Regulatory effect of G-protein in Transpiration

Abhishek Konar

Department of Botany, Seacom Skills University, Kendradangal, Bolpur, W.B-731236.

Abstract:

Transpiration is one of the most important Part of the plant. Transpiration occurs through the Stomata and Lenticels. The factors that greatly influence and control stomatal movements i.e., opening and closing of stomata, e.g., Light, Temperature, Atmospheric Humidity, Wind, Available Soil Water, Root/Shoot Ratio. But modern research found that Stomata Controlled by G-protein or G-protein's subunit. Land plants must balance CO_2 assimilation with transpiration in order to minimize drought stress and maximize their reproductive success. The ratio of assimilation to transpiration is called transpiration efficiency (TE). TE is under genetic control, although only one specific gene, *ERECTA*, has been shown to regulate TE. We The α-subunit of the heterotrimeric G protein in Arabidopsis (*Arabidopsis thaliana*), GPA1, is a regulator of TE. *gpa1* mutants, despite having guard cells that are hyposensitive to abscisic acid-induced inhibition of stomatal opening, have increased TE under ample water and drought stress conditions and when treated with exogenous abscisic acid. The increased TE and reduced whole leaf stomatal conductance of *gpa1* can be primarily attributed to stomatal density, which is reduced in *gpa1* mutants. In this study, the G-protein signaling pathway was also found to regulate stomatal density on the lower epidermis of Arabidopsis cotyledons. The loss-of-function mutation of the G-protein alpha-subunit (GPA1) showed a reduction in stomatal density, while overexpression of the constitutively active form of GPA1(QL) increased stomatal density, indicating a positive role of the active form of GPA1 in stomatal development, which help transpiration rate. GPA1 regulates stomatal density via the control of epidermal cell size and stomata formation. GPA1 Mutants Have vital role for transpiration or transpiration efficiency i.e., Increased TE under Ample and Low Soil Water Conditions, *pa1* Mutants Have Reduced Carbon Isotope Discrimination When Treated with ABA, *gpa1* Mutants Are More Sensitive to Low-CO_2-Induced Stomatal Opening, *gpa1* Mutants Have Reduced Stomatal Density and Stomatal Index in Mature Leaves. G-protein-coupled receptors (GPCRs) are so named because they interect with G protein, as discussed below. This work in this thesis investigates G protein function at the whole-plant level in attempt to understand this missing component of our knowledge of G protein function in plants.

***Keywords*:** G-protein-coupled receptors, Heterotrimeric G-proteins, Transpiration efficiency, GPA1, Transpiration, Water use efficiency, Stomata open & Close.

1.Introduction:

Heterotrimeric G-proteins regulate diverse signaling events in plants, following the dissociation of heterotrimer into GTP-bound Gα subunit and Gβγ dimers, which further activate the various downstream effectors for the coordinated regulation of plant responses.

Stomata are essential for efficient gas and water-vapor exchange between the atmosphere and plants. Stomatal density and movement are controlled by a series of signal molecules including phytohormones and peptides as well as by environmental stimuli. It is known that heterotrimeric G-proteins play an important role in the ABA-inhibited stomatal opening. GPA1, as a positive regulator of

transpiration efficiency, despite stomatal ABA sensitivities of gpa1 mutants that would suggest the opposite. GPA1 regulates transpiration efficiency in part via stomatal density control which modulates whole-leaf stomatal conductance.

G proteins have been shown to function in developmental processes and hormonal and environmental signaling, including stomatal aperture. In response to drought stress, ABA concentration increases in the leaves, where it promotes stomatal closure and inhibits stomatal opening. The G protein α- and β-subunit mutants, *gpa1* and *agb1*, respectively, are hyposensitive to ABA inhibition of stomatal opening while displaying wild-type ABA promotion of stomatal closure. ABA inhibits stomatal opening in part by inhibiting inward-rectifying K^+ channels, reducing K^+ influx and therefore water entry into the cell. ABA inhibition of inward K^+ channel activity is reduced in both *gpa1* and *agb1* mutants. *agg1* and *agg2* mutants show no altered regulation of ABA-induced stomatal movements or ion channel activities, suggesting that the genome contains additional unknown Gγ(s) or that heterotrimeric G protein signaling in plants does not always operate according to the mammalian paradigm.*gcr1* mutants are hypersensitive to both ABA inhibition of opening and ABA promotion of stomatal closure.*gtg1 gtg2* double mutants show a wild-type response for ABA inhibition of stomatal opening and are hyposensitive in ABA promotion of stomatal closure.

While the altered stomatal sensitivities of the G protein mutants to ABA suggest that heterotrimeric G proteins may function in the regulation of whole plant water status, few experiments have been performed at the whole leaf or whole plant level. *gpa1* mutants in the Wassilewskija background display increased water loss from excised leaves.

2.Review of literature:

The Some World-Wide researches on regulatory effect of G-Protein in transpiration of plant. Some Scientist observed that G-Protein play vital role in Transpiration i.e., stomatal opening and promotion of stomatal closure, controls stomatal apertures, Stomatal density etc.

Table 1: Review of worldwide researches on Regulatory effect of G-Protein in Transpiration

Year	Reports	Study Location	Reference
2001	Manipulation of G protein status in guard cells may provide a mechanism for controlling plant water balance. In higher plants, guard cell ion-channel regulation controls stomatal apertures. Stomatal opening relies on increases in K^+, Cl^-, malate^{2-}, and sucrose in the guard cell symplast to drive water influx and cell	New York	Qing Wang *et al.,*

	swelling.		
2003	It was discovered in plants that S1P is a signalling molecule involved in abscisic acid (ABA) regulation of guard cell turgor. Here we report that the enzyme responsible for S1P production, sphingosine kinase (SphK), is activated by ABA in *Arabidopsis thaliana*, and is involved in both ABA inhibition of stomatal opening and promotion of stomatal closure	United States	E. Sylvie Coursol *et al.,*
2008	Stomatal density and movement are controlled by a series heterotrimeric G-proteins play an important role in the ABA-inhibited stomatal opening.	China	Lingang Zhang *et al.,*
2010	A-subunit of the heterotrimeric G protein in Arabidopsis (Arabidopsis thaliana), GPA1, is a regulator of TE.	United States	E.Nilson & M.Assmann

2.1Qing Wang, Hemayet Ullah, Alan M. Jones, Sarah M. Assmann[1] :

Year: 2001, Study location: New York, USA.

E. Xi-Qing Wang *et al.,* observed that the phytohormone abscisic acid (ABA) promotes plant water conservation by decreasing the apertures of stomatal pores in the epidermis through which water loss occurs. They found that Arabidopsis thaliana plants harboring transferred DNA insertional mutations in the sole prototypical heterotrimeric GTP binding (G) protein a subunit gene, GPA1, lack both ABA inhibition of guard cell inward K^+ channels and pH-independent ABA activation of anion channels. Stomatal opening in gpa1 plants is insensitive to inhibition by ABA, and the rate of water loss from gpa1 mutants is greater than that from wild-type plants. Manipulation of G protein status in guard cells may provide a mechanism for controlling plant water balance.

In higher plants, guard cell ion-channel regulation controls stomatal apertures. Stomatal opening relies on increases in K^+, Cl^- , $malate^{2-}$, and sucrose in the guard cell symplast to drive water influx and cell swelling. These processes result in an outbowing of the guard cell pair and an increase in pore aperture. During stomatal opening, K^+ uptake is mediated by inwardly rectifying K^+ channels.

2.2. E. Sylvie Coursol, Liu-Min Fan, Herve Le Stunff, Spiegel, Simon Gilroy & M. Assmann[2] :

Year: 2003, Study location: Department of Biology, Pennsylvania State University, 208 Mueller Laboratory, University Park, Pennsylvania 16802-5301, USA.

They report that the enzyme responsible for S1P production, sphingosine kinase (SphK), is activated by ABA in *Arabidopsis thaliana*, and is involved in both ABA inhibition of stomatal opening and promotion of stomatal closure. Consistent with this observation, inhibition of SphK attenuates ABA regulation of guard cell inward K^+ channels and slow anion channels, which are involved in the regulation of stomatal pore size. Surprisingly, S1P regulates stomatal apertures and guard cell ion channel activities in wild-type plants, but not in knockout lines of the sole prototypical heterotrimeric G-protein α-subunit gene, *GPA1*. This Results implicate heterotrimeric G proteins as downstream elements in the S1P signalling pathway that mediates ABA regulation of stomatal function, and suggest that the interplay between S1P and heterotrimeric G proteins represents an evolutionarily conserved of Stomatal movement.

2.3. Lingang Zhang, Guangzhen Hu,Yuxiang Cheng & Jirong Huang[3] :

Year: 2008, Study Location: Institute of Plant Physiology and Ecology Shanghai Institutes for Biological Sciences, Chinese Academy of Sciences, China.

Lingang Zhang *et al.,* wanted to see Stomata are essential for efficient gas and water-vapor exchange between the atmosphere and plants. Stomatal density and movement are controlled by a series of signal molecules including phytohormones and peptides as well as by environmental stimuli. It is known that heterotrimeric G-proteins play an important role in the ABA-inhibited stomatal opening. In this study, the G-protein signaling pathway was also found to regulate stomatal density on the lower epidermis of Arabidopsis cotyledons. The loss-of-function mutation of the G-protein α-subunit (GPA1) showed a reduction in stomatal density, while overexpression of the constitutively active form of GPA1QL increased stomatal density, indicating a positive role of the active form of GPA1 in stomatal development. In contrast, stomatal density increased in the null mutant of the G-protein β-subunit (AGB1) but decreased in transgenic lines that overexpressed AGB1. Stomatal analysis of the gpa1 agb1 double mutants displayed an average value of stomatal density compared to the single mutants. Taken together, these results suggest that the stomatal density in Arabidopsis is modulated by GPA1 and AGB1 in an antagonistic manner.

2.4. E. Nilson and M. Assmann[4] :

Year: 2010, Study location: Biology Department, Pennsylvania State University, University Park, Pennsylvania, United States.

Nilson and M. Assmann are found that the a-subunit of the heterotrimeric G protein in Arabidopsis (Arabidopsis thaliana), GPA1, is a regulator of TE. gpa1 mutants, despite having guard cells that are hyposensitive to abscisic acid-induced inhibition of stomatal opening, have increased Transpiration efficiency (TE), under ample water and drought stress conditions and when treated with exogenous abscisic acid. Leaf-level gas-exchange analysis shows that gpa1 mutants have wild-type assimilation versus internal CO2 concentration responses but exhibit reduced stomatal conductance compared with ecotype Columbia at ambient and below-ambient internal CO2 concentrations. The increased TE and

reduced whole leaf stomatal conductance of gpa1 can be primarily attributed to stomatal density, which is reduced in gpa1 mutants. GPA1 regulates stomatal density via the control of epidermal cell size and stomata formation. GPA1 promoter::β-glucuronidase lines indicate that the GPA1 promoter is active in the stomatal cell lineage, further supporting a function for GPA1 in stomatal development in true leaves.

TE is under genetic control, although only one specific gene, ERECTA, has been shown to regulate TE. Recently, a new class of G proteins, GPCR type G proteins (GTG1 and GTG2), have been identified in Arabidopsis that also serve as one class of abscisic acid (ABA) receptors.

One Figure: 2.1 was added in below depends on Nilson and M. Assmann.

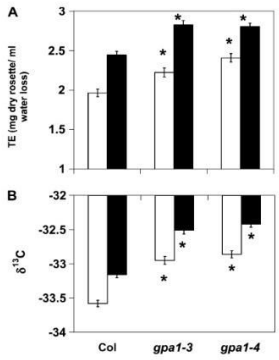

Figure 2.1: gpa1 mutants have increased TE and increased $\delta\ ^{13}C$ (reduced discrimination) compared with Col. Mean TE and mean $\delta\ ^{13}C$ values of rosette tissue of gpa1 and Col under ample water (white bars) and drought stress (black bars) conditions are shown. Error bars represent SE. Asterisks indicate that means differ significantly from the mean of Col within the treatment (P, 0.05)

Conclusion:

In higher plants water is absorbed through root hairs which are in contact with soil water and from a root hair zone a little the root tips. he walls of root hairs are permeable to water and are hydrophilic in nature. They contain vacuoles filled with cell sap. Absorption of water by roots takes place by two Mechanism namely, active absorption and passive absorption.

Transpiration one of the most important Factor for plant life. Transpiration in plants is a crucial process. In the absence of transpiration, excess water will get accumulated in the plant cells**,** and the cells will eventually burst. More than 10% of the earth's moisture is from transpiration. It is known to be a part of the water cycle.

Stomata are minute pores present on the lower side of the leaves that help in the exchange of gases and water vapour. When the stomatal pores open the rate of transpiration increases, and when the pores are closed, the loss of water is reduced. lants need CO_2 to enter and O_2 to exit. Stomata close when it is dark and dry, unless carbon dioxide levels inside the leaf start to fall.

The factors that greatly influence and control stomatal movements i.e., opening and closing of stomata, e.g., Light, Temperature, Atmospheric Humidity, Wind, Available Soil Water, Root/Shoot Ratio, G-protein. GPA1 increased stomatal density, indicating a positive role of the active form of GPA1 in

stomatal development. The first concrete genetic evidence for involvement of heterotrimeric G-proteins in defense mechanisms came from the research done in rice mutant.

Given the involvement of GPA1 in the regulation of stomatal movements and interestingly, gpa1 mutants displayed increased TE under both ample water and drought stress conditions. the plant G protein complex regulates nitrogen signaling and modulation of heterotrimeric G protein activity provides a strategy for environmentally sustainable increases in rice grain yield.

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