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RESPIRATION PATHWAYS AND ECONOMIC ASPECT OF BARLEY (*Hordeum vulgare*). A REVIEW

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ABSTRACT

Barley is one of the nutritious cereals consumed in their diet but still in limited use. Respiration is one of the most critical processes in the growth, development, and overall production of barley's iconic cereal crop (Hordeum vulgare L.). The complex molecular processes, complex regulatory systems, and ecological significance of barley respiration are all explored in this article. The analysis includes key data from the literature, covering topics such as metabolic pathways, water activity conditions, and regulatory elements affecting barley respiration. The study's objectives are gaining knowledge about barley respiration, understanding biochemical and molecular mechanisms, looking into regulatory pathways, emphasizing the value of agriculture, and identifying knowledge gaps. With a focus on providing insights for crop management, stress tolerance, supporting economic aspects, and sustainable agriculture in the face of global issues, this review seeks to advance our understanding of barley respiration and develop economical valuation

Keywords: Barley; economic valuation; metabolic pathway; production

ABSTRAK

Barli merupakan salah satu sereal bergizi yang dikonsumsi dalam makanan mereka namun penggunaannya masih terbatas. Respirasi adalah salah satu proses paling penting dalam pertumbuhan, perkembangan, dan produksi keseluruhan tanaman serealia ikonik jelai (Hordeum vulgare L.). Proses molekuler yang kompleks, sistem pengaturan yang kompleks, dan signifikansi ekologis dari respirasi jelai semuanya dieksplorasi dalam artikel ini. Analisis tersebut mencakup data penting dari literatur, yang mencakup topik seperti jalur metabolisme, kondisi aktivitas air, dan elemen pengaturan yang mempengaruhi respirasi jelai. Tujuan studi ini untuk mengetahui tentang respirasi jelai, memahami mekanisme biokimia dan molekuler, mencari jalur regulasi, menekankan nilai pertanian, dan mengidentifikasi kesenjangan pengetahuan. Dengan fokus memberikan wawasan tentang pengelolaan tanaman, toleransi terhadap stres, mendukung aspek ekonomi, dan pertanian berkelanjutan dalam menghadapi isu-isu global, ulasan ini berupaya untuk meningkatkan pemahaman kita tentang respirasi barli dan nilai-nilai ekonomi yang bisa dikembangkan.

Kata kunci: Barli; jalur metabolik; produksi; valuasi ekonomi

INTRODUCTION

The improvement of barley quality is helpful for producing better healthy food, while understanding of the chemical and functional components as well as their genetic regulation in barley grains and their health benefts is fundamental to improve relevant quality and meet the requirement by market. One of metabolic pathway is respiration. Respiration is a vital process for producing energy in plants, including barley. Oxygen is essential for conducting respiration. The internal oxygen levels in plants depend on respiratory rates. Tissues such as underground roots experience hypoxia due to their isolation from atmospheric oxygen, and their internal oxygen depends on tissue size and local oxygen in the soil and rhizosphere (Jacobsen & Fleurat-Lessard, 2017). The rate of respiration in barley dramatically increases during the first few days of germination. The experiment involved accelerating airflow through the germination chambers. Since the respiration rates were unaffected, it may be assumed that anaerobiosis and carbon dioxide narcosis do not limit them. The process by which carbon dioxide produced by plant roots and soil microorganisms is discharged into the atmosphere is known as soil respiration. Under cultivated conditions, this mechanism can potentially contribute a sizable portion of the carbon dioxide fixed by photosynthesis (Simojoki, 2000).

The iconic cereal crop of barley (Hordeum vulgare L.) has a long history of agricultural use and is intricately intertwined into the fabric of human society. As a staple food source and an essential component in malt creation for brewing and distilling, it has been grown for millennia in various environments, adapting to different climates. But barley's remarkable adaptability and toughness go beyond only its agricultural significance (Zhong et al., 2016a). Underneath its simple exterior is a sophisticated metabolic system that controls respiration, one of life's essential functions. The importance of the respiration process in barley goes far beyond the area of fundamental plant biology. This cereal crop's growth, development, and total production are supported by a fundamental process. Barley respiration plays a crucial role in agricultural sustainability and food security since it directly affects grain output, nutrient quality, and stress tolerance (Cicuéndez et al., 2020). The complexity of barley respiration can also be understood to improve crop management techniques, reduce the effects of environmental stressors, and boost crop resilience in the face of climate change. Understanding the intricacies of barley respiration holds

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the key to improving agricultural innovation and guaranteeing our agricultural future as the world's demands for food and resources continue to rise (Usman, 2015a).

A carefully organized sequence of molecular events occurs within the barley cells during respiration, with the mitochondria taking center stage. A symphony of proteins and enzymes interact within these organelles to promote the oxidative breakdown of organic substances, producing ATP, the cell's energy currency (Lou et al., 2017). The tricarboxylic acid (TCA) cycle, electron transport chain, and oxidative phosphorylation are intricately synchronized during this process (Ahmad et al., 2023). Furthermore, the availability of substrates for respiration is influenced by the interactions between several metabolic processes, such as glycolysis and the pentose phosphate pathway (Bilandžija et al., 2021). Furthermore, environmental elements like light, temperature, and the availability of nutrients control these interactions, enabling barley to adapt and flourish in many ecological niches. Understanding these intricate molecular interactions is essential for elucidating the fundamentals of plant biology and advancing strategies in crop improvement and sustainable agriculture (Carrillo-Reche et al., 2021, Kusumiyati et al., 2023).

Barley's respiration routes must be understood in order to maximize growth, increase yield, and guarantee the quality of the finished goods (Iqbal et al., 2023). Recent developments in bioinformatics and molecular biology have shed important light on the complex processes and control of barley respiration (Nazir et al., 2024). In order to shed light on the molecular and physiological mechanisms involved, this review attempts to compile and synthesize the most recent information available on barley respiration routes (Ahmad et al., 2023). We will also discuss the economic significance of figuring out these paths, highlighting the possible uses in industry and agriculture. This review aims to provide a comprehensive understanding of how this crop supports itself and interacts with its environment by shedding light on the molecular mechanisms, regulatory networks, and ecological significance of respiration in barley.

Objectives

Gaining a more transparent comprehension of the mechanisms behind barley respiration is the primary goal of this endeavor (Table 1). It

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comprises a thorough analysis of all the available information on barley respiration, as well as new findings and insights. Research into metabolic pathways and energy production, as well as how they connect to the growth and development of barley, may fall under this category. The specific biochemical and molecular mechanisms underlying barley respiration. It examines the enzymes, metabolic routes, and molecular relationships specific to barley's respiratory processes. The regulation of respiratory pathways in barley. It examines how different elements affect barley respiration, including genetic regulation, hormone indicators, and environmental settings. A thorough examination of the regulatory components and their function in adjusting to shifting ecological circumstances may be necessary. Emphasize the importance of studying barley respiration, especially concerning agriculture. It might cover themes like crop production, stress tolerance, and how crop management techniques and barley farming can benefit from understanding respiration. Pointing out gaps in our knowledge of barley respiration that need to be filled in.

RESEARCH METHODS

Article selection procedures

The phenomenon of connected papers has been operated in order to find the relevant article of the mentioned theme.

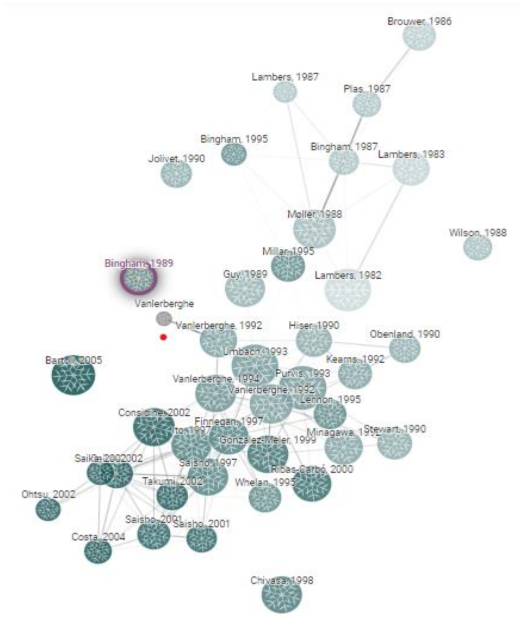

Figure 1. The phenomenon of connected papers has been utilized in order to link and generate relevant reference papers: A self-generated tactic

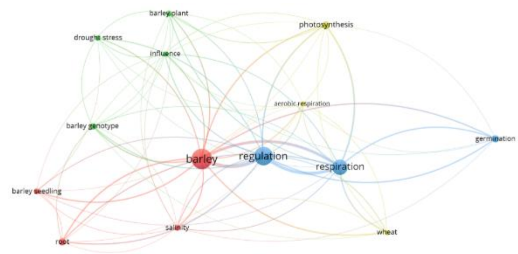

Figure 2. Creating a comprehensive keyword network: A self-generated tactic

Inclusion and exclusion criteria of literature

A systematic approach was utilized throughout the identification stage of our review article on barley respiration to choose the most appropriate content. During our searches across four well-known academic databases—Scopus, Web of Science, PubMed, and ScienceDirect—we applied particular inclusion criteria. We concentrated on English-language research on respiration in barley that was published in peer-reviewed journals. We used keywords, abstracts, and article titles together with terms like "respiration," "barley pathway respiration," "mechanism," and "regulation" to carry out our searches. 426 articles were identified as a result of this methodology. After a thorough deduplication process, which turned up 93 duplicate articles, we had a revised dataset with 333 unique articles for analysis. This method was essential to maintaining the accuracy and thoroughness of the material we looked at for our review.

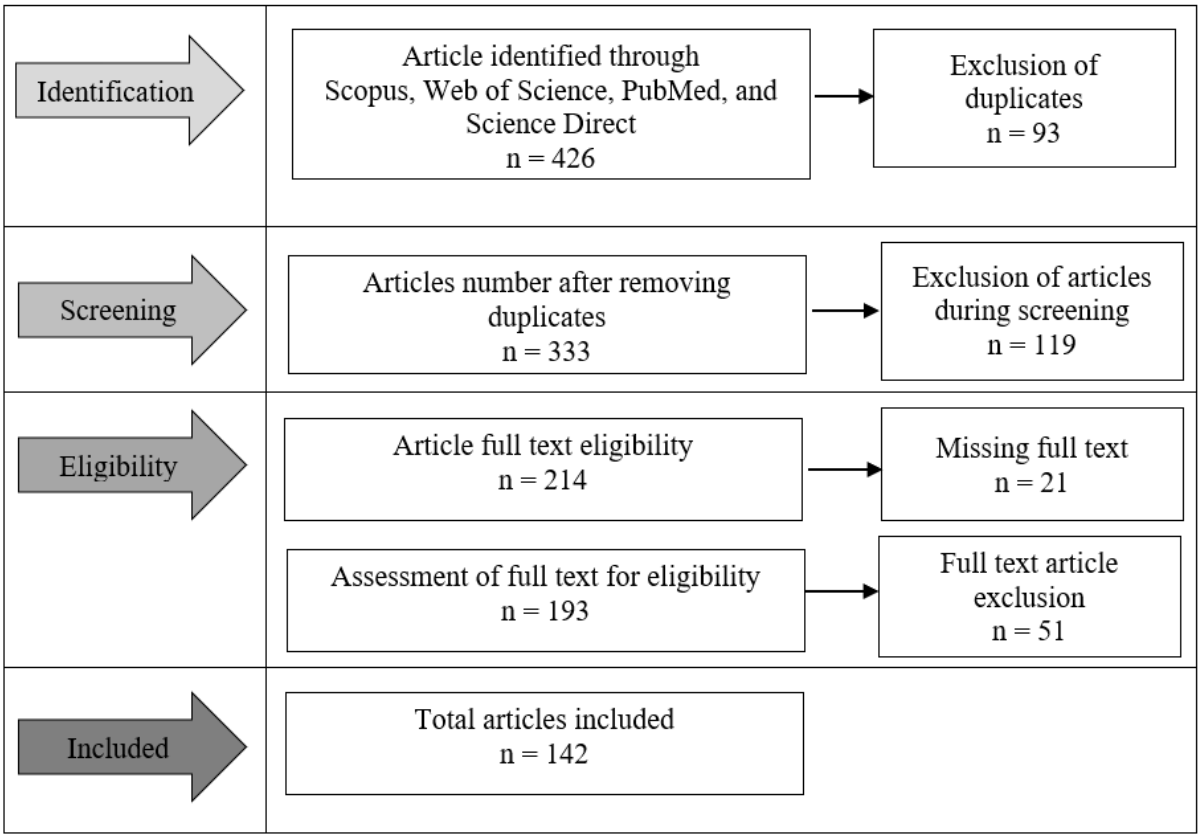

Fig 3. PRISMA flow for inclusion and exclusion criteria of literature.

In the first stage of the screening process, the corresponding author evaluated the titles and abstracts of the 333 publications separately to see if they were relevant to our review's main goals, which were to produce chilies in enclosed spaces. To maintain objectivity, we followed a specific protocol. To meet the objectives of the study, 119 articles were removed from the initial pool. Only articles that received approval from two or more co-authors moved on to the next phase. Discussions were conducted to resolve situations of disagreement, and only one co-author favored an item being included.

The lead author separately read the abstract and decided if a consensus could not be achieved. After a thorough screening procedure, 214 objects were kept for additional analysis. After all, three co-authors approved an article's inclusion, it moved on to the next stage. The lead author decided to include an article when just two co-authors voted for it to be included. 142 publications were eventually chosen for a thorough review after this procedure. The supplementary material contains an extensive list of these selected articles.

Analysis

This study adhered to the Preferred Reporting Materials for Systematic Review and Meta-Analysis (PRISMA) criteria. PRISMA provides clear methods for carrying out systematic literature reviews, raising the standard of reporting and methodology. Bibliometric analysis was used to examine the articles. Bibliometric analysis is a systematic approach to literature evaluation that assesses an article's sound knowledge through statistical metrics. For data analysis, both quantitative and qualitative research approaches were adopted.

Reputation of included literature

Table 2 gives details about a set of academic papers' reputation, Scopus indexing status, and quartile ranking. Regardless of the articles' quartile rankings (Q1, Q2, Q3, and Q4), the chart clearly shows that they all have been indexed in Scopus, demonstrating their acceptance and inclusion in a highly regarded academic research database. The relative influence and reputation of the journals where these publications have been published are shown by the quartile rankings. To be more precise, Q1 consists of 47 items that are prominent and have a high impact. There are 34 articles in Q2, which corresponds to journals that have a good reputation but marginally less impact. Journals having a moderate impact are represented by the 31 articles in Q3, while the journals with the lowest impact within the quartile system are

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represented by the 30 articles in Q4. This data offers essential insights into the distribution and recognition of research articles across different quartile rankings in the context of Scopus indexing.

Table 2. Reputation of the included articles

Quartile ranking	*Scopus index ing Yes (Y), No (N)*	*Articles number*
Q1	Y	47
Q2	Y	34
Q3	Y	31
Q4	Y	30

RESULTS AND DISCUSSION

Sophisticated respiration mechanisms that barley experiences significantly affect its growth, development, and yield. Barley is an essential cereal crop. Comprehending these routes has significant economic ramifications and adds to fundamental scientific understanding (Usman, 2015a). Anaerobic and aerobic mechanisms are included in barley respiration. When oxygen is present, aerobic respiration takes place and produces the most energy when glucose is ultimately converted to carbon dioxide and water. Maintaining cellular functioning and promoting development depends on this process. However, when oxygen is scarce, anaerobic respiration occurs, resulting in the incomplete breakdown of glucose and the build-up of metabolites such as lactic acid and ethanol (Gordon et al., 1980). Anaerobic respiration produces less energy but is necessary in stressful situations like hypoxia or waterlogging. Barley respiration is a biological process involving several metabolic events in different organelles. Initiating the breakdown of glucose in the cytoplasm, glycolysis yields pyruvate and a negligible quantity of ATP. After that, pyruvate reaches the mitochondria, which converts into ATP and reduces equivalents (NADH and FADH2) through the citric acid cycle, known as the Krebs cycle (Lou et al., 2017). These reducing equivalents provide energy to the inner mitochondrial membrane's electron transport chain, which enables oxidative phosphorylation, which in turn facilitates the synthesis of ATP. Furthermore, pyruvate is transformed into ethanol or lactic acid in anaerobic environments, promoting the regeneration of NAD+ to support glycolysis (Cicuéndez et al., 2020). Comprehending the respiration pathways of barley holds noteworthy economic consequences in diverse domains. Enhancing crop production and yield stability through agriculture through optimal barley respiration can help ensure food security (Farrar, 1980). Gaining more knowledge about anaerobic respiration pathways will help cultivators of barley produce cultivars that are more resilient to environmental challenges like waterlogging, which will ultimately reduce yield losses (Lücke et al., n.d.). Moreover, since barley is a significant element in the brewing and malting industries, knowledge of respiratory metabolism is relevant. Altering the respiration pathways of barley can affect the sensory qualities, efficiency of fermentation, and malt quality of brewed beverages; these factors can affect customer preferences and market competitiveness (Igamberdiev et al., 1997).

Table 3. Findings from literature

Water activity (aw) conditions substantially impact barley seed respiration.	(Cicuéndez et al., 2020)
Under some activity water conditions, it is found that the seeds' respiration rates are negligible, underscoring the significance of environmental factors in barley seed respiration.	(Bilandžija et al., 2021)
An in-depth comprehension of these pathways' reactions to various physiological and environmental stimuli is essential for deciphering the respiration mechanisms in barley.	(Gordon et al., 1980)
An alternate respiratory pathway (AP) involving particular genes and components is present in barley.	(He et al., 2019)
Important information on the regulatory mechanisms of barley respiration can be gained from observing how genes involved in alternate respiratory pathways express themselves in response to different stressors and environmental factors.	(Igamberdiev et al., 1997)
An essential cereal crop, barley depends on complex respiratory routes to supply its energy needs. The review's findings clarify the vital processes in barley respiration, including oxidative phosphorylation, glycolysis, and the tricarboxylic acid (TCA) cycle.	(He et al., 2019)
Barley's capacity to control these pathways adaptably guarantees energy output in various environmental circumstances.	(Lou et al., 2017)

Analyzing barley's glycolysis reveals complex regulation mechanisms. Hexokinase and phosphofructokinase are two examples of enzymes that are essential for regulating glycolytic flow.	(Ashilenje et al., 2023)
How temperature and oxygen availability affect glycolytic activity illustrates how flexible barley respiration is in response to varying environmental conditions.	(Jacobsen & Fleurat-Lessard, 2017)
The TCA cycle is a significant hub for respiratory metabolism. This article examines the significance of the TCA cycle in barley and highlights the function of essential enzymes, including isocitrate dehydrogenase and succinate dehydrogenase, in controlling the TCA cycle flux.	(Lücke et al., 2017)
The roles of ATP synthase and cytochrome c in the electron transport chain are closely examined about energy coupling.	(Hill, 1994)
To maintain cellular redox homeostasis, the significance of preserving an ideal balance between energy production and reactive oxygen species (ROS) creation.	(Jensen, 2001)
The respiratory systems of barley react to stimuli in its surroundings. The impact of temperature, oxygen availability, and other variables on barley plants' respiration rates and the general metabolic state is examined.	(Zhong et al., 2016b)
A significant portion of barley's respiration is aerobic, highlighting the importance of oxygen-dependent activities in creating energy.	(Bloom et al., 1992)
The vital role that mitochondria play in the respiration of barley clarifies the precise processes that control mitochondrial activity and ATP production.	(Ryle et al., 1976)
Comparative research shows that barley's respiration pathways differ from those of other cereal crops like wheat and rice in several unique ways.	(Todd, 1982)
Temperature, light intensity, and food availability are environmental elements that may affect barley's respiratory rates, demonstrating the dynamic nature of respiration regulation.	(Usman, 2015b)
Examining germination processes reveals significant changes in respiratory pathways, providing insight into the significance of many enzymes during the switch from anaerobic to aerobic metabolism.	(Hill, 1994)
Biotic and abiotic stresses shed light on how barley adjusts its respiratory pathways in response to adversity, which enhances the plant's capacity to withstand stress overall.	(Jensen, 2001)
Identifying important genes and transcription factors that control the production of respiratory enzymes has raised interest in the genetic regulation of respiration in barley.	(Carlson, 1970) (Iqbal et al., 2023)
Across the application of metabolic flux analysis, the passage of metabolites across different respiratory pathways in barley provides insight into the metabolic network's intricate workings.	(Bloom & Epstein, 1984)
The mutual interaction between these two essential processes for energy balance—photosynthesis and respiration—and highlights how intertwined they are in barley.	(Morell & Whitmore, 2012) (Iqbal et al., 2024)
Investigating the post-translational changes of respiratory enzymes has shown how phosphorylation, acetylation, and other alterations facilitate the fine-tuning of respiratory activity in barley.	(Bingham & Farrar, 1988)
Many growth stages of barley yield essential insights into the variations in respiration rates that occur during the development of seedlings, reproductive stages, and senescence.	(Bingham & Farrar, 1987)

The optimization of fertilization tactics to improve respiratory efficiency and overall crop output is impacted by the efficiency of barley's nutrient use.	(Yemm & B, 1937) (Nazir, Li, et al., 2024)
Deciphering the total carbon economy of barley, which affects biomass output and quality, requires understanding the carbon partitioning across respiratory pathways and other metabolic processes.	(Igamberdiev et al., 1997) (Teshita et al., 2024)
The amalgamation of omics methodologies, including transcriptomics, proteomics, and genomes, has facilitated scholars in acquiring a comprehensive comprehension of the molecular processes that regulate barley respiration.	(John & John, 1990) (Nazir et al., 2024)
The consequences of barley respiration at the ecosystem level offer a more comprehensive understanding of the ecological significance of barley metabolism, including its role in soil respiration and carbon cycling.	(Gupta et al., 2009)
The application of crop modeling methodologies yields insightful predictions about the potential effects of climate and atmospheric variables on barley respiration, providing information for sustainable farming operations.	(Lücke et al., 2017) (Ahmad et al., 2023)
Identifying molecular markers linked to several respiratory pathways in barley advances our comprehension of metabolic fluxes and their regulation on a more intricate level.	(Gordon et al., 1980)
For barley crop improvement to address its many facets, respiration pathways must be linked to grain quality metrics like protein composition and starch content.	(Farrar, 1980)
The discovery of the genetic variables influencing respiration rates has made it possible to use focused breeding techniques to create barley cultivars with higher respiratory efficiency.	(Todd, 1982)
Barley respiration pathway modification has the potential to increase crop yields and quality significantly.	(Ashilenje et al., 2023)
With better knowledge, barley types that are more resistant to environmental stresses can be developed, guaranteeing a steady and reliable supply for industrial and food uses.	(Zhong et al., 2016b)
Developing barley cultivars with improved respiratory efficiency can reduce resource inputs and have less environmental effects.	(He et al., 2019)

It has remained an essential food in several places, although the main uses now are animal feed and beer manufacturing. The other major cereal crops, maize, rice, and wheat, have continued to expand, whereas barley output has stalled during the last two decades. Nonetheless, throughout the last century, barley has been a significant crop model for a wide range of studies on genetics, biochemistry, and developmental biology, notably barley's near relative, wheat.

Social and Economic Aspect

Nonetheless, smallholder barley growers suffered a lower degree of technical efficiency due to many variables (Moges, at.al., 2023). Returns to scale analysis may be used to estimate total factor productivity. The coefficients are determined to be 1.139, indicating that increasing returns to scale causes an increase in rate since the value of returns to scale exceeds one. This indicates that there is potential for barley producers.

Credit use has a good and considerable impact on the technical efficiency of barley growers. This suggests that farmers who used loans were more productive than those who did not. As a result, regional and local governments should act to enhance the functioning of rural saving and credit institutions at the village level while also raising farmer knowledge. Amhara Credit and Savings Institution should focus on how to provide credit services, raise credit knowledge, and improve farmer access (Moges, at.al., 2023).

CONCLUSION

This thorough analysis explores the complex molecular and regulatory elements of barley respiration, illuminating its essential function in this well-known cereal crop's growth, maturation, and yield. The review highlights the importance of comprehending barley respiration's regulatory routes, biochemical and molecular mechanisms, and ecological effects. It aims to close knowledge gaps and offer insightful information on crop management, stress tolerance, and sustainable agriculture. It emphasizes the significance of expanding our knowledge of barley respiration in light of the world's agricultural issues. The study of barley's respiration routes has applications in industry and agriculture and is not only a scholarly endeavor. Barley production could undergo a revolution by incorporating molecular insights into breeding programs and cultivation practices, thereby meeting the growing need for raw materials and food. A deeper exploration of the mechanics and regulation of barley respiration opens up new avenues for agricultural sustainability and economic prosperity.

A mix of technologies, such as a fertilized barley-vetch rotation (instead of the typical barley-weedy fallow cycle), may give the most viable method of preserving present farm revenues while simultaneously improving the sustainability of regional agriculture.

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