The role of silicon as a nutrient/biostimulant in strawberries

B. Liu[1], C. Asiana[1], H. Wileman[1], X. Jin[2] and A.M. Hall[1]
[1]School of Life and Medical Sciences, University of Hertfordshire, Hatfield, UK;
[2]Department of Biological Sciences, National Sun Yat-Sen University, Kaohsiung, Taiwan

Introduction

- All plants grown in soil contain silicon (Si) in their tissues, with concentrations that vary from 0.1% to 10% of their dry weight.
- Si is referred to as "quasi-essential" for the growth of higher plants due to its important role in alleviating abiotic and biotic stresses. It can be taken up in a bio-available form - H_4SiO_4 (Ma et al., 2011).
- Work at the University of Hertfordshire showed that regular use of a Si nutrient enhanced constitutive (passive) defence pathway (i.e. morphological changes in the leaf structure) in strawberry plants, resulting in increased resilience to diseases (e.g. strawberry powdery mildew *Podosphaera aphanis*) and pests (e.g. two-spotted spider mites *Tetranychus urtiae*). An increase in plant biomass and improvements on other agronomic traits were also found (results shown from 2018-2019 glasshouse hydroponic experiments).
- Si is mainly laid down in epidermis and in the form of phytoliths.

Aim: to investigate the role of bioavailable Si as a nutrient/biostimulant in strawberry growth; its effects on enhancing the passive defence pathway and how did these changes contribute to improved plant resilience.

Materials and Methods

2013-2018 field experiment

- All field experiments (Table 1) were done in polythene tunnels on a commercial strawberry farm at Wisbech, Cambridgeshire, UK;
- The Si nutrient product used was Sirius® (main active ingredient: 70-80% tetraethyl silicate, OrionFT), applied via the fertigation system;
- Area Under the Disease Progress Curve (AUDPC) was used for the analysis of *P. aphanis* development.

2018-2019 Glasshouse experiment

- Two hydroponic experiments were set up in the glasshouse in 5L plastic containers filled with Hoagland's solution and equipped with aeration pumps. Hoagland's solution comprised of deionised water, macronutrients and micronutrients essential for plant growth (no Si) (Jones, 2016).

Table 1 Details of Si field and glasshouse experiments between 2013 and 2019

	Year	Cultivation type	Treatment	Application interval	Assessment
Field experiment	2013	Tunnel	0.017% Si root application, 0.017% Si root application + commercial fungicide, Commercial fungicide only, Untreated control	Twice a week	Number of *P. aphanis* colonies per leaf
	2014, 2015	Tunnel	0.017% Si root application, 0.017% Si root application + commercial fungicide, Commercial fungicide only, Untreated control	Weekly	% *P. aphanis* mycelium leaf coverage, Number of *T. urticae* per leaf
	2016, 2017-2018	Tunnel		Twice a week	% *P. aphanis* mycelium leaf coverage
Glasshouse hydroponic experiment	2018	Glasshouse	50ml 0.017% Si, 50ml deionized water	Weekly	Number of leaves/fruits, Leaf chlorophyll content, Total biomass
	2019	Glasshouse	50ml 0.017% Si, 50ml 0.17% Si, 50ml 1.7% Si, 50ml deionized water	Weekly	

Table 2 AUDPC values for *P. aphanis* from Si field experiments between 2013 and 2016

Treatment	2013 Root	2014 Root	2015 Root	2016 Root
Untreated control	60.4	662	281	3,423
Commercial fungicide only	1.2	106	69	2,825
0.017% Si only	12.8	475	267	1,610
0.017% Si plus commercial fungicide	0.6	63	53	732

Table 3 Agronomic traits results from Si glasshouse hydroponic experiments in 2018 and 2019

	2018 experiment		2019 experiment			
Assessment criteria	Untreated control	0.017% Si	Untreated control	0.017% Si	0.17% Si	1.7% Si
Average number of leaves at the end of treatment	20	29	15	15	18	7
Average chlorophyll content of leaves (µmol m^2-1)	665.1	813.5	-	-	-	-
Average number of fruits	15	32	55	75	73	25
Average total biomass (g)[a]	144	169	28.42/4.15	23.9/4.55	26.67/4.31	9.06/2.89

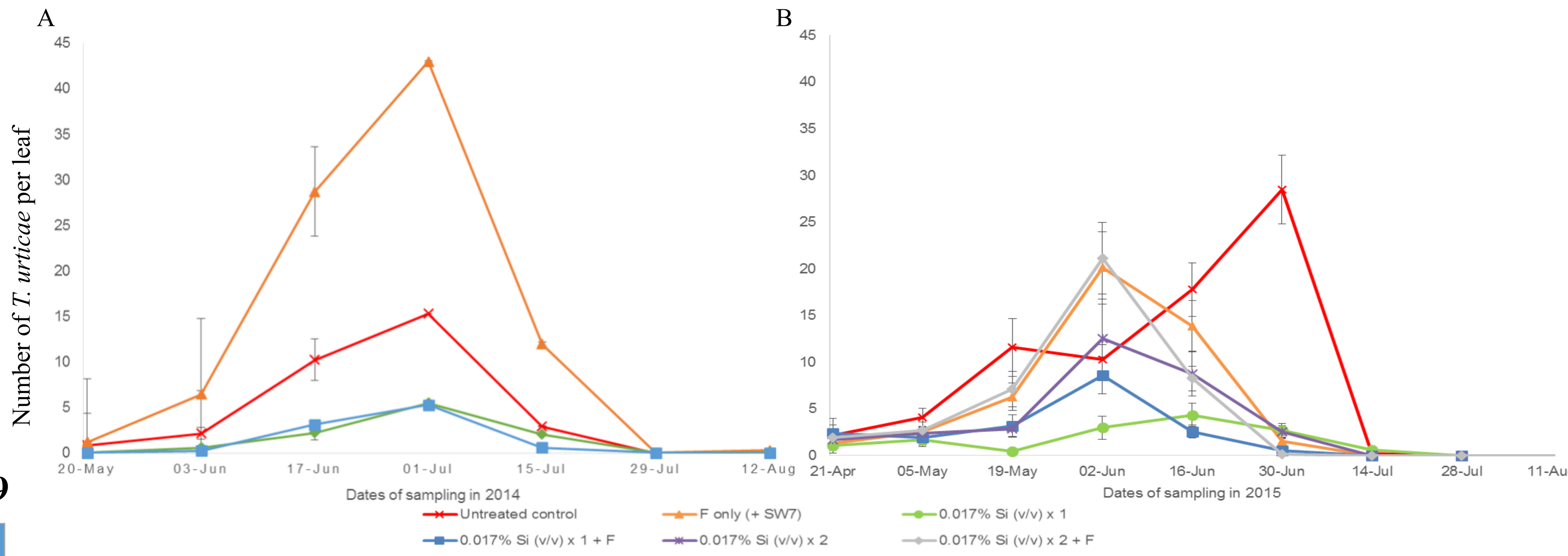

Fig. 1 Number of *T. urticae* per strawberry leaf from 2014 (A) and 2015 (B) Si fertigation trials. Treatments were: untreated control (2014 & 2015), commercial fungicide only (2014 & 2015), 0.017% Si only (2014 & 2015), 0.017% Si plus commercial fungicide (2014 & 2015), 0.017% Si double dosage only (2015), 0.017% Si double dosage plus commercial fungicide (2015).

Results

1. Field experiment on plant resilience:

- Strawberry crops that received weekly Si application (with or without fungicide) had reduced severities to *P. aphanis* ($P < 0.05$) (2013-2016, Table 2) and *T. urticae* (2014-2015, Fig. 1) than the untreated control crops;
- In particular, Si only treatment had lower disease level (represented by AUDPC values, Table 2) than untreated control (2013-2016);
- Si only treatment delayed the epidemic for two weeks compared to the no Si treatment (2013-2014).

2. Glasshouse experiment on agronomic traits:

- The wet biomass of Si treated plants was significantly higher ($P < 0.05$) than untreated plants (2018) (Table 3);
- More leaves and higher chlorophyll content ($P < 0.05$) and significantly more fruits ($P < 0.05$) in Si treated plants (2018 & 2019);

3. Si deposition:

- Si treated plants had thicker leaf cuticle (Fig 2A&B) and denser layer of leaf wax (Fig 2C&D).
- A significantly ($P < 0.05$) higher level of Si content was found in Si treated plants than untreated ones (Fig. 3). Si was mainly deposited in leaf epidermis and palisade layers (Fig. 3B).

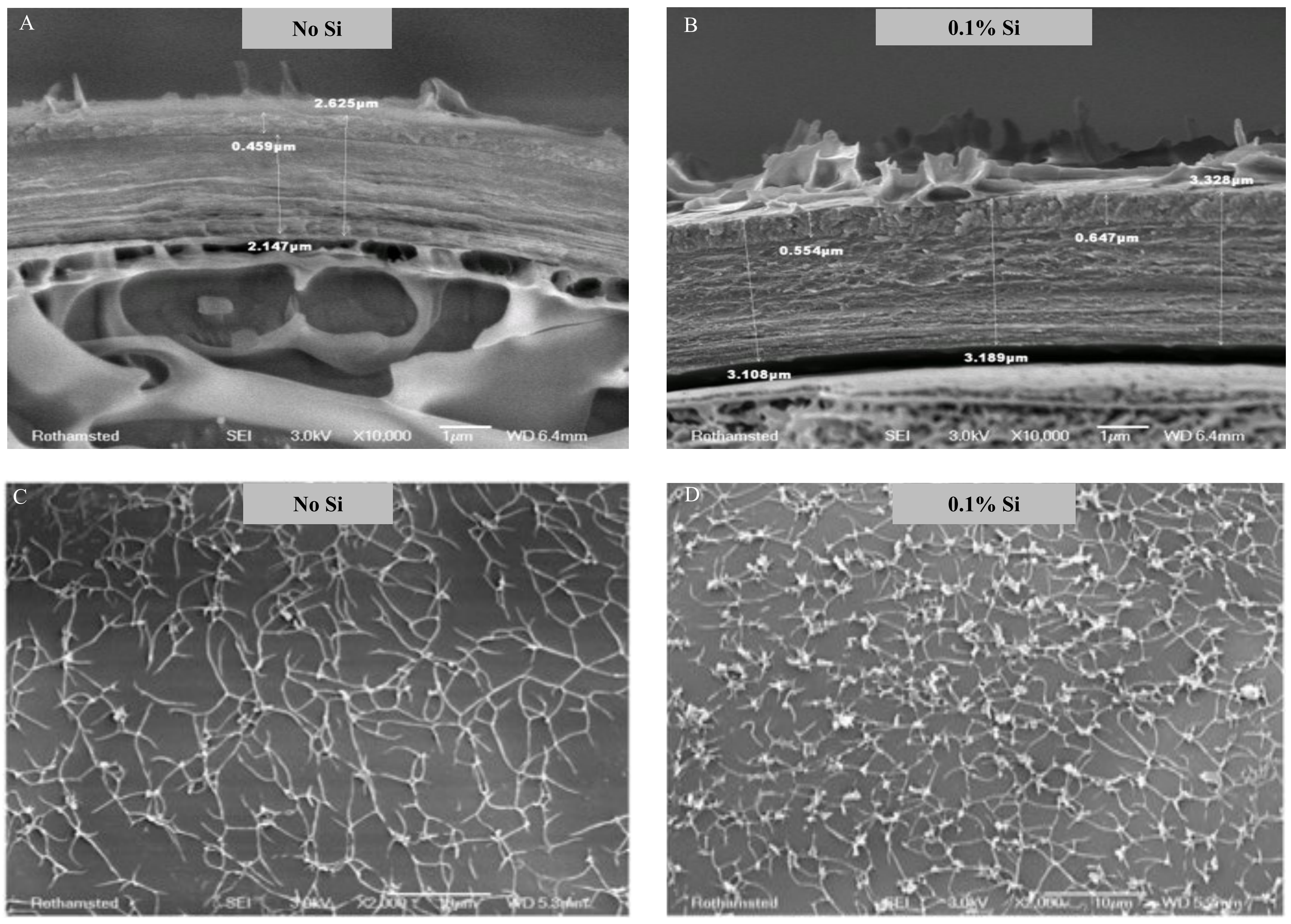

Fig. 2 Scanning Electron Microscope images taken at Rothamsted Research (UK) of strawberry leaf cuticle without Si application (A) and with 0.1% Si root application (B); Wax formation on strawberry leaves without Si (C) and with 0.1% Si root application (D). (Jin, 2016)

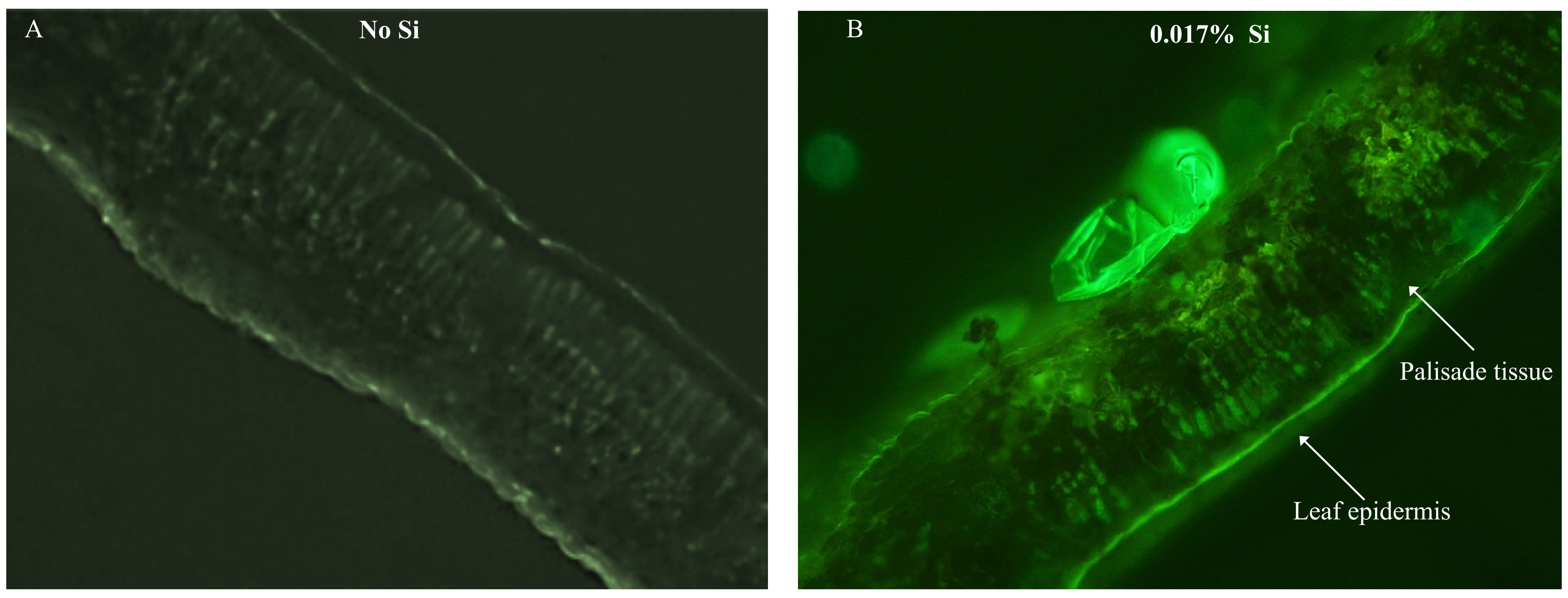

Fig. 3 Cross section of strawberry leaves from control (A) and 0.017% Si root application (B) treatments stained with molecular tracker dye observed under the Confocal microscope. Si was mainly deposited (areas showing fluorescence) in leaf epidermis and palisade layers (B) (Asiana, unpublished)

Discussion

- Regular application of Si nutrient improved crop resilience against *P. aphanis* and *T. urticae*. Si enhanced the constitutive defence pathway of strawberry plants, resulting in increased leaf cuticle thickness and wax density, hence strengthening plant physical barriers against external attacks;
- Stimulatory effects Si nutrient on plant agronomic traits, including biomass, leaf and fruit numbers of strawberry plants have also been found;
- Good crop management can be achieved by a continuous supply of bioavailable Si at a recommended rate via the farm fertigation system.

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