# Role of ARGONAUTE 1 in Balancing Plant Immunity and Development

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**Abstract**

Plants face a constant dilemma: to allocate resources to growth and development or to focus on defending themselves from pathogens. Striking a balance between these two essential functions is crucial for survival. A key player in this balancing act is ARGONAUTE 1 (AGO1), a protein well-known for its role in gene silencing through small RNA pathways. Recent research highlights its significance in coordinating plant disease resistance with growth and development, making it a critical node in plant biology.

**Keywords:** ARGONAUTE 1 (AGO1), Plant immunity, Small RNA pathways, Gene regulation

## Introduction

The ARGONAUTE proteins are an integral part of the RNA-induced silencing complex (RISC) that regulates gene expression by binding small RNAs (such as microRNAs or siRNAs) and guiding them to target mRNAs. Among the different AGO proteins in plants, AGO1 is the most extensively studied due to its pivotal role in post-transcriptional gene regulation. It binds primarily to microRNAs (miRNAs) and is involved in various biological processes, including growth, development, and immune responses (Bologna *et al.*, 2021).

## ARGONAUTE 1 in Growth and Development

In plants, AGO1-mediated miRNA pathways regulate a wide array of developmental processes. One of the most studied roles of AGO1 is in shoot apical meristem (SAM) maintenance and leaf development. By repressing target mRNAs, AGO1 ensures proper leaf size, shape, and organ polarity. This function is crucial for optimizing the plant's growth under favorable conditions. For example, the miR156-AGO1 pathway modulates the expression of SQUAMOSA PROMOTER BINDING PROTEIN-LIKE (SPL) genes, which control vegetative phase transition. Similarly, the miR166-AGO1 interaction regulates class III HOMEODOMAIN LEUCINE ZIPPER (HD-ZIP III) genes to establish leaf polarity. These pathways show that AGO1 not only participates in maintaining normal plant growth but also helps adjust development in response to environmental cues (Bologna *et al.*, 2021.

## ARGONAUTE 1 and Plant Defense

While AGO1 plays a vital role in development, its functions in plant immunity are equally important. Plants have developed sophisticated defense mechanisms to detect and respond to pathogens. The plant immune system is typically divided into two layers: pattern-triggered immunity (PTI) and effector-triggered immunity (ETI). AGO1 is involved in both.

1. **Small RNA Defense Pathways**: AGO1 partners with small RNAs like miRNAs and small interfering RNAs (siRNAs) to regulate genes involved in defense responses. For example, the miR393-AGO1 pathway modulates the expression of AUXIN RESPONSE FACTORS (ARFs), which in turn affect auxin signaling pathways and plant immunity. miR393 directs AGO1 to suppress genes encoding F-box auxin receptors, reducing auxin levels and enhancing resistance to bacterial pathogens like *Pseudomonas syringae* (Mallory *et al.*, 2020).
2. **Viral Defense**: AGO1 plays a direct role in defending against viral pathogens through its interaction with viral-derived siRNAs. By loading viral siRNAs, AGO1 can target and degrade viral RNA, thus limiting viral replication.
3. **Cross-talk Between Growth and Defense**: One of the key features of AGO1 is its ability to mediate the trade-off between growth and defense. Plants must often make the tough decision to prioritize either growth or defense, as both processes are energy-intensive. AGO1 facilitates this balance by regulating miRNAs that suppress growth-related genes during pathogen attack and by downregulating defense genes when conditions are favorable for growth (Li *et al.*, 2023).

**Coordination of Growth and Immunity: The Trade-off**

The interaction between growth and defense is a tightly regulated process in plants. AGO1 sits at the intersection of this trade-off. When plants encounter pathogens, AGO1-associated miRNAs such as miR398 are activated to suppress cytochrome C oxidase and downregulate metabolic activities. This slows down plant growth, redirecting energy towards activating defense pathways. In another case, miR319-AGO1 interaction regulates TCP transcription factors, balancing cell cycle control and defense responses (Li *et al.*, 2023).

AGO1 plays a crucial role in mediating both plant growth and defense by interacting with small RNAs (sRNAs) from endogenous and exogenous sources. Fig 1 explains a forms an autoregulatory loop with miR168, where AGO1 stabilizes miR168, while miR168 suppresses AGO1 expression (1). This interaction is central to balancing plant growth and immunity. On one side, AGO1-associated sRNAs suppress plant mRNAs essential for growth and development (2). On the other side, AGO1 is involved in plant defense mechanisms, including PAMP-triggered immunity (PTI) and effector-triggered immunity (ETI) (3), though these immune responses often lead to trade-offs that affect growth.

Plants growing under stress conditions require AGO1 to fine-tune these miRNA pathways, ensuring that defense responses are prioritized while minimizing the adverse effects on development. Pathogenic fungi and oomycetes can exploit this system by generating sRNAs that are loaded into AGO1, effectively hijacking the host's RNAi pathway to facilitate infection (4). Viral pathogens, on the other hand, may induce the expression of miR168 to downregulate AGO1, thus compromising the plant's antiviral defense mechanisms (5). Interestingly, in rice, AGO18 competes with AGO1 for miR168 binding, reducing the suppression of AGO1 and thereby mounting a more robust antiviral defense (6). Furthermore, AGO1 also binds viral small interfering RNAs (vsiRNAs) to mediate antiviral defense (7), though in some cases, this may inadvertently silence endogenous genes, which could facilitate infection (8). Viruses also employ various suppressors of RNA interference (VSRs) to manipulate AGO1. These suppressors either sequester the plant's sRNAs (9), promote the degradation of AGO1 (10), or block its cleavage and RNA-induced silencing complex (RISC) activity (11). Hormonal regulation further modulates AGO1 activity. Jasmonic acid (JA) and indole-3-acetic acid (IAA) promote AGO1 binding to chromatin, enhancing the expression of genes responsive to environmental stimuli (12). Meanwhile, abscisic acid (ABA) increases both AGO1 expression and miR168 levels (13), whereas salicylic acid (SA) inhibits AGO1 expression (14). Additionally, brassinosteroids (BRs) inhibit the localization of AGO1 at the endoplasmic reticulum (ER), limiting its role in miRNA-mediated gene repression (15).

This complex network highlights AGO1 as a pivotal regulator that balances growth, development, and immunity, adapting to various internal and external stimuli to optimize plant survival (Zhao *et al.*, 2023).

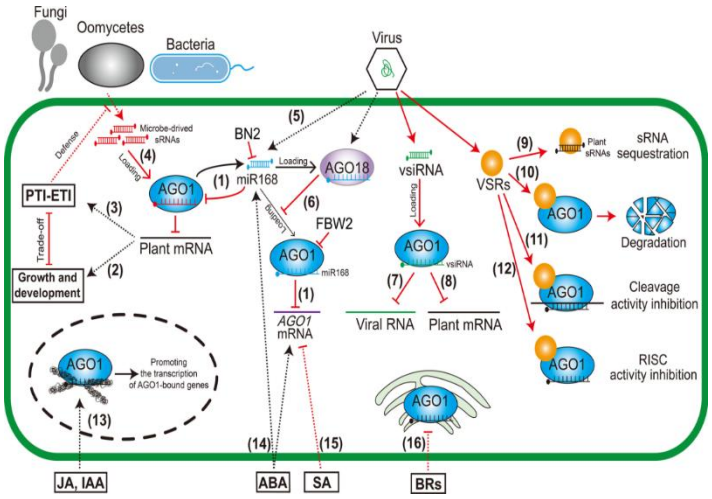


**Fig 1**. ARGONAUTE 1: a node coordinating plant disease resistance with growth and development (Zhao *et al.*, 2023)

**Emerging Research and Current Perspectives**

Recent studies are shedding new light on how AGO1 integrates environmental signals to optimize plant responses. A 2023 study published in Nature Communications highlighted how AGO1 interacts with the salicylic acid (SA) pathway, a key hormonal route in systemic acquired resistance (SAR). This research demonstrated that AGO1 can mediate cross-talk between SA and jasmonic acid (JA) pathways, linking it to both biotic stress responses and developmental signals. Similarly, ongoing work on AGO1 phosphorylation shows how post-translational modifications fine-tune its function in different contexts, further reinforcing its role as a molecular

switch between growth and defense. Moreover, advances in bioinformatics have revealed that AGO1 interacts with hundreds of miRNAs, expanding its influence across different cellular functions. This complexity underscores the importance of AGO1 as a regulatory hub in plants (Zhang & Dong 2022 and Mallory *et al.,* 2020).

**Conclusion**

The ARGONAUTE 1 serves as a critical node in coordinating the intricate balance between plant growth, development, and immune response. By modulating small RNA pathways, AGO1 ensures that plants can adapt to environmental stresses while maintaining proper growth. As research progresses, a more comprehensive understanding of AGO1's role in these processes could lead to novel strategies for crop improvement, such as enhancing disease resistance without compromising growth.

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