MINISTRY OF FOOD & AGRICULTURE

KNOWLEDGE SHARING

MASTER OF AGRICULTURE

FOOD SECURITY AND AGRICULTURAL DEVELOPMENT

KYUNGPOOK NATIONAL UNIVERSITY

DAEGU, SOUTH-KOREA.

PRESENTED TO STAFF OF THE CIVIL SERVICE OF GHANA

26TH JUNE 2024

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ACCRA

2022 KOICA scholarship
Master of Agriculture
Food Security and Agricultural Development
Kyungpook National University
Daegu, South-Korea

Presentation Outline

- Background and Introduction
- Research and Thesis
- Achievement
- Comments

Introduction

KOICA
Korea International Cooperation Agency

The Korean International Cooperation Agency in collaboration with the Kyungpook National University (KOICA-KNU) offers educational scholarships for a 17-month Master's Degree Program under the Capacity Improvement and Advancement for Tomorrow (CIAT) initiative for partner countries including Ghana.

KNU

Acknowledged as Korean No. 1 University, established in 1946 and located in Daegu, Republic of Korea. Made up of 17 Colleges, 74 Departments and 26 Schools. Runs 146 Masters programs and 133 PhD programs. Student population stands at 35, 482 (Undergraduate 28, 693, Graduate 6,789).

Agricultural Production Program

Exposes participants to the Korean experience and practical knowledge of agricultural production technology and best agricultural practices that accelerated Korea's growth and development. The overall goal is to equip participants to solve developmental issues in the agricultural sector.

Specifically, the program;

- Trains public officials to become changing agents for development, contribute to the agricultural production development of their respective countries, region, and the global society as a whole.
- Shares Korean experiences of economic and social development and provides practical knowledge of agricultural production technology and good practices that accelerated Korea's growth.
- Strengthens strategic partnership with developing countries for future collaboration in the agricultural production sector.

Class make-up


Ghana


Philippines


Rwanda


Uganda


Bangladesh


Tanzania


Nepal


Cambodia


Laos PDR


Nigeria

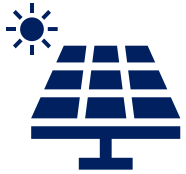

Zimbabwe


Vietnam

Total of 19 students, from 12 countries

Program modules and Courses

Crop Seed Production



Crop Cultivation Technology

Environment and Crop Protection

Agricultural Policy

- Climate Change and Food Production
- Comprehensive Crop Physiology
- Introductory Plant Biotechnology
- Advanced Seed Production Technology
- Post-Harvest Technology
- Weed Management
- Advanced Food Safety
- Korean Language
- Field Seminar (I & II)
- Research and Thesis Writing

Academic Internship

1. Korean Agric. Machinery
2. Agric. Technology Extension
3. Rice Processing Complex (RPC)
4. Yam and Sweet-potato processing
5. Hydroponic Farming

Research and Thesis Presentation

KOICA
Korea International Cooperation Agency

Presentation for the Degree of Master of Agriculture

KNU

The Dynamics of Humic Acid, Silicon and Biochar in Mitigating Diverse Abiotic Stresses in Rice (*Oryza sativa* L.)

Appiah Gregory Aneefi (2022427853)

Supervisor: **Professor In-Jung Lee**

Laboratory**:** Crop Physiology

The Graduate School

Kyungpook National University

Department of Food Security and Agricultural Development

Presentation Outline

01 Introduction

02 Objectives

03 Materials & Methods

04 Results & Discussion

05 Conclusion

01. Introduction

* Sustainable Development Goal 2 focuses on availability of food for the world's population.
* Over 520 million people depend on rice for daily food.
* Rice production is threatened by abiotic factors.

* Climate change, rapid population upsurge, and massive anthropogenic activities are the three main causes of
  - Salinity Stress: 50% productivity ↓
  - Drought Stress : 70% productivity ↓
  - Heavy Metal toxicity : 20% productivity ↓

Mode: Interfere with critical **physiological pathways**, leading to plant death or low productivity.

Impact of saline soil on plant physiology

Saline Soil

Osmotic stress

Changes in plant morphology and yield contributing characteristics

- Decrease in shoot and root growth
- Less biomass accumulation and decrease in crop productivity
- Nutritional disorder (low K^+/Na^+ ratio) and ionic homeostasis

Changes in physiological and biochemical attributes

- Decrease in chlorophyll (a & b) content in leaves
- Increase in ROS generation
- Changes in antioxidant enzymatic activities
- Increased proline accumulation

Effects of drought stress

Plant response to drought stress

Decline in photosynthesis and other processes and finally reduced yield

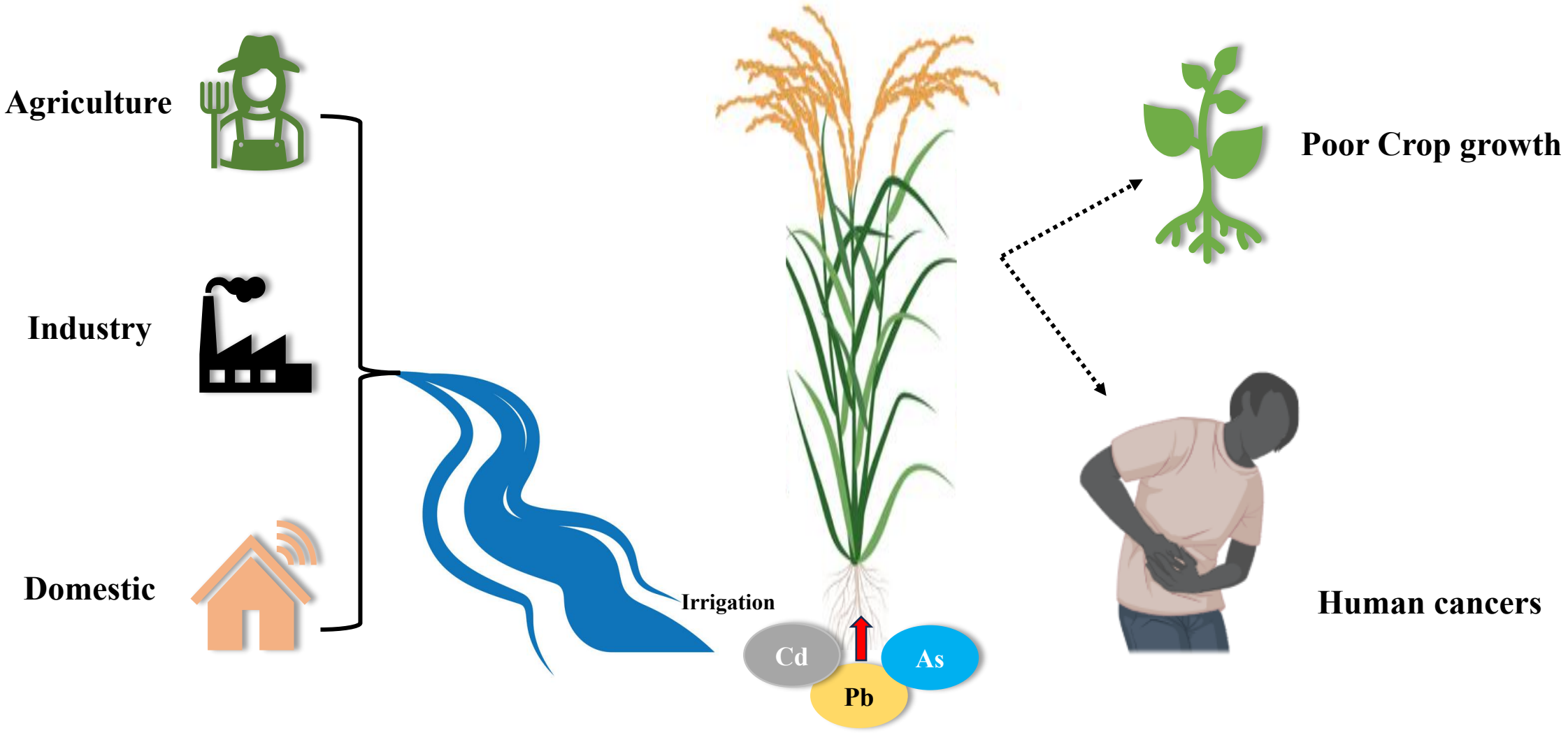
- Stomata conductance
- Decrease in CO_2 intake
- Lower tissue water potential
- Oxidative damage to chloroplast
- ATP synthesis obstruction
- Decrease nutrient uptake

- Increase in ROS scavenging substances (SOD, POD, CAT, APX)
- Stomata closure
- Production of phytohormones
- Water uptake from around and deeper soil

Maintain photosynthesis and other drought related processes, finally maintain and improve yield.

Transpiration and Evaporation

Heavy metal sources and impact



Contribution of silicon against plant stresses

Si deposition in the plant tissues in the form of silicate bodies

Silicic acid/Potassium silicate/Sodium silicate

Biotic stress

Abiotic stress

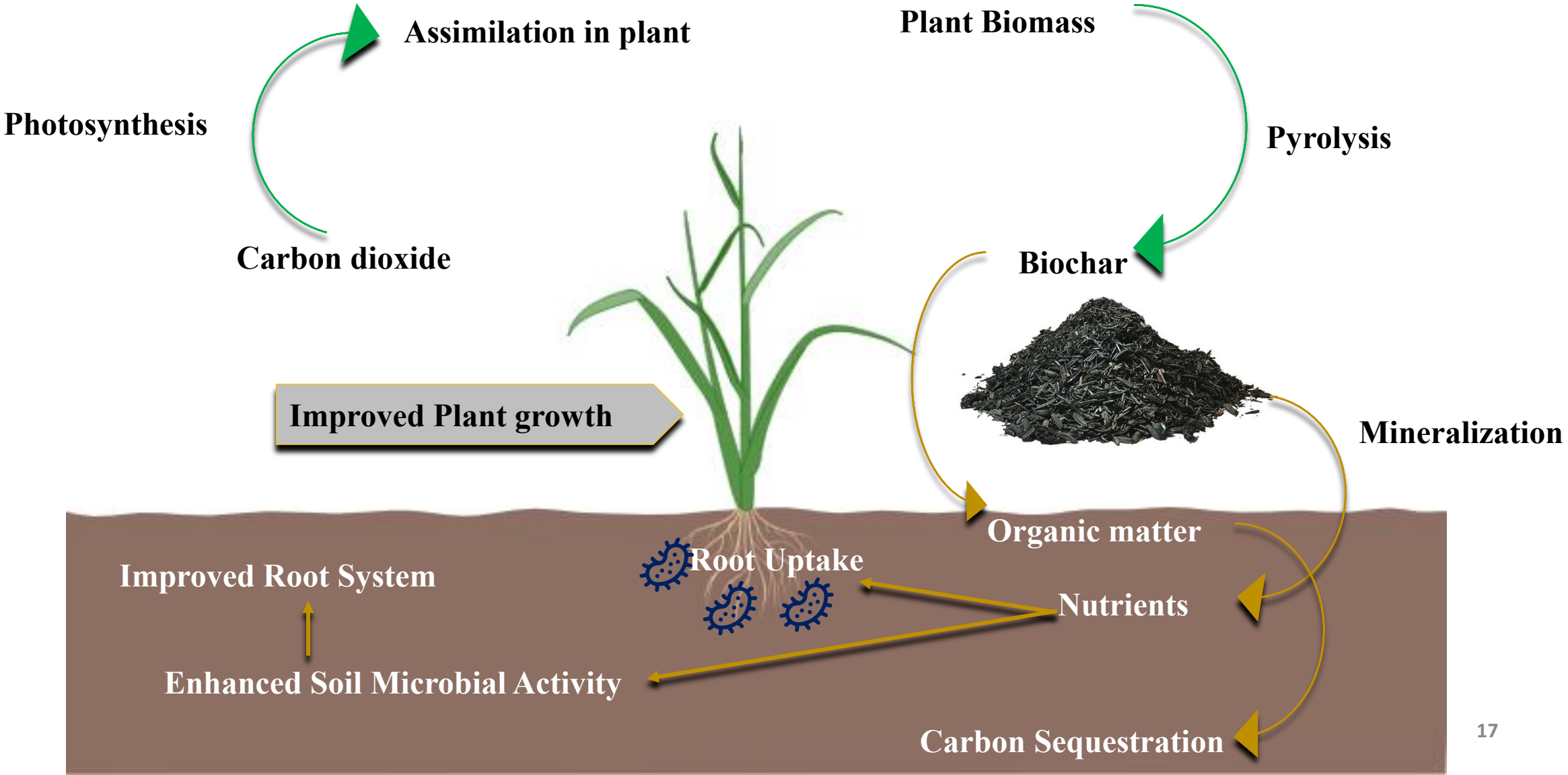
Physical barrier

- Strengthen cell wall
- Prevent pathogen entry
- Reduce transpiration

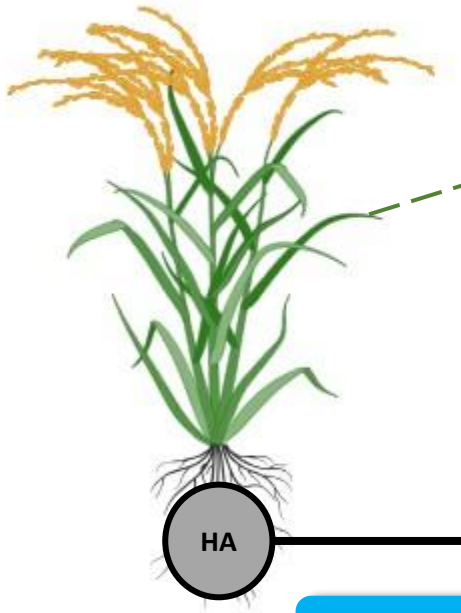
Physiological and Biochemical responses

- Regulation of defense enzymes level
- Increase nutrient uptake
- Regulation of mineral uptake
- Antioxidant defense
- Osmolyte regulators
- Phytohormones signaling

Biochar effect on plant growth



Humic Acid effect on plant stress



Response

ROS Scavenging

Osmoprotection

Membrane Stability

Ion Homeostatis

HA

Physically

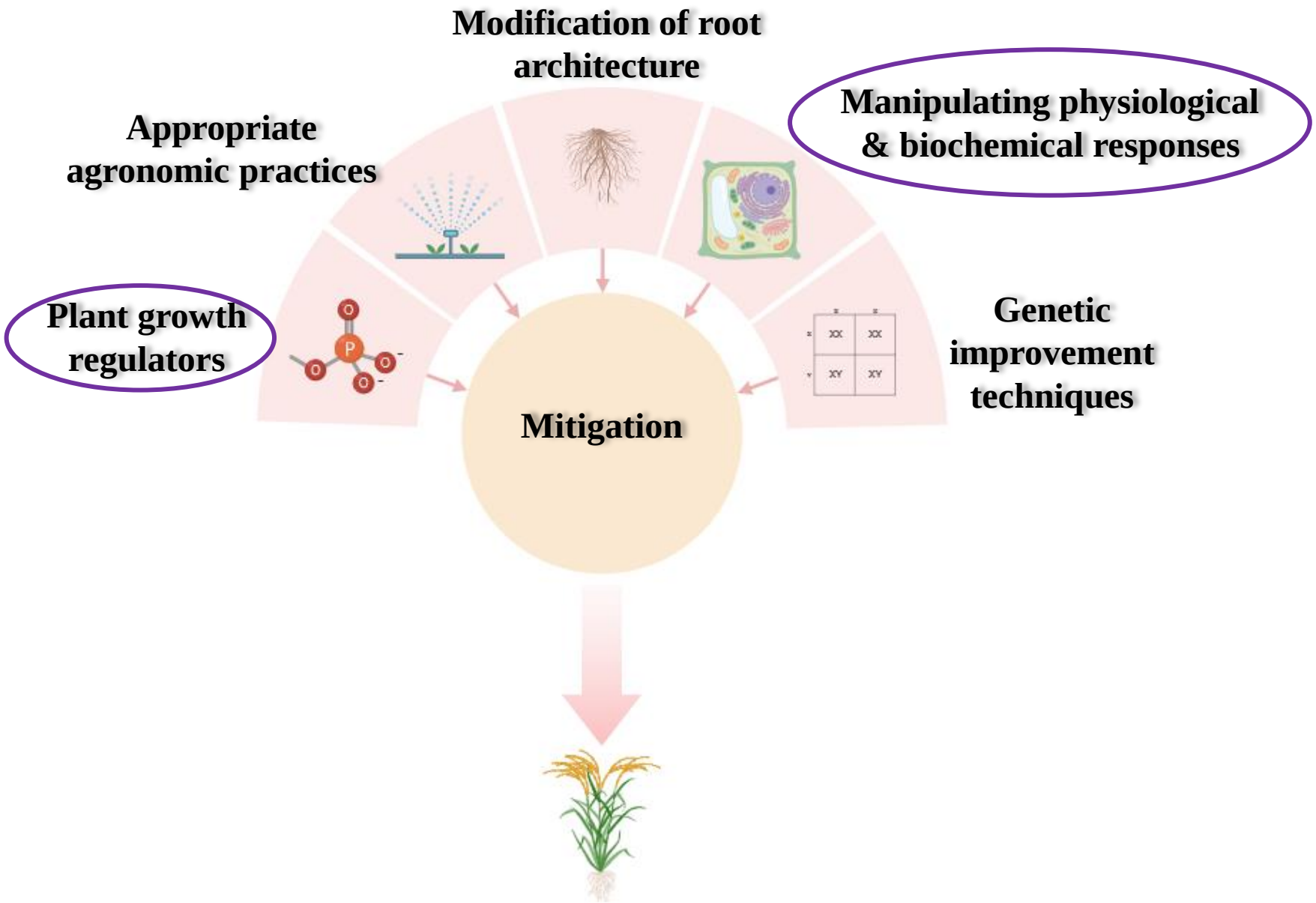
Improves soil structure, water & nutrient holding capacity and aeration, Reduces risk of soil erosion

Chemically

Main source of N,P,&K, Reduces soil toxicity and increases fertilization efficiency

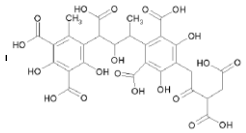
Biologically

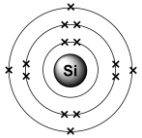
Stimulates soil microbiological activity, increase plant membrane permeability, respiration, photosynthesis & cell elongation. Produces growth hormones


Modification of root architecture
Appropriate agronomic practices
Manipulating physiological & biochemical responses
Plant growth regulators
Genetic improvement techniques
Mitigation
Strategies to mitigate rice stress

Objective

Main:
To determine the dynamics of HA, Si, and Bio in ameliorating the resilience of rice plants under drought, salinity and heavy metal stresses.





OBJECTIVE 1

Investigate the effect of the combined application of HA+Si+Bio in enhancing rice resilience to **drought stress**.

OBJECTIVE 2

Evaluate the influence of the combined application of HA+Si+Bio in improving rice resilience to **salt stress**.

OBJECTIVE 3

Establish the role of the combined application of HA+Si+Bio in enhancing rice resilience to **heavy metal (Cd, Pb, As) toxicity.**

02. Materials and methods

Screening for appropriate Concentrations of HA, Si and Bio

Method

- Variety: Hwayeongo **(화영여)** rice
- 21 days old equal sized seedlings raised in hydroponic system.
- Treated with ;
  - HA: 1%,2%, 3%, 4%, 5%
  - Bio: 1%,2%, 3%, 4%, 5%
  - Si:1mM,2mM,3mM,4mM, 5mM
- 7 consecutive days (observation and response documentation)

Ctrl **Bio** **HA** **Si**

Optimum doses were selected as **2mM Si, 1% HA, and 2% Bio** for all the stresses, and applied in the greenhouse experiment.

Response

- Si (5mM) showed burning effect on rice shoots & retarded plant growth characteristics.
- Biochar showed optimum growth with no detrimental effects in all the doses.
- Humic acid although showed no detrimental effects, significantly reduced the water pH with an increase in doses.

Experimental Design

Completely randomized design **(CRD)** consisting of eight **(8) treatments**, categorized **into four (4) growing conditions** and five **(5) replications** per treatment.

Condition	Treatment Number	Treatment Composition
No-Stress (Control) (NS)	T1	Water only
	T2	HA+Si+Bio
Salt-Stress (SS)	T3	NaCl only
	T4	NaCl + (HA+Si+Bio)
Drought-Stress (DS)	T5	Dr only
	T6	Dr + (HA+Si+Bio)
Combined Heavy Metal	T7	HM-C (As+Pb+Cd)
Stress (HM-C)	T8	HM-C

Graphical Presentation of Experimental Procedure

Seed treatment and pre-germination

Transplanting into seed trays (3wks)

Si/HA priming (8hrs)

Bio (2%)

CTRL NaCl DRT HM-C

Transplanted into pots

Observation of plant response

NaCl (200mM) DRT (30-40%) HM-C

-ve treatment application

+ve treatment application (10 DAT)

Harvesting & Sample collection

Analysis

Statistical analysis

Treatment Effect on plant growth (morphological) characteristics

Treatment	Tiller Number	Shoot Weight (g)
Control	15±0.86 ab	46.02±0.26 a
HA+Si+Bio	16.33±0.57 a	48.63±0.96 a
NaCl	11±1.32 c	27.92±0.34 d
NaCl(HA+Si+Bio)	14±0.5 b	36.15±0.34 c
Drought	14.5±0.5 b	34.92±2.30 c
Drought(HA+Si+Bio)	15.66±0.76 ab	41.61±1.98 b
HM-C	10.66±1.6 c	23.16±0.34 e
HM-C +HA+Si+Bio	11.66±1.44 c	27.28±2.82 d

HA+Si+Bio treatments significantly improved the Tiller Number and Rice Shoot weight

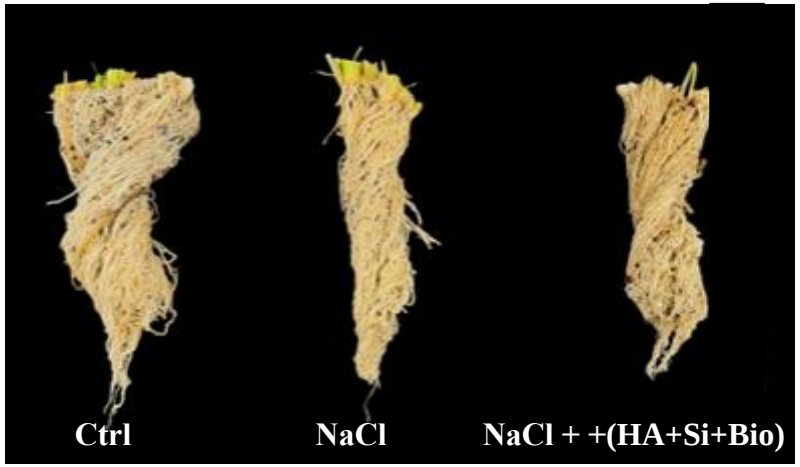
Ctrl NaCl NaCl +(HA+Si+Bio)

Ctrl Dr Dr +(HA+Si+Bio)

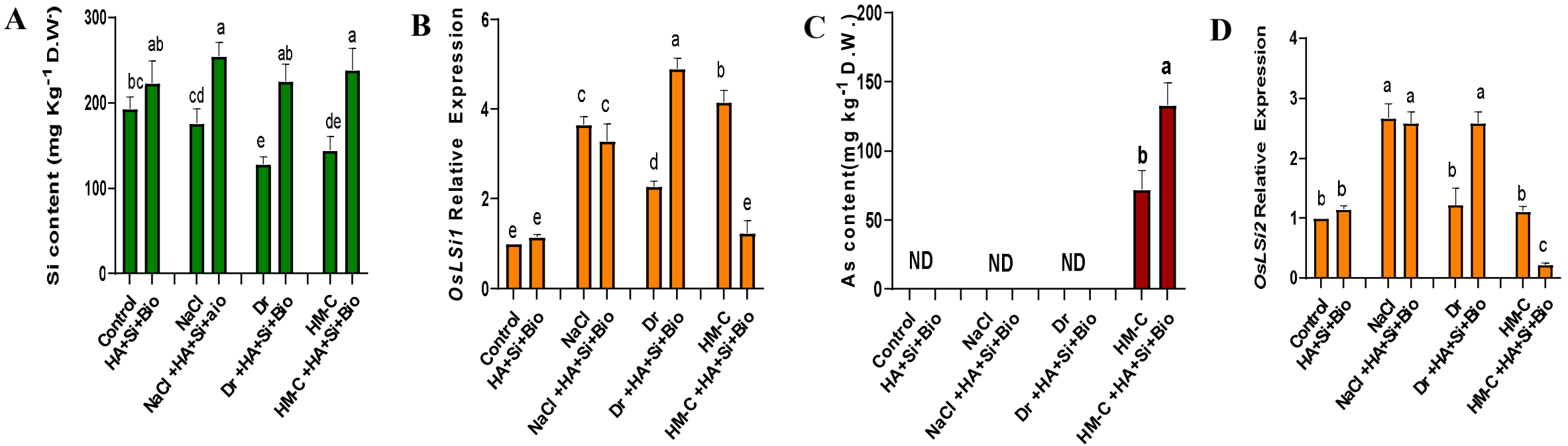
Treatment Effect on Plant Growth (morphological) characteristics

Treatment	Root Weight (g)	Shoot Length (cm)
Control	32.94±0.54 b	61.2±0.43a
HA+Si+Bio	34.81±1.07 a	61.8±0.44a
NaCl	18.12±0.49 e	59.46±0.20b
NaCl(HA+Si+Bio)	27.99±0.39 c	61.36±0.8a
Drought	25.35±0.37 d	59.2±0.45b
Drought(HA+Si+Bio)	31.92±1.43 b	61.7±0.43a
HM-C	19.2±1.25 e	56.16±0.32c
HM-C +HA+Si+Bio	24.16±1.92 d	56.13±0.37c

HA+Si+Bio treatments significantly enhanced root weight and shoot length of rice



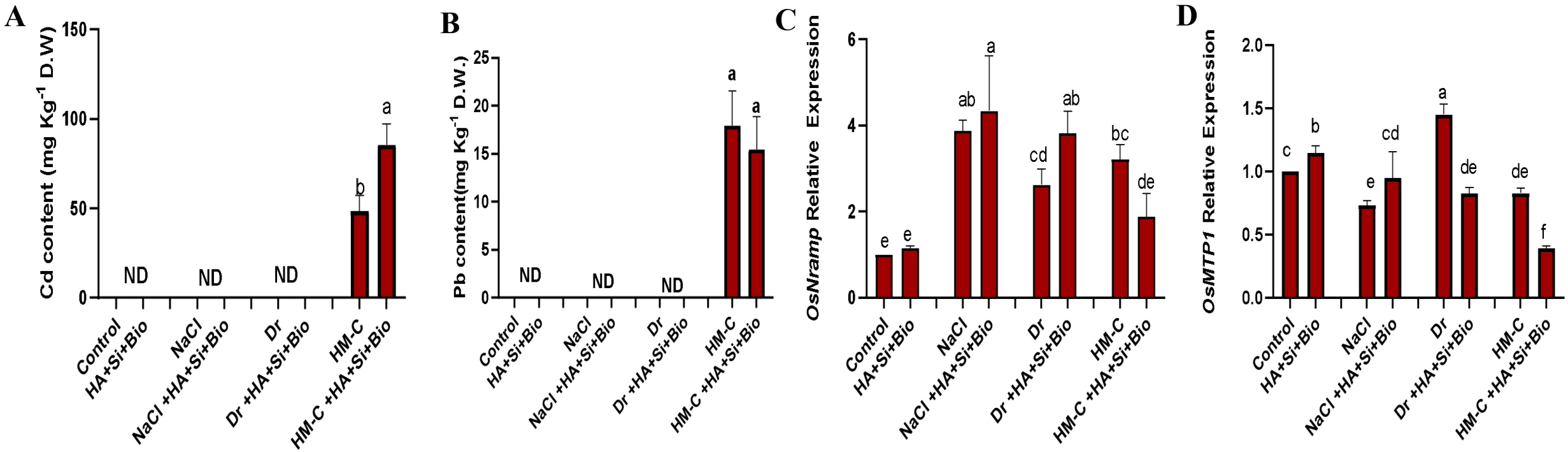
Quantification of Si and As and their transporters gene *Lsi1 and Lsi2* expression



- Metal transporter genes are pivotal in the **translocation and deposition** of mineral elements in a plant cell.
- **Higher** concentrations of Silicon **(Si)** and Arsenic **(As)** observed in rice plants treated with Si+Bio+HA.
- *LSi1* and *LSi2* exhibited elevated expression levels in response to drought stress, remained relatively unchanged during salt stress, and decreased in heavy metal (HM-C) stress conditions when treated with Si+Bio+HA.

(A)= Silicon content (B)= OsLSi1 expression (C)= As content (D)=OsLSi2 expression

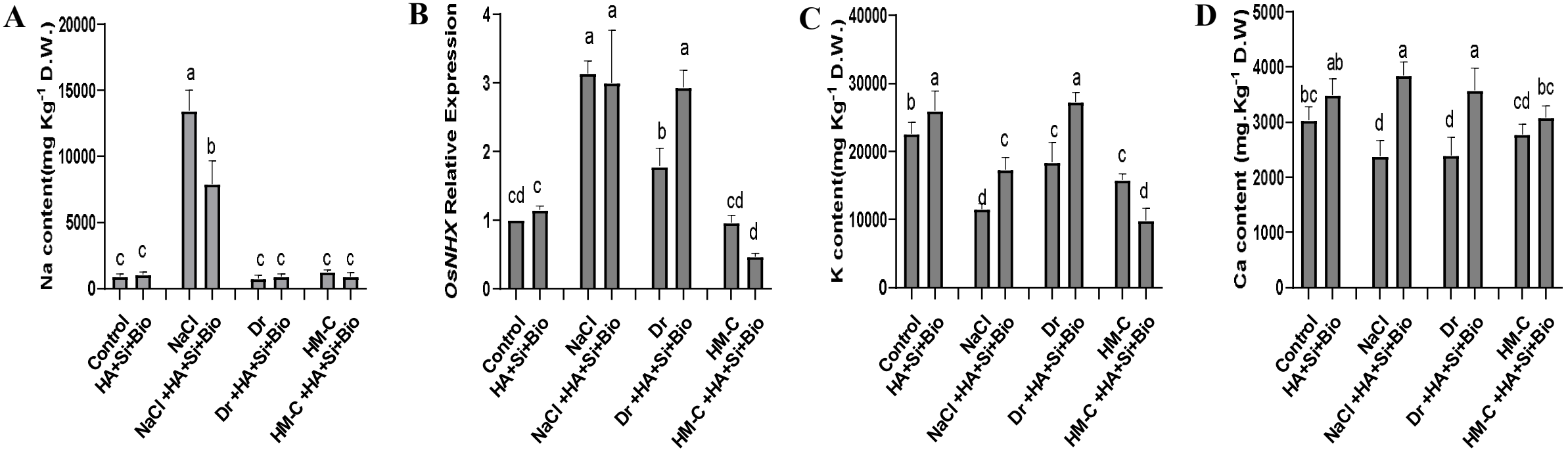
Quantification of Cd, Pb, and its related gene *OsMTP1 and OsNramp* expression



- Cd concentration was significantly increased by Si+Bio+HA whereas, Pb concentration remained stable.
- Si mitigates several abiotic stresses including heavy metals.
- Metal tolerance protein genes (MTPs) are the specific transporter involved in the sequestration of heavy metal ions.
- *OsMTP1* and *OsNramp* were significantly elevated in stressed condition but were lowered by Si+Bio+HA treatments under HM-C stress.

(A) = Cadmium content (B) = Lead content (C) = *OsNramp* expression (D)= *OsMTP1* expression

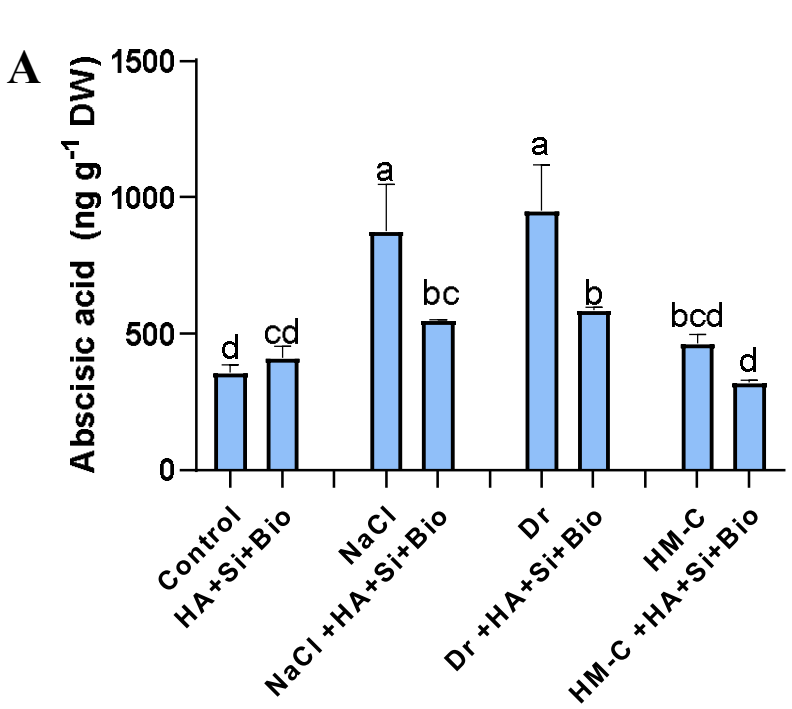
Analysis of $Na^+/K^+/Ca^{2+}$ and its regulator *OsNHX1* expression

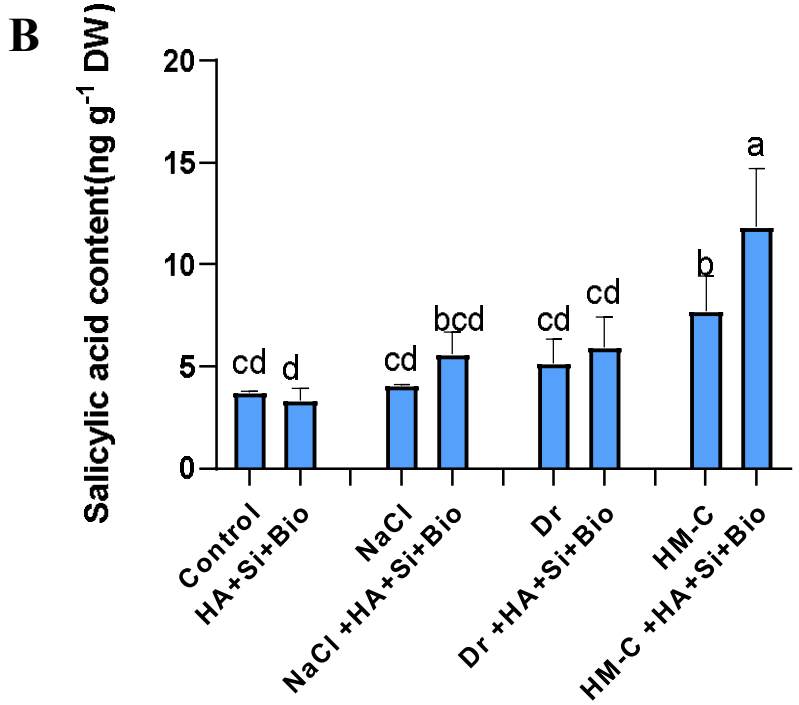


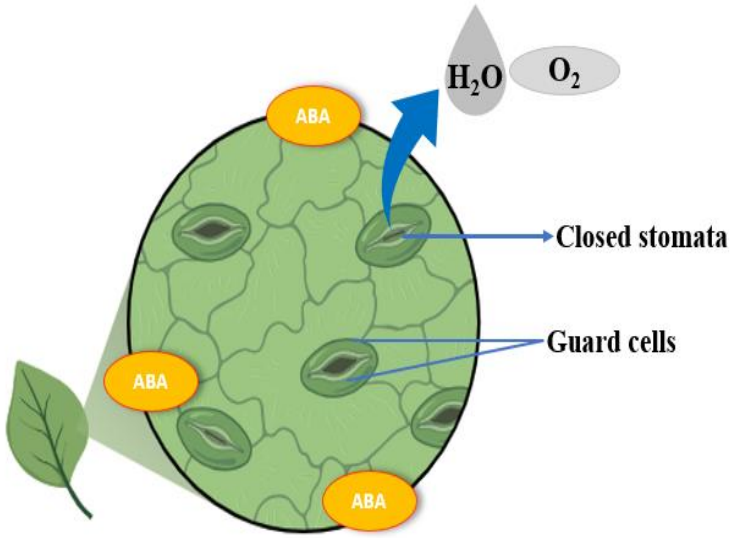
- Si+Bio+HA combination significantly elevated the uptake of Ca^{2+} and K^+ under all conditions, while substantially reducing the influx of Na+ in salt-stressed crops.
- NHX family genes contributes significant role in maintaining and regulating Na^+ homeostasis in crops to enhance stress tolerance.
- Si+Bio+HA treated plant showed significant improvement in plant growth attributes under salt and drought stress where the expression of the Na^+/H^+ antiporter gene *(OsNHX1)* was found to be considerably elevated.

(A)= Sodium content (B)= *OsNHX* expression (C) = Potassium content (D)= Calcium content

Endogenous phytohormones analysis (ABA and SA)





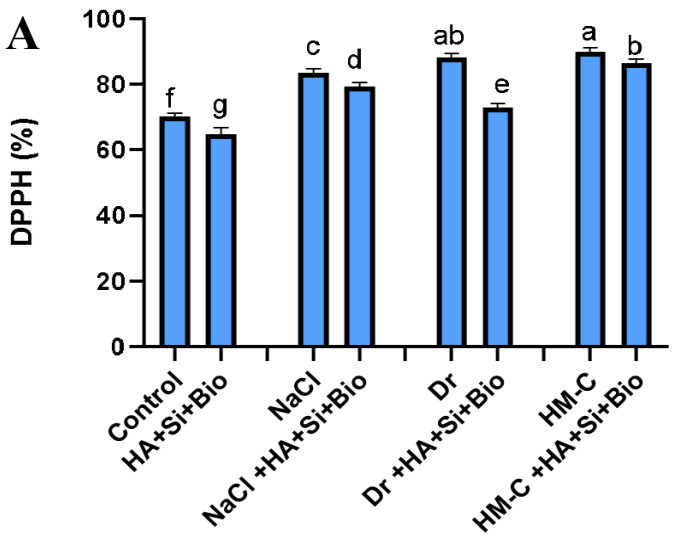


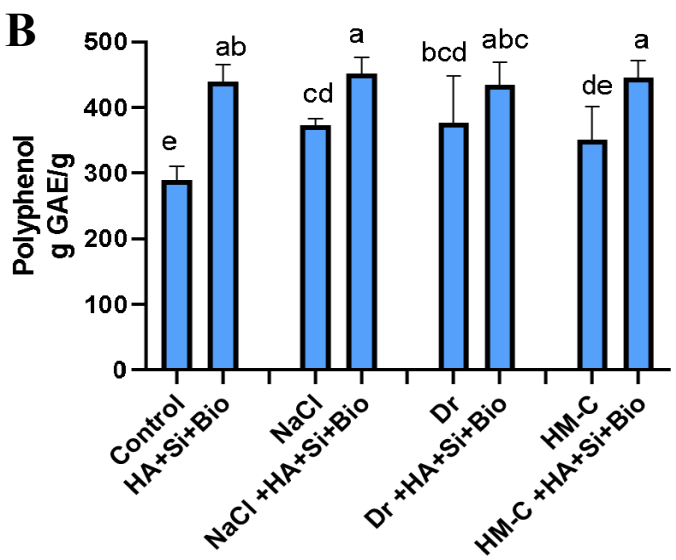
- ABA, a key regulator of stomata closure, induces expression of stress-responsive genes.
- High ABA level = high plant stress.
- SA is noted for signaling network to induce plant defense against stress.

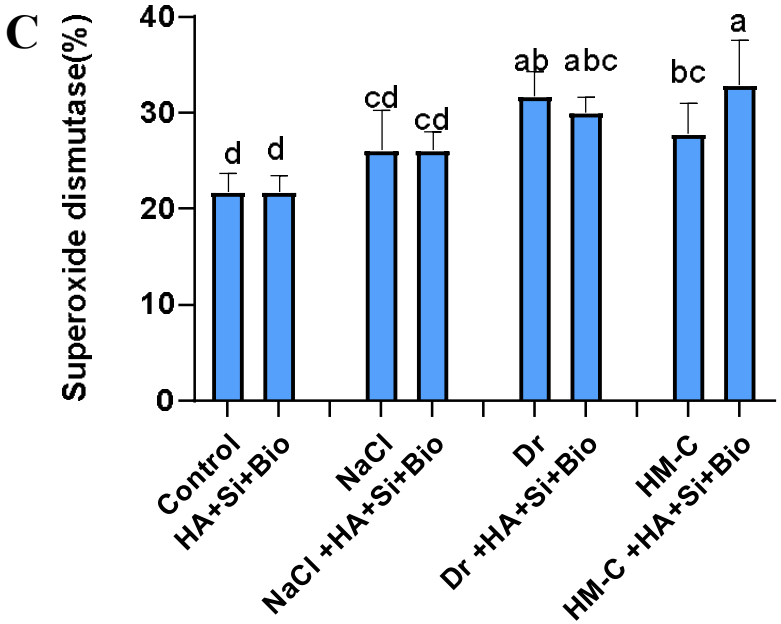
Treatment with Si+Bio+HA significantly reduced the ABA levels while elevating the concentration of SA.

(A) = Abscisic acid content (B) = Salicylic acid content

Assay of Antioxidant activities



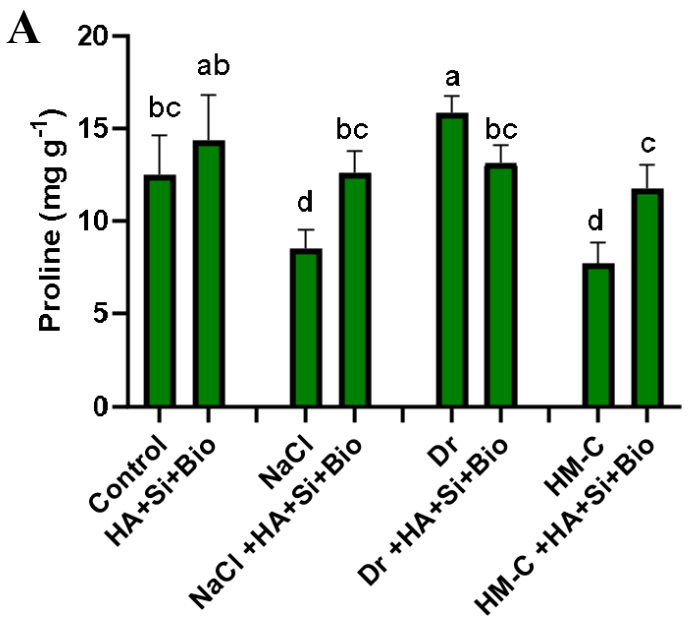


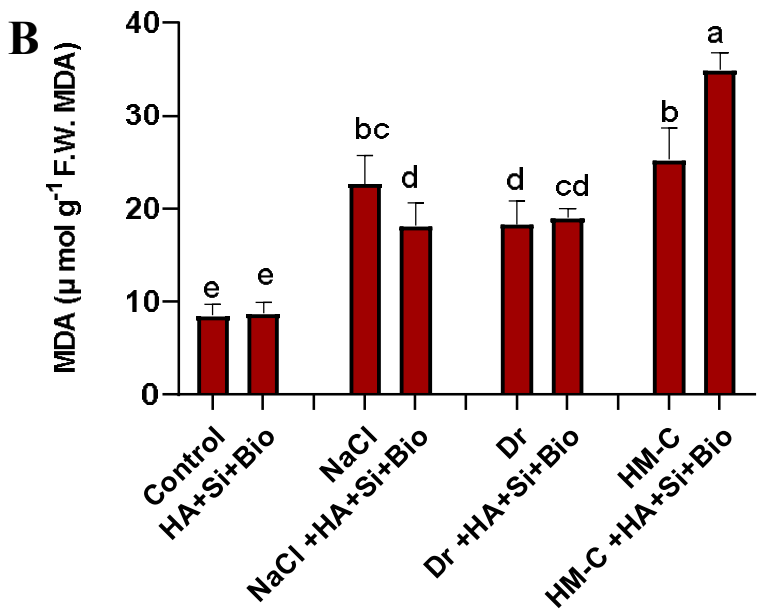


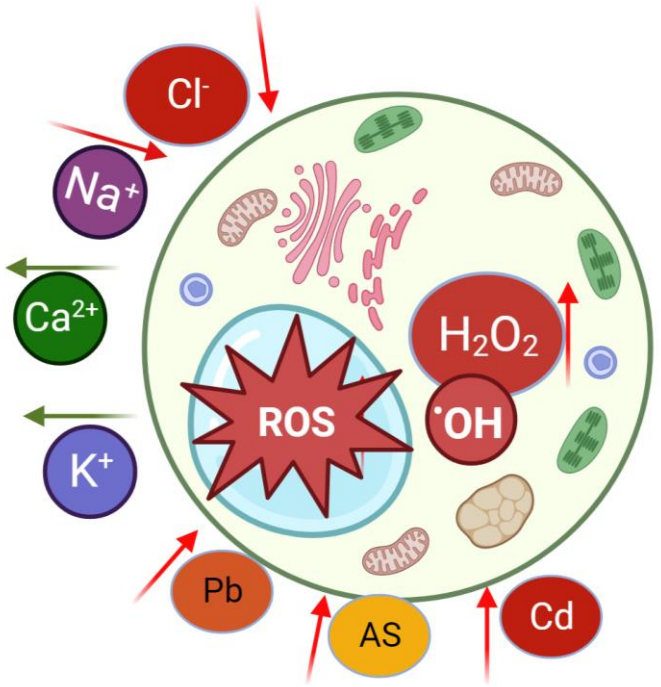
- ROS (e.g. superoxide radicals, H_2O_2) damage cells.
- Antioxidants protect plants from oxidative stress caused by ROS.
- Antioxidants scavenge and neutralize ROS for cell integrity.

Si+Bio+HA treatments notably enhanced antioxidant activities, particularly polyphenol content, while the activities of SOD and DPPH radical scavenging displayed distinct patterns.

Determination of Proline and MDA level







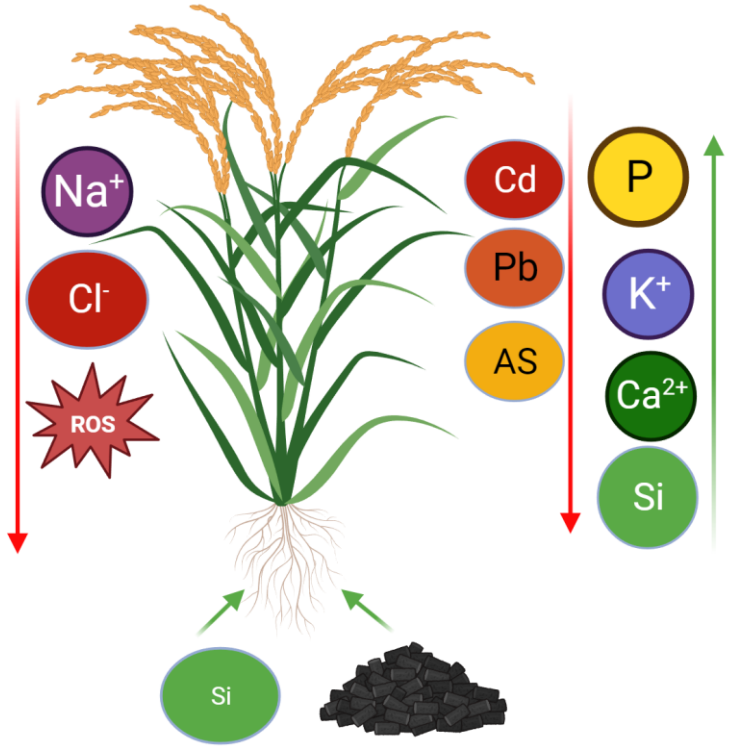
- Proline, an osmoprotectant linked to stomatal conductance, and regulates transpiration rate to maintain cell turgor and water balance during stress.
- Malondialdehyde (MDA) serves as a lipid peroxidation biomarker for oxidative stress.

- Si+Bio+HA led to an increase in proline content in (HM-C) and (SS) conditions, while it decreased in the case of (DS).
- Si+Bio+HA reduced MDA levels under SS, and DS but remained high under HM.

Summary of findings

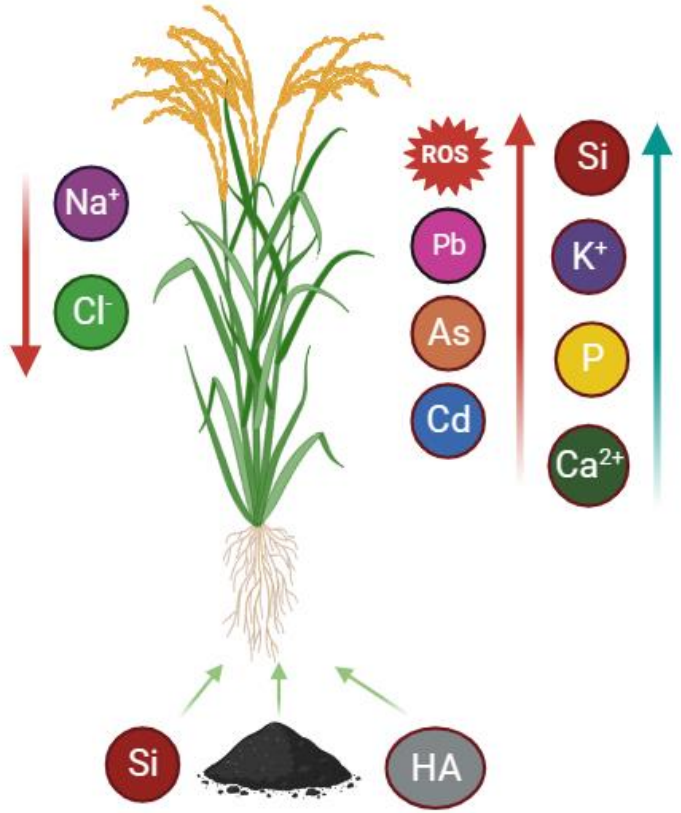
Summary of findings

A



A: Si+Bio enhances rice plant tolerance against Salinity, Drought, and HM stress.

B



B: HA+Si+Bio better enhances tolerance against Salinity and Drought stress but increases HM toxicity in rice plants.

CONCLUSION

Challenge

- Abiotic stresses interfere with plant morphological arrangements.
- Affect physiological and biochemical functions of plant cell.
- Hampering growth and yield of rice plants

Findings

- HA+Bio+Si combination could be employed to confer tolerance against **salt** and **drought** stress.
- However under heavy metal stress, should be reconsidered since **HA** presence could enhance the **phytotoxicity**.

Application

- The environmentalist approach: **Phytoremediation**
- Agriculturist approach: **Detoxification** of crops through lowering the heavy metal accumulation in crops.

Future Research

Identify PGPR (microbes) with the potential of conferring multiple stress tolerance on rice plants.

Research Application in Ghana

- Fortify fertilizer blends with Silicon and Humic Acid to enhance crop resilience to drought and salt stress.
- Promotion of Biochar use in crop production.
- Promote use of HA for phytoremediation

Lessons learned

General Korean Society

- Strong leadership
- Effective Policy implementation
- Discipline towards work & Time
- Honest
- Result-oriented
- Patriotic (Believe in home-grown policies and products)

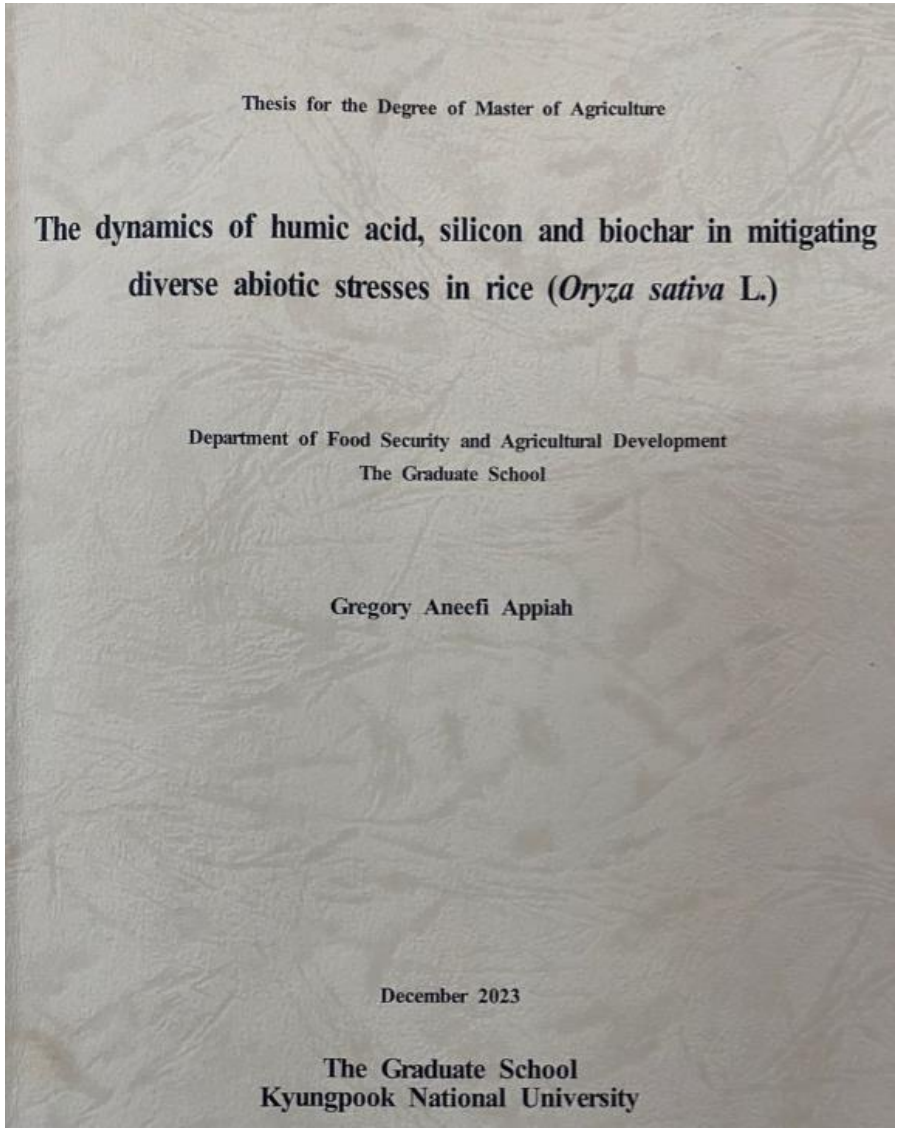
Lessons learned

Korean Agricultural Policies and Practices

- Technology development
- Incentives for Machinery Extension
- Market support for Rice farmers (import control)
- Province specific and specialized commodity production
- Strong farm cooperatives
- Support for value addition (processing and packaging)
- Effective Extension Service (courses, school)

Achievements

- Successful course completion and submission of a standard and approved research thesis on the topic “The Dynamics of Humic Acid, Silicon and Biochar in Mitigating Diverse Abiotic Stresses in Rice (*Oryza sativa* L.)”, supervised by Professor In-Jung Lee.
- Award of a Master of Agriculture (Food Security and Agricultural Development) degree.


Thesis for the Degree of Master of Agriculture

The dynamics of humic acid, silicon and biochar in mitigating diverse abiotic stresses in rice (*Oryza sativa* L.)

Department of Food Security and Agricultural Development
The Graduate School

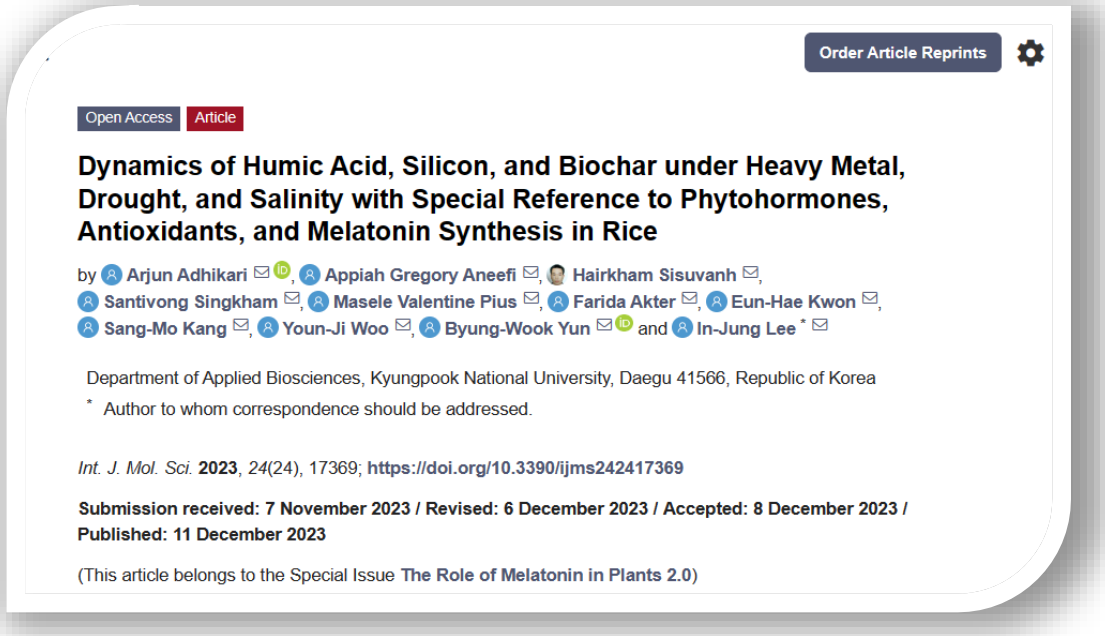
Gregory Aneefi Appiah

December 2023

The Graduate School
Kyungpook National University

Achievements

Co-authored an article published in the International Journal of Molecular Sciences under the title “Dynamics of Humic Acid, Silicon, and Biochar under Heavy Metal, Drought, and Salinity with Special Reference to Phytohormones, Antioxidants, and Melatonin Synthesis in Rice”. https://doi.org/10.3390/ijms242417369



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Dynamics of Humic Acid, Silicon, and Biochar under Heavy Metal, Drought, and Salinity with Special Reference to Phytohormones, Antioxidants, and Melatonin Synthesis in Rice

by Arjun Adhikari, Appiah Gregory Aneefi, Hairkham Sisuvanh, Santivong Singkham, Masele Valentine Pius, Farida Akter, Eun-Hae Kwon, Sang-Mo Kang, Youn-Ji Woo, Byung-Wook Yun and In-Jung Lee *

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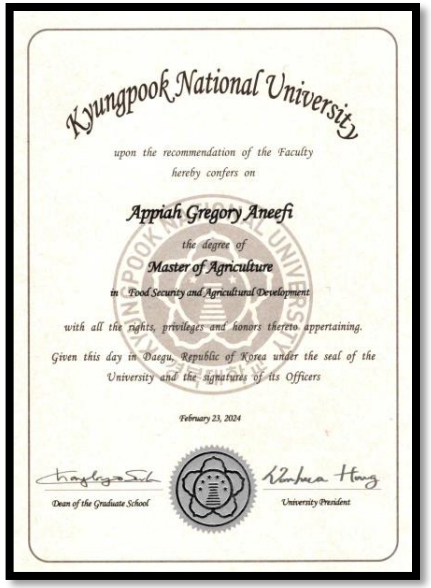
(This article belongs to the Special Issue **The Role of Melatonin in Plants 2.0**)

Achievements

- Recipient of the 2023 KOICA-KNU **Master's Leadership Certificate**, in recognition for service as the Student President for the Master's Degree Program in Agricultural Production.
- Recipient of the 2023 KOICA-KNU **Outstanding Academy Award**, in recognition of outstanding academic performance during the Master's Degree Program in Agricultural Production.
- Gained practical expertise in **conducting laboratory assays, specializing in analyses of plant phytohormones** and other crop physiological attributes.
- Successful completion of **Kyungpook National University's Academic Writing** and Presentation Seminar.
- Successful participation in the **15th International Association for Plant Biotechnology Congress** (IAPB 2023), held from 6th to 11th August at the Daejeon Convention Centre (DCC), Daejeon, South-Korea.
- Gained fundamental knowledge of the Korean language (Hanguel).

Certificates & Awards



Kyungpook National University

upon the recommendation of the Faculty hereby confers on

Appiah Gregory Aneefi

the degree of

Master of Agriculture

in Food Security and Agricultural Development

with all the rights, privileges and honors thereto appertaining.

Given this day in Daegu, Republic of Korea under the seal of the University and the signatures of its Officers

February 23, 2024

Dean of the Graduate School

University President

석제 33662 호

학 위 기

성명 아피아 그리고리 아니피

1992년 8 월 4 일생

위 사람은 이 대학원 식량안보및농업개발학과에서 소정의 과정을 이수하고 논문을 제출하여 대학원위원회의 심사에 통과하였으므로 농학석사의 자격을 갖추었음을 인정함

2024 년 2 월 23 일

경북대학교 대학원장 산업공학박사 서 창 교

위 인정에 의하여 농학석사 학위를 수여함

2024 년 2 월 23 일

경 북 대 학 교 총 장 공학박사 홍 원 화

경북대학교

학위수여번호 : 경북대2023(석)0411

Certificate of Recognition

This is to certify that

Mr. Gregory Aneefi Appiah

was assigned to a student president for

the KOICA-KNU Master's Degree Program

in Agricultural Production

from August 17, 2022 to December 22, 2023

December 14, 2023

KNU

Hwang, Hwa-Seok

Director of Daegu Gyeongbuk International Development Cooperation Center

Outstanding Academy Award

This certificate is awarded to

Mr. Gregory Aneefi Appiah

in recognition of outstanding academic performance during the KOICA-KNU Master's Degree Program in Agricultural Production

December 14, 2023

KNU

Yun, Byung-Wook

Director of Institute of International Research & Development

Certificate

This is to certify that

Mr. Gregory Aneefi Appiah

has successfully completed the scholarship program on

KOICA-KNU Master's Degree Program in Agricultural Production

from August 17, 2022 to December 22, 2023,

organized by the Korea International Cooperation Agency

and the Institute of International Research & Development, Kyungpook National University

under the International Cooperation Program of the Government of Korea.

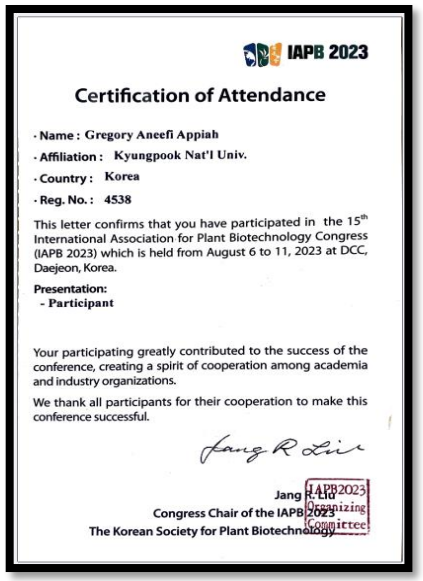
December 14, 2023

Won Sam Chang
President
Korea International Cooperation Agency

Byung-Wook, Yun
Director
Institute of International Research & Development, Kyungpook National University

KOICA

KNU



IAPB 2023

Certification of Attendance

- Name : Gregory Aneefi Appiah
- Affiliation : Kyungpook Nat'l Univ.
- Country : Korea
- Reg. No. : 4538

This letter confirms that you have participated in the 15th International Association for Plant Biotechnology Congress (IAPB 2023) which is held from August 6 to 11, 2023 at DCC, Daejeon, Korea.

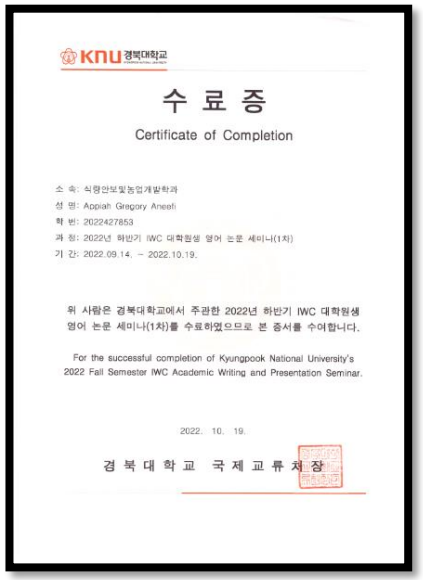
Presentation:
- Participant

Your participating greatly contributed to the success of the conference, creating a spirit of cooperation among academia and industry organizations.

We thank all participants for their cooperation to make this conference successful.

Jang R. Liu
Congress Chair of the IAPB 2023
The Korean Society for Plant Biotechnology

IAPB2023 Organizing Committee



KNU 경북대학교

수 료 증

Certificate of Completion

소 속: 식량안보및농업개발학과
성 명: Appiah Gregory Aneefi
학 번: 2022427853
과 정: 2022년 하반기 IWC 대학원생 영어 논문 세미나(1차)
기 간: 2022.09.14. ~ 2022.10.19.

위 사람은 경북대학교에서 주관한 2022년 하반기 IWC 대학원생 영어 논문 세미나(1차)를 수료하였으므로 본 증서를 수여합니다.

For the successful completion of Kyungpook National University's 2022 Fall Semester IWC Academic Writing and Presentation Seminar.

2022. 10. 19.

경 북 대 학 교 국 제 교 류 처 장

제 2023-2-210 호

위 촉 장

Letter of Appointment

국 적 : 가나
Nationality : Ghana
성 명 : 아피아그리고리아니피
Name : Appiah Gregory Aneefi

국립 경북대학교의 더 큰 발전을 위해 관심과 애정을 쏟아주실 귀하를 경북대학교 명예홍보대사로 위촉하고 이 증서를 수여합니다.

In recognition of your enthusiasm and achievement as an international student during your studies at Kyungpook National University, you are hereby officially appointed as an Honorary International Ambassador of KNU.

2023년 12월 22일

경 북 대 학 교 총 장

Won-Hwa Hong, Ph.D.
President
Kyungpook National University

Recommendations

The KOICA-KNU Master's Degree Program provides participants with a mindset, skills, and practices that enhance their impact on the development of their respective sectors and countries.

Officers should be actively engaged in the planning and development of policies and programs.

Officers should be resourced to transfer the technologies and strategies they have learned.

Consideration for PhD offers should be extended to officers, enabling them to consolidate their experiences and skills for enhanced performance, contributing significantly to the advancement of the nation.

Appreciation

1. Office of the Head of Civil Service (OHCS)
2. Ministry of Food and Agriculture and the Directorate of Crop Services (MoFA, DCS)
3. Korean International Cooperation Agency (KOICA)
4. Kyungpook National University (KNU)
5. Ghanaian Students in Korea and Associates (GHASKA)

Thank you for your attention (감사합니다)

Any Questions??

(+233 541 646 877)

(gregory.aneefi-appiah@mofa.gov.gh)