growth, and resistance to major flowering diseases. These characteristics give them a relatively stable pod-setting ability in adverse conditions such as continuous rain. Current breeding work also pays more and more attention to the stress resistance of peas, and some new strains suitable for planting under rainy conditions have been selected, which provides a possibility for increasing yields in adverse climates.

4.2 Correlation between varieties' pod set rate and rainy periods

Through field trials and multi-point monitoring, the differences in pod setting rate changes of different pea varieties under continuous rainy weather can be quantified. A study compared the pod setting performance of multiple pea varieties under continuous rainy conditions, and the results showed that there were extremely significant differences in the decline in pod setting rate among varieties: the pod setting rate of sensitive varieties decreased by more than 50% compared with normal weather, while the pod setting rate of shade-tolerant varieties only decreased by about 20% (Zaman et al., 2025). This shows that variety characteristics are highly correlated with the degree of damage caused by continuous rain. A study on waterlogging tolerance of leguminous crops also supports this point: after 14 days of flooding, the yield difference between the two pea varieties was more than twice, and the ability of the waterlogged variety to recover growth was significantly stronger than that of the sensitive variety. Although this study is aimed at waterlogging stress, the excessive soil moisture caused by continuous rain is similar to mild waterlogging, and its variety difference trend is of reference significance. Similarly, in terms of light stress, flowering and podding of different pea genotypes respond differently to reduced sunlight. It has been reported that under shading treatment, the flowering period of some pea varieties was delayed by 7 days and the pod setting rate was reduced by 30%, while the flowering period of another shade-tolerant variety was only delayed by 2 days and the pod setting rate was almost unaffected (Naveed et al., 2024).

Through correlation analysis, it was found that the high-yield potential of varieties under normal conditions is not completely positively correlated with their relative yield under rainy conditions. Some high-yield varieties have obvious advantages in good weather, but they suffer serious yield reductions when encountering continuous rain; on the contrary, some stable varieties with medium yields usually perform relatively well in rainy weather. Therefore, for rainy and low-light climates, varieties with good stability should be selected. The interannual fluctuations in the pod setting rate of pea varieties are significantly correlated with the number of rainy days in the year: in years with many rainy days, the pod setting rate of sensitive varieties decreases significantly, while the

fluctuation of shade-tolerant varieties is small. This further proves that variety resistance is one of the decisive factors affecting the magnitude of losses caused by continuous rain disasters. In the future, we should strengthen the evaluation of the resistance of pea varieties to rain, establish a variety resistance database, and provide a scientific basis for variety layout in different regions and climatic conditions.

4.3 Application value of selecting resistant varieties

Selecting excellent pea varieties suitable for local climatic conditions is one of the most economical and effective measures to deal with the damage of continuous rain. Promoting shade-tolerant and moisture-tolerant varieties in areas with frequent continuous rain can significantly reduce the risk of yield reduction due to weather reasons. Under rain stress, the yield of pea varieties is closely related to their antioxidant enzyme activity, chlorophyll content and root ventilation capacity. Shade-resistant and moisture-tolerant varieties often have stronger antioxidant systems (such as higher POD and SOD activities), which can slow down the damage of photosynthetic organs, and the roots are more adaptable to low-oxygen environments, thereby maintaining normal water and nutrient absorption functions (Yang et al., 2022a).

In the plum rain area in the middle and lower reaches of the Yangtze River, by introducing early-maturing and waterlogging-resistant pea varieties, we can avoid the peak of the plum rain season to complete pod formation and maturity, and reduce the impact of continuous rain. While selecting varieties for stress resistance, we must also take into account market demand and quality. For example, some shade-tolerant varieties are for feeding or processing, and the fresh taste is poor. Therefore, in actual promotion, it is necessary to balance resistance and commerciality. Overall, the screening and application of excellent varieties that are resistant to continuous rain have many values: for farmers, it can reduce losses due to disasters and ensure stable income; for agricultural production as a whole, it can improve the resilience of the system and ensure that grain and bean crops still have a certain level of production under abnormal climatic conditions, which is conducive to food security. At present, scientific research units in various places are strengthening research in this area. For example, the northwest rain-fed areas such as Dingxi, Gansu are evaluating the stress resistance performance of a batch of new pea lines to provide a basis for variety replacement in rainy years; humid areas such as Guizhou are also exploring the introduction of highly disease-resistant varieties for rainy season cultivation. The Yunnan Academy of Agricultural Sciences also screened shade-tolerant and moisture-tolerant pea germplasm through resource gardens to lay the foundation for stress-resistant breeding. It can be expected that with the successful breeding and promotion of more shade-tolerant and moisture-tolerant pea varieties, my country's pea production's adaptability to adverse climates such as continuous rain will be further improved (Chen et al., 2021).

5 Indirect Agronomic Impacts of Continuous Rain

5.1 Facilitation of pest and disease outbreaks

Continuous rainy weather not only directly affects the pea pod setting rate, but also induces pest and disease problems by changing the ecological environment, which has an indirect impact on agricultural production. The most obvious of these is the large-scale occurrence of various diseases. High humidity conditions are prone to outbreaks of pea gray mold, sclerotinia and other flowering and pod diseases. In fact, continuous rain also contributes to the spread of other diseases and pests. Long-term humidity will reduce the disease resistance of plants, making it easier for latent pathogens to break through host defenses. Many fungal diseases (such as rust and downy mildew) do not show symptoms immediately in the early stages of bacterial infection, but will quickly expand into disasters in the high humidity environment caused by continuous rain. For example, the pea rust pathogen needs a water film on the leaf surface to germinate and invade. Continuous rain provides continuous leaf surface moisture conditions, allowing rust to spread in a timely and large area. After severe infection of the leaves, the photosynthetic capacity of the plant is weakened, indirectly affecting pod setting and filling. Looking at pests, continuous rain has different effects on different pests. Some moisture-loving pests reproduce more on rainy days, such as slugs, snails and other mollusks that eat pea seedlings and pods in a humid environment. However, most field pests are restricted in their activities during continuous rainfall. For example, aphids will be knocked down in the rain, and continuous rain sometimes has an inhibitory effect on aphids.

The secondary disasters caused by continuous rain are mainly diseases, followed by insect pests. In the pea-wheat rotation system, the delayed wheat sowing date caused by continuous rain may also increase the base number of pea rust sources in the next season, making the pea disease more severe. In terms of countermeasures, it is necessary to strengthen the prediction, early warning and timely prevention and control of diseases during continuous rain. The meteorological department cooperates with the plant protection department to organize pesticide application during the weather window before and after continuous rain, which can effectively control the spread of diseases. For example, the Hunan region has carried out rapeseed sclerotinia control in the intervals between rainy days, successfully controlling the disease to a light level. Similar measures should also be used in pea production. When there is a slight break in continuous rain, broad-spectrum fungicides should be sprayed in time to prevent further threats to pod formation. At the same time, after continuous rain, the diseased remains in the field should be cleaned up to destroy the places where pathogens survive summer and winter, so as to prevent the return of diseases and pests in the next season.

5.2 Disruption of fertilization and field management schedules

Agricultural production requires timely field management, but continuous rainy weather often disrupts the normal rhythm of farming. First, the sowing and harvesting periods are affected: if continuous rain occurs during the pea sowing period, the fields are muddy and seeds cannot be sown. Missing the appropriate sowing period will lead to slow growth and delayed maturity in the seedling stage, and ultimately reduce yields. In autumn, continuous rain may affect the harvest of the previous crop, thereby delaying the sowing of peas (Zhang et al., 2020). If peas are delayed in sowing and miss the best growing season, they are prone to adverse conditions such as high temperature and drought in the later period, resulting in reduced yields. Secondly, it is difficult to carry out management measures such as topdressing and pesticide application in time. Continuous rainfall causes water accumulation in the fields, and machinery and manpower cannot go to the fields to apply fertilizers; even if chemical fertilizers are spread, they are easily leached or volatilized by rain, which greatly reduces the fertilizer efficiency. Continuous rain will also affect the effect of foliar fertilization and plant protection. It is impossible to spray foliar fertilizers and pesticides when it rains all the time, and the window period for pest and disease control is missed. When remedial measures are taken after the rain, the crops may have suffered irreversible damage.

Continuous rain causes the soil to be too wet, and "farming during the rain" can easily cause soil compaction, and some agricultural operations can only be delayed. For example, in the early rice seedling raising in the south, if there is continuous rain and low temperature, the seedling raising will be delayed, and the quality of the seedlings will deteriorate; too long seedling age will affect the tillering of the field. For peas, too late planting or too late topdressing is not conducive to pod formation. The survey shows that the inadequate field management during the critical growth period of peas caused by rain is one of the important reasons for the reduction in production. For example, farmers in the mountainous areas of Guizhou reported that it rained for three consecutive weeks in the spring of a certain year, and weeding and soiling work in the pea fields could not be carried out at all. As a result, weeds grew, plants fell over, and the number of pods decreased by nearly 40%. Therefore, the interference of continuous rain on agricultural arrangements cannot be ignored. In terms of response strategies, some flexible measures can be adopted: for example, the application of slow-release fertilizers to reduce the impact of rain erosion; rush to apply base fertilizer before the rain, and apply topdressing in time after the rain; promote protective tillage to avoid soil compaction due to rain; use rain-resistant mechanical equipment (such as light plant protection drones) to operate under wetland conditions, etc. There should be a management idea of "taking advantage of every opportunity" to complete key agricultural work in the intervals between rainy days to minimize the losses caused by weather delays.

5.3 Poor field ventilation leading to crop crowding

During the continuous rainy period, due to insufficient sunshine and high air humidity, the microclimate in the pea field becomes stuffy and unventilated, which is prone to group closure. This closed environment will in turn aggravate the trend of declining pod setting rate. Specifically, when it rains continuously, the wind speed over the farmland is low and the humidity is high. The transpiration of the leaves in the pea canopy is suppressed, and the

water vapor around the plants cannot dissipate, forming a high-humidity microenvironment in the field. Peas are vine crops. In the late growth period, the vines are entangled with each other. If the planting density is too high and there is continuous rain, the ventilation and light transmittance of the lower part will be extremely poor. Group closure will bring multiple adverse effects: First, the leaves in the lower part of the closed canopy can hardly receive sunlight, and the photosynthesis is weak but still consumes nutrients, becoming a net "energy-consuming" part. Not only does it not contribute to the yield, but it also competes with the pods for limited nutrients. Secondly, pests and diseases are more likely to spread in a closed environment. For example, gray mold can quickly spread between the lower branches and leaves of the closed canopy, causing large spots and mold layers. The poor ventilation of the farmland also limits the penetration effect of pesticide spraying, making it difficult to prevent and control. Third, group closure makes the lower part of the plant prone to premature aging. Many lower pods have yellowed leaves before they mature, and they can no longer provide assimilates for grain filling, resulting in an increase in barren pods. For every 10% increase in plant density, the number of days with extremely high humidity increases by 2 to 3 days. This shows that the degree of canopy closure is proportional to the high humidity state in the field. Continuous rain is equivalent to artificially creating a "dense but not ventilated" condition, and even normal density planting will produce a similar canopy closure effect. Therefore, in the case of continuous rain, we should be more vigilant about the problem of group canopy closure. The solutions include: appropriately reducing the sowing density, especially the varieties that are prone to leggy growth should be sown reasonably sparsely to avoid excessive competition for light between plants; the vines of peas cultivated on trellises should be straightened out in time to guide them to be evenly distributed; clearing ditches and draining water in time after rain to reduce field humidity; and artificial pruning and topping can be carried out when necessary to improve ventilation and light transmittance. Foreign studies have suggested that the row closure time can be delayed by increasing the row spacing, so as to maintain good ventilation conditions for a longer period of time. Some domestic regions have also begun to adopt the "peak sowing" technology to make the peas grow unevenly to form a ladder structure that is conducive to ventilation. In disaster-resistant agriculture, these are experiences worth promoting, which can alleviate the adverse effects of group canopy closure caused by continuous rain on the pod setting rate of peas to a certain extent.

6 Preventive Strategies and Field Management

6.1 Proper plant spacing and resistance cultivar combinations

In view of the adverse effects of continuous rain on peas, agricultural production should first adopt strategies from variety selection and planting layout. Different varieties have significant differences in pod-setting performance under low light and high humidity conditions, so the reasonable matching of stress-resistant varieties is a basic measure for disaster prevention and mitigation. In areas with frequent continuous rain, pea varieties with strong shade and humidity tolerance and good disease resistance should be given priority. For example, in the rainy mountainous areas in the southwest, varieties with thick stems that are not easy to fall and resistant to gray mold can be selected; while in the rainy and flood-prone areas in the north, varieties with developed waterlogging-resistant root systems can be selected. Some bred stress-resistant pea varieties need to be demonstrated and promoted to let farmers recognize their value. In terms of variety matching, a combination of "main planting + auxiliary planting" can also be adopted. While planting the main varieties in large areas, a certain proportion of shade-tolerant varieties can be intercropped or surrounded. Once the continuous rain seriously affects the main varieties, the auxiliary shade-tolerant varieties can still partially set pods to achieve risk dispersion. In addition, staggered sowing dates are also part of variety matching. For example, early, medium and late maturing varieties can be selected for sowing in stages to avoid all peas being in the flowering period at the same time and collectively suffering from continuous rain. Reasonable close planting is also an important means to deal with continuous rain. Usually, for high yields, people tend to plant at a higher density, but in areas or seasons prone to continuous rain, appropriately reducing the density can reduce the degree of group closure (Gawłowska et al., 2022; Kumar et al., 2022). It is generally recommended to reduce the sowing amount by 10%~15% compared with the usual amount to ensure ventilation and light transmission between plants. Especially for peas, which are legumes, if the density is too large, they are very likely to entangle with each other and fall

over in rainy weather. It is better to plant them sparsely and increase the firmness of the support. Production practice has shown that in years with continuous rain, the incidence of peas in fields with moderately reduced density is significantly reduced, and the number of pods and yield are higher than those in overcrowded fields. It should be emphasized that the density should be considered in combination with the characteristics of the variety: the density of varieties with strong branching ability should be lower, while the density of varieties with less branches can be slightly higher. By optimizing the planting varieties and density layout, the adaptability of the pea population to the continuous rainy environment can be improved at the source, and the impact of disasters can be minimized.

6.2 Pre-rain regulation and drainage infrastructure

In the face of continuous rainy weather, taking farmland engineering and cultivation control measures in advance is the key to preventing and reducing damage. First of all, before the rain comes, the field drainage system should be ensured to be unobstructed. Digging ditches and arranging soil is an important part of pea planting. Especially when planting in the rainy season, it is necessary to "match the ditches". There should be vertical and horizontal ditches around and in the middle of the field so that the water in the field can be quickly drained within one or two days after the rain (Singh et al., 2021). Permanent drainage facilities can be built in places with conditions, such as underground drainage systems or small water pumps installed in low-lying areas of the field. Practice has shown that perfect field ditches can shorten the duration of waterlogging by at least 30%, thereby greatly reducing the root flooding time and increasing the survival and pod setting rate of peas in continuous rain. Secondly, in response to the meteorological forecast of continuous rain, appropriate control measures can be taken before the rain. For example, before the rainy season in the Yangtze River Basin, local agricultural technical departments will remind farmers to carry out inter-row tillage and soil loosening before the continuous rain begins to increase soil aeration and improve the plant's resistance to lodging (Rajpoot, 2021). For another example, spraying a protective fungicide once before the rain can form a drug film on the plant surface to prevent pathogen infection during the continuous rain, which is widely used in vegetable production. For peas grown in greenhouses, the greenhouse can be properly closed to keep warm when continuous rain comes, reducing the direct invasion of dampness and cold on crops. At the same time, the circulating fan in the greenhouse can be turned on to enhance air flow and prevent excessive humidity. In addition, continuous rain often has low temperatures, and cold prevention measures should be taken in advance, such as covering with non-woven fabrics and small arch sheds, to reduce low temperature damage. In addition to field and cultivation management, agricultural meteorological services should also keep up. The meteorological department should issue continuous rain warnings in a timely manner to allow farmers to harvest mature crops early and postpone sensitive agricultural operations. For example, for peas at the end of the grain filling stage, if long-term heavy rainfall is predicted, farmers can be advised to harvest some mature pods early to avoid mildew in the rain. For another example, in the northern region, if continuous rain in autumn may delay the sowing of winter wheat, government departments will issue guidance, requiring farmers to rush to plant in the intervals after the rain stops, and provide technical support such as increasing the application of seed fertilizer for late-sown wheat. Through the two-pronged approach of "engineering + management", taking corresponding measures before, during and after the continuous rain can effectively reduce the damage of excessive soil moisture and low temperature and high humidity to peas.

6.3 Use of plant growth regulators and nutrient compensation techniques

In addition to varieties and engineering measures, the application of modern agricultural technologies such as plant growth regulators and nutritional compensation methods can also help reduce the adverse effects of continuous rain on pea pod formation. Plant growth regulators include a variety of substances with similar effects to plant hormones, and proper use can regulate the growth and development process of crops. In the face of weak light stress caused by continuous rain, some growth retardants can be used to prevent leggy growth and lodging. For example, on soybeans, spraying growth retardants such as oxadiazole can effectively control excessive plant growth and enhance stress resistance. Similarly, if long-term rain is predicted before peas enter the flowering period, an appropriate amount of retardant can be sprayed to keep the plant compact and reduce the adverse effects of stem and leaf growth on pod formation during continuous rain. In addition, growth-promoting regulators

are also useful. Natural hormone analogs such as brassinolide (BR) can improve the photosynthetic efficiency and antioxidant capacity of crops and maintain a high metabolic level under low light and disease stress. Studies have found that BR treatment can reduce the inhibitory effect of low light on nitrogen fixation of leguminous crop nodules, increase leaf chlorophyll content and net photosynthetic rate, and thus alleviate the growth restriction caused by low light. Therefore, spraying low-concentration brassinolide before continuous rain can enhance the ability of pea plants to tolerate rain (Chen et al., 2024).

Using fruit-setting regulators to prevent flower and pod drop is also one of the ideas. For example, anti-drop agents (to prevent abscission layer formation) have been used to increase cotton boll formation. They can also be sprayed as appropriate during the pea flowering period when there is continuous rain to help retain young pods. However, the use of plant growth regulators should be scientific and appropriate, and excessive doses may be counterproductive. In terms of nutrient compensation technology, continuous rain leads to insufficient photosynthetic products of peas and obstructed root absorption, which can be supplemented by foliar fertilization. Spraying foliar fertilizers such as urea and potassium dihydrogen phosphate in the intervals between rainy days can directly provide available nitrogen and phosphorus to the leaves and improve the nutritional level of the plants. Especially when spraying in the early sunny days after rain, high humidity opens the stomata of the leaves, which is conducive to nutrient absorption and has a better effect (McGuinness et al., 2020). After rainy days, the soil is often lacking in oxygen and the root activity is low. Some preparations containing active oxidants (such as calcium peroxide, etc.) can be applied to improve the rhizosphere environment. Microbial agents can also play a role: some rhizosphere growth-promoting bacteria can improve plant resistance to stress. Applying them to pea fields with root irrigation can help restore root function damaged after continuous rain. It is worth mentioning that there are cases of using photosynthetic bacterial fertilizers in greenhouse pea cultivation in Japan and Taiwan, my country, to supplement the soil microecology when light energy is insufficient on cloudy days and improve the photosynthetic efficiency of crops. This type of new nutritional compensation method deserves further research and promotion. The combined use of regulators and nutritional compensation can "escort" the growth of peas during continuous rainy days and play a positive role in improving the pod setting rate.

7 Case Studies

7.1 Adaptation strategies in the pea cultivation base of Qiubei, Yunnan

Qiubei County, Yunnan Province is located in the plateau hilly area, with diverse climate and abundant rainfall. The local area is one of the important pea production areas, but continuous rainy and low-sun weather often occurs in spring, which poses a challenge to the pea pod setting rate. Taking the spring of 2022 as an example, the Qiubei pea planting base experienced 20 consecutive days of rainy weather in March, during which the sunshine hours decreased by more than 40% compared with the same period of previous years, and the peas generally grew weakly. In response to this continuous rainy process, the base took a series of response measures in time and successfully minimized the losses. First, before the continuous rain came, the technicians checked and cleared the field drainage ditches and reinforced the pea supports to prevent the plants from lodging due to excessive soil moisture. During the continuous rainy process, the base seized the short break and applied foliar fertilizer (0.5% urea + 0.3% potassium dihydrogen phosphate) once in mid-March to supplement nutrients for the plants. At the same time, a broad-spectrum fungicide was sprayed every 7 days to protect the pea inflorescence from gray mold infection. Since mechanical operations were not possible in the field, the base organized manual topping and thinning of the plots with severe canopy to improve ventilation. After these efforts, the pea pod setting rate of the base remained at around 70%, which was slightly lower than that in normal years (about 80% or more), but much higher than the 40% pod setting rate of nearby farmers' plots that did not take measures. Breeding rain-resistant varieties is also one of the key factors. The "Yunwan No. 7" variety mainly planted in the base is more resistant to moisture, has a shorter flowering period, and is highly resistant to gray mold. It showed good pod setting stability during this continuous rain (Semenova et al., 2025). The base also summarized the long-term strategy for developing pea production in Qiubei to cope with continuous rain: including improving soil to increase water permeability, promoting high-bed cultivation, and promoting small arch sheds for rain-sheltered seedlings. These experiences provide valuable reference for pea production in rainy mountainous areas.

7.2 Variety screening and management practices during flood years in Dingxi, Gansu

Dingxi, Gansu belongs to a semi-arid plateau area. In normal years, there is less precipitation, but rain and flood disasters may also occur under extreme climatic conditions. In 2018, Dingxi experienced an unusually rainy summer. The concentrated precipitation caused waterlogging and serious disease in some pea fields. That year, the local agricultural research department seized this "natural experiment" opportunity to screen and evaluate the performance of multiple pea varieties under rain and flood conditions. The results showed that some traditional high-yield varieties (such as Dingwan No. 3) had a pod setting rate of less than 50% in this rainy and flood-prone year, while the two introduced new moisture-resistant varieties still achieved a pod setting rate of more than 70%, and ultimately achieved a significant yield advantage (Figure 2) (Yang et al., 2022a).



Figure 2 The characteristic of individual plant and population of pea variety ((a,b) for G1 and (c,d) for G10) in the field at E1 location in 2021. G1 = Semi-leafless pea variety Longwan 10; G10 = Check variety Zhongwan 6 (Adopted from Yang et al., 2022a)

Based on this, the Dingxi Agricultural Station promptly adjusted the variety promotion catalog for the second year, giving priority to the supply of disease-resistant and moisture-resistant varieties to low-lying and flood-prone plots for planting, in order to improve the ability of these areas to resist abnormal weather. In terms of field management, Dingxi agricultural technicians advocate "special management in rainy and flooded years": when there is more rainfall, timely inter-cultivation and loosening of soil moisture should be carried out, and ditches should be dug to drain open water when necessary; during the pea pod filling period, appropriate topdressing of phosphorus and potassium fertilizers should be applied according to the growth of the plants to enhance the plant's resistance to stress; for seriously infected fields, they should be eradicated as soon as possible and replaced with other crops to avoid the spread of the disease. After the 2018 rain disaster, farmers reflected at the summary meeting that the plots with good drainage ditches and pea roots that were not soaked and rotten could still bloom

and set pods later; while the peas in the fields with poor drainage were almost completely lost. This once again confirms the importance of drainage measures. Dingxi's lessons and experiences show that in years with abnormal climate, emergency management should be carried out quickly, and at the same time, the rare opportunity should be used to select suitable local varieties. Through scientific variety layout and strengthening of wet damage prevention, Dingxi's pea production losses were significantly reduced when it encountered heavy rainfall in the following years. This case reflects the active adaptation measures of the northern dryland areas to continuous rain (or short-term waterlogging): good varieties and good methods are used simultaneously to achieve stable production and reduce losses.

7.3 Protected cultivation models in mountainous central Guizhou

The mountainous areas of central Guizhou have abundant rainfall and uneven temporal and spatial distribution, and continuous rainy weather frequently occurs in autumn and winter. In order to protect the production of high-value vegetable peas, some local cooperatives have begun to explore simple rainproof shed cultivation models. The rainproof shed is an arched shed built in the field, covered with a transparent film to prevent crops from being directly exposed to rain. At the same time, the shed film can be uncovered for ventilation and light when it is sunny. In 2021, the Guizhou demonstration base installed a retractable rain shelter on 20 acres of pea fields. In the autumn of this year, many places in Guizhou experienced 15 consecutive days of rain and little sunshine. In the demonstration base, due to the shelter of the shed film, most of the rainfall did not fall directly on the plants, the soil moisture was controlled, and the pea root environment was relatively good. At the same time, the shed film increased the field temperature to a certain extent, reducing the adverse effects of low temperature on the flowering period. More importantly, the rain shelter effectively prevented the soil carried by rain from splashing onto plants and flowers, thereby reducing the spread of pathogens. The incidence of gray mold and rust in the demonstration field was 50% lower than that of the open-field control. Although insufficient light during the continuous rainy period inevitably affected pod setting, the pod setting rate of peas in the greenhouse (about 65%) was still significantly higher than that of the open-field control (below 50%). This rain shelter model also has some problems: high input costs, high humidity in the greenhouse, requiring artificial ventilation, and high management requirements (Santos et al., 2018; Wang et al., 2022). However, a comprehensive economic benefit evaluation shows that in a high-humidity mountain environment such as Guizhou, the rain shelter can ensure the normal production of peas in the off-season or rainy season, and the market price also makes up for the facility investment. Through exploration in recent years, some cooperatives have improved the design, such as using a simple device with a rollable film to facilitate flexible opening and closing under different weather conditions; at the same time, drip irrigation is introduced to control the humidity in the greenhouse. The local government also provides certain subsidies to encourage this type of facility agriculture. This exploration in Guizhou provides a new idea for solving the problem of continuous rain, that is, using facilities to convert open-field cultivation into semi-protected cultivation, creating a controllable microclimate, and minimizing the impact of continuous rain on vegetables such as peas. In the future, with the advancement of materials and technology, rain shelters are expected to be more economical and practical, and be promoted and applied in areas with frequent continuous rain.

8 Concluding Remarks

Continuous rainy weather has an adverse effect on the pod setting rate of peas in many ways. First, continuous rainy weather leads to a serious lack of light, which limits the photosynthesis of peas and causes a shortage of nutrient supply, resulting in an increase in flower and pod drop. This is the primary factor for the decline in pod setting rate. Secondly, continuous rainy weather causes excessive soil moisture, which hinders root respiration and nutrient absorption, weakens the physiological functions of the plant, and makes it difficult to maintain normal pod setting. In addition, high humidity also promotes the prevalence of flowering and pod diseases such as gray mold, directly destroys pea flower organs and hinders pollination and fertilization. The above three aspects (weak light, waterlogging, and diseases) often occur simultaneously and overlap with each other, causing the pod setting rate of peas to be significantly reduced under continuous rainy weather. Once a long-lasting and high-intensity continuous rainy process occurs, peas may experience large-scale pod drop and a significant decrease in yield.

To deal with the adverse effects of continuous rainy weather on peas, we must first emphasize the importance of good varieties and good methods. On the one hand, the selection of shade-tolerant and moisture-tolerant pea varieties with strong stress resistance can reduce the decline in pod setting rate from the source; on the other hand, supporting scientific cultivation management such as reasonable dense planting, perfect drainage, and timely plant protection can minimize the losses caused by continuous rain. In production practice, both are indispensable. It is difficult to achieve ideal results if there are only stress-resistant varieties but poor management, or only relying on management to make up for the weakness of the varieties themselves. This study once again confirmed the importance of integrated disaster prevention technology through a systematic analysis of varieties, physiology and management. For example, the case of Qiubei, Yunnan shows that the use of shade-tolerant varieties and strengthening field management can still achieve good harvests in years of continuous rain; while the fields without supporting measures suffered heavy losses. It can be seen that in order to bring out the potential of disaster-resistant varieties, it must be supported by sophisticated cultivation technology. Especially in the current climate change, "disaster-resistant varieties + emergency management" should be considered and promoted as a whole. The government and scientific research and promotion institutions should strengthen technical training for farmers so that advanced disaster prevention concepts and measures can be deeply rooted in the hearts of the people. At the same time, through policy guidance, we encourage planting cooperatives and large households to adopt new varieties and technologies, set up demonstration models, and achieve point-to-surface. Only when the selection of suitable varieties and scientific management are truly combined with production practice can we effectively improve the pea production system's ability to resist disasters such as continuous rain and ensure stable agricultural production and increase.

In the face of extreme weather events that may become more frequent in the future, research and countermeasures on the impact of continuous rain on peas and other grain and bean crops need to be further deepened. For example, my country's edible bean industry has seen a decline in export advantages and an increase in import shocks, and it is necessary to learn from international experience to enhance the risk resistance of local production. In the context of climate change, frequent extreme weather has become a challenge that agriculture must face. In the future, we should respond to this challenge with more open ideas and more sophisticated technical means, and work together in genetic improvement, cultivation management, and agricultural meteorological services. In terms of genetic improvement, we should strengthen the study of the genetic mechanism of peas' resistance to stress traits such as low light and moisture tolerance, discover related functional genes, and use molecular breeding methods to cultivate new varieties that are both high-yielding and resistant to continuous rain. In terms of cultivation technology, more innovative measures can be explored to alleviate the harm caused by continuous rain, such as developing low-cost rain shelter and covering facilities, establishing intelligent monitoring and emergency lighting and moisture removal systems, etc. In terms of agricultural meteorological services, it is necessary to establish a forecasting and early warning model for continuous rain disasters and a disaster reduction countermeasure library. Once it is predicted that continuous rain will occur, early warnings can be issued and professional technical guidance can be organized to minimize losses. In short, the impact of continuous rain on the pod setting rate of peas is a complex agricultural issue that requires coordinated response from scientific research, promotion and production entities. Only by continuously strengthening variety resistance and improving agronomic measures, and enhancing the adaptability of the production system, can we ensure that important crops such as peas can be produced stably under various weather conditions and contribute to maintaining food security and sustainable agricultural development.

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