Australian Government
Department of Agriculture, Fisheries and Forestry

Science and Innovation Awards for Young People in Agriculture, Fisheries and Forestry

2023 round - 12-month and final report

As part of your 2023 Science Award grant you are required to report on your project at the six month and 12-month milestones. This is the 12-month and final report template. These reports will be provided to ABARES and your Award sponsor. When completing this report, provide detailed and clear information on your project and results. Challenges or unexpected obstacles, and how you have addressed these, are also an important part of your project reporting, as is the professional relationships you are building with your Award partner and other industry networks. Photos, charts, graphs and other documentation can be included. Refer to your grant agreement and the milestones you agreed to, when completing this report.

As noted in your grant agreement, this final report should also include

1. a financial acquittal -a statement accompanied by a reconciliation of the expenditure against budget, signed and certified but not audited. It is to be on the grantee's letterhead and in their preferred format;
2. a signed statutory declaration as to whether the Project was carried out in accordance with the objectives, milestones and key performance indicators. The signatory can be the chairperson, managing director, chief executive, or equivalent officer of the grantee.

We understand that these two items may take longer to coordinate and will accept these up to one month after the final report.

The due date of your 12-month progress report will be advised by the Community Grants Hub / Department of Agriculture, Fisheries and Forestry

Name: Cong Vu
Award Sponsor: CRDC

1. **Description of your project** provide a short paragraph describing your project, including any variations.

In this project, silica nanoparticle technology was used to boost drought stress tolerance in cotton. Silica nanoparticles with different sizes and shapes have been synthesised. The silica nanoparticles were then coated on cotton seeds. Various concentration of nanoparticles to be used for seed coatings have been tested. Silica nanoparticles/seed mass percentage of 0.6% were found to have the best effect on seed germination and plant development and potentially reduce the irrigation water for cotton growers. The work of this project is known and invited to do showcase at evoke2024 and two international conferences in American. The researcher of this project was selected to be one of 30 global Sustainability Stars recognised by American Chemical Society.

2. **Milestones completed** Describe the milestones and outcomes completed in this stage. If any milestones were not undertaken or varied from your grant agreement, please provide an explanation. Refer to your grant agreement for the agreed list of milestones.

Milestone	Due Date	Progress
Synthesis of silica nanoparticles	Within 6 months of the execution date	Completed. About 10 different types of silica nanoparticles with different size, shape, and surface chemistry have been synthesised.
Test the effectiveness of nanoparticles on the cotton seed.	Within 12 months of the execution date	Completed. The proof of concept of the benefit of nanoparticles on helping cotton cope with drought stress has been validated.

3. **Results** What results do you have from your project? Have the original aims and objectives of your project been achieved? Were there any factors that caused difficulties or setbacks in achieving your goals? Be detailed in documenting the project outcomes.

Key achievements:

- ✓ Ten different silica nanoparticles have been successfully synthesised. All of the silica nanoparticles show benefits for cotton seed germination. The nanoparticles have a positive impact on the roots.

- ✓ Financial model and commercialisation plan of nanoparticles have been proposed. Nanoparticles costs $2-5 to be used for one kg of cotton seeds.

- ✓ The project is known and invited to do the showcase at evoke2024 and two international conferences in American.

Results

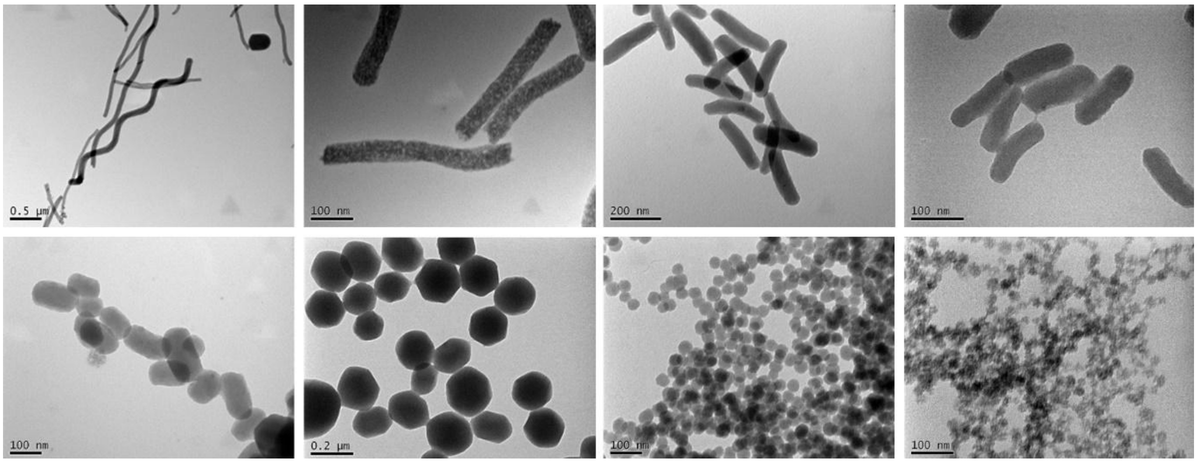


Figure 1. Transmission electron microscopy (TEM) images of silica nanoparticles.

Various types of silica nanoparticles have been successfully synthesised (Figure 1). The size of silica nanoparticles can be controlled from 30 nm to 2 µm. The shape of nanoparticles can be controlled from spherical to rod-like shapes.

The prepared silica nanoparticles were used to coat cotton seeds (Figure 2).

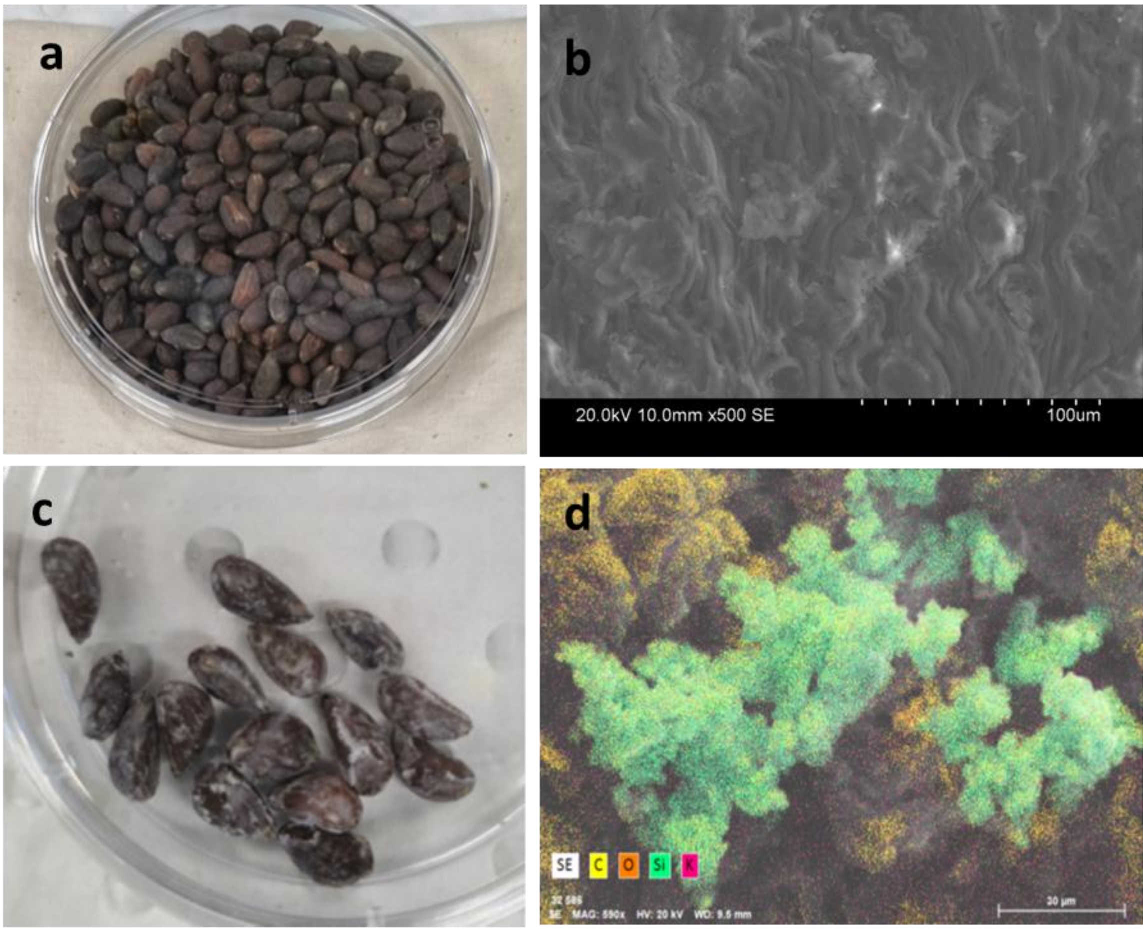


Figure 2. (a) photography image of cotton seeds without nanoparticles, (b) scanning electron microscope image (SEM) of cotton seed without nanoparticles with the magnification of 500 times; (c) photography image of cotton seeds coated with silica nanoparticles, (d) SEM image of cotton seed coated with nanoparticles. The green part is silica nanoparticles confirmed by energy dispersive X-ray (EDX).

Next, germination tests of cotton seed coated with silica nanoparticles were conducted (Figure 3).

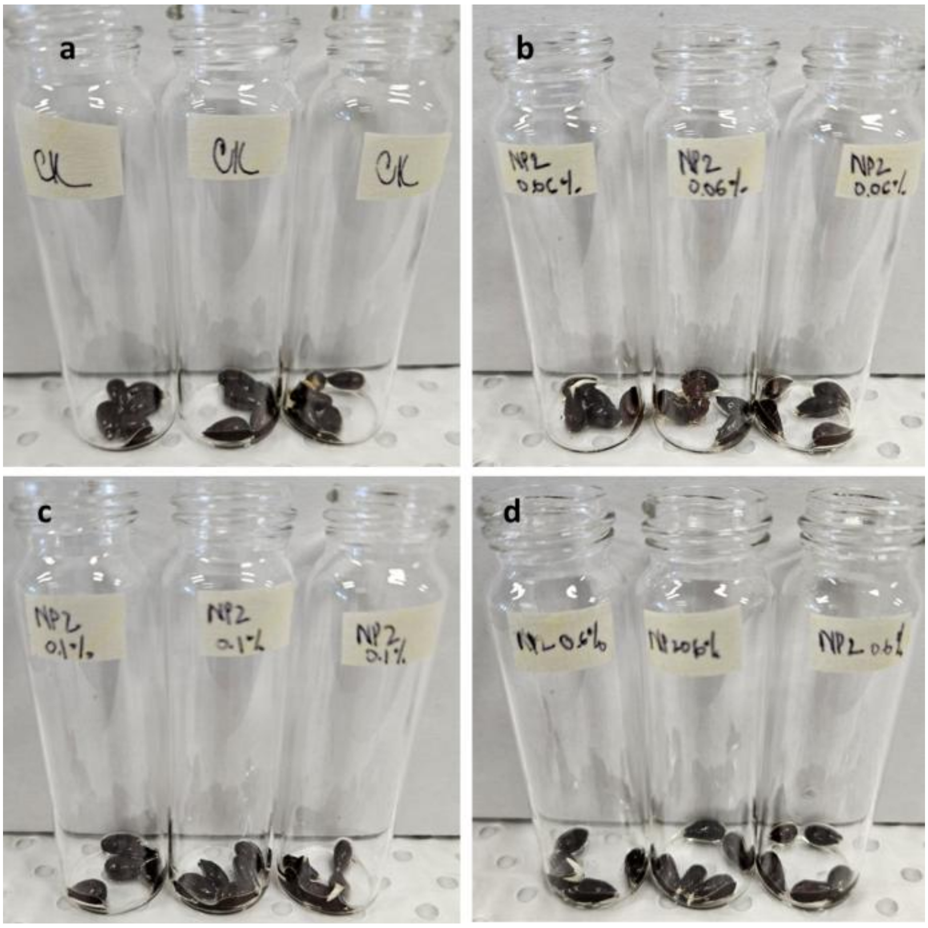
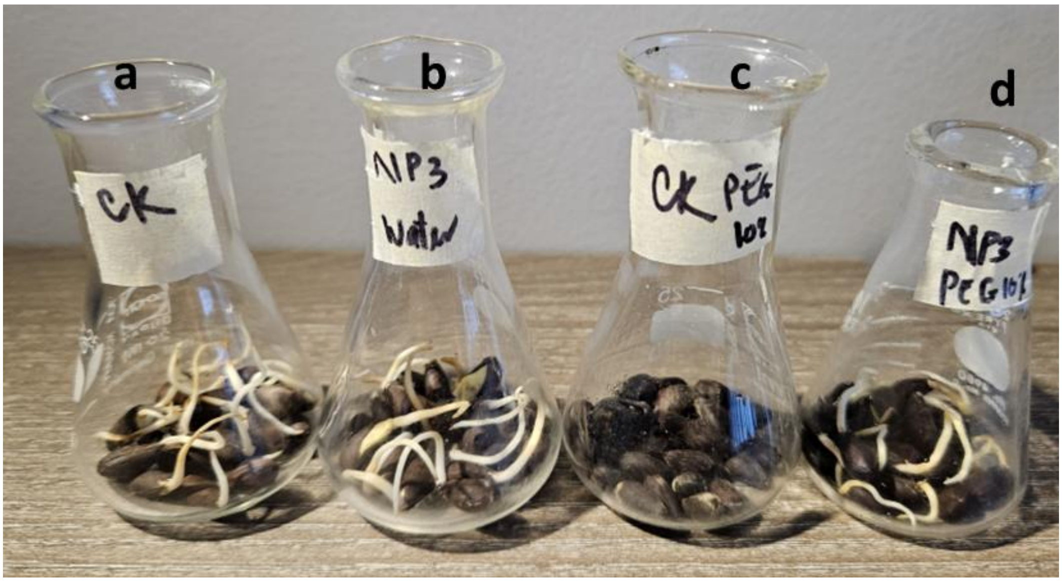


Figure 3. Compare the germination of cotton seeds with and without silica nanoparticles coated. Seeds coated and non-coated with nanoparticles were soaked in water for 3 days. (a) control (CK) seeds without nanoparticles. (b,c,d) cotton seeds coated with nanoparticles at different mass ratios. (b) 0.6 g nanoparticles per 1 kg of seeds or the mass percentage between nanoparticle and seeds is 0.06%; (c) 0.1 g nanoparticles per 1 kg of seeds or mass percentage of 0.1%; (d) 6 g nanoparticles per 1 kg of seeds or mass percentage of 0.6%.

It can be seen that nanoparticles boosted the seed germination even though at a very low mass percentage of 0.06% (Figure 3b). Nanoparticles at the percentage of 0.1% (0.1 g nanoparticles per 1 kg seeds) and 0.6% (6 g nanoparticles per 1 kg seeds) also boosted the germination (Figure 3c,d). Nanoparticles at a concentration higher than 0.6% inhibited the germination. Nanoparticles/seed mass percentage of 0.6% were used for the rest of the test.

As mentioned, the main focus of this project is to design nanoparticles to help cotton tolerate drought stress and potentially help save irrigation water for cotton growers. To validate this, control seeds and seeds treated with nanoparticles were soaked in a solution of polyethylene glycol (PEG) 10% (1 g of PEG in 9 g of water) (Figure 4). PEG 10% is widely used for screening for drought tolerance at earlier growth of seeds (*Heliyon* 9 (2023) e20209) because PEG reduces seed germination and growth by reducing water potential- a drought-mimicked environment.



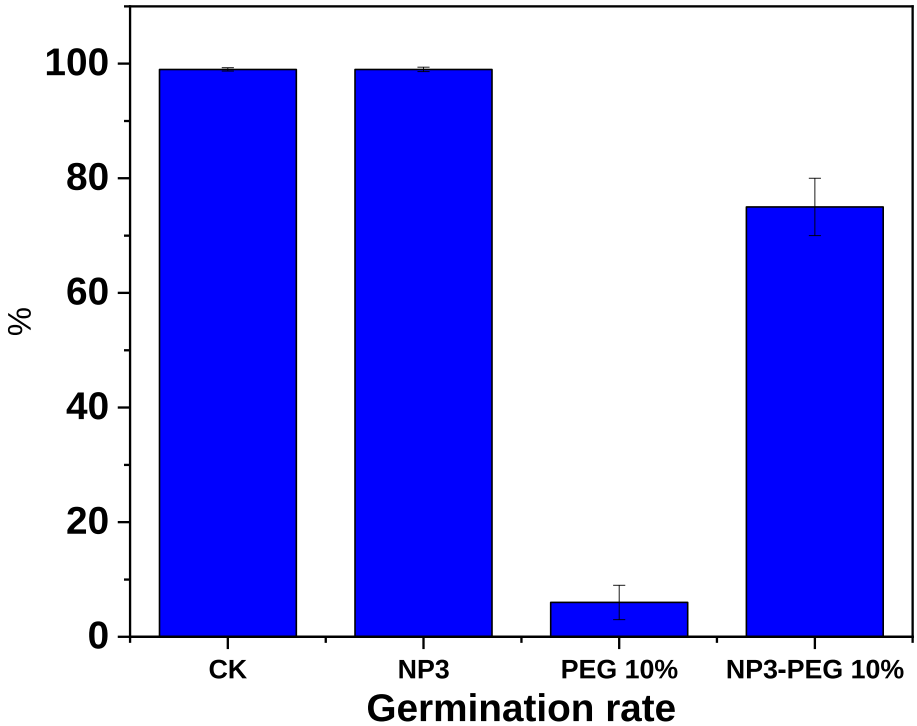


Figure 4. (a) Cotton seeds without nanoparticles (CK); (b) cotton seeds coated with nanoparticles. (a, b) seeds were soaked in 2 mL water. (c, d) seeds were soaked in 2 ml of PEG 10% to mimic the drought-stress environment. (c) cotton seeds without nanoparticles in PEG (CK PEG 10%); (d) cotton seeds coated with nanoparticles in PEG (NP3 PEG 10%). The graph presents the seed germination rate of the treatments.

It can be seen that cotton seeds in PEG 10% germinated around 5%, but cotton seeds coated with nanoparticles germinated about 75% in PEG 10%. Control seeds and seeds treated with nanoparticles germinated almost 100% in water.

To further validate the drought stress tolerance of seeds-coated nanoparticles, the seeds were sown in pre-irrigated soils. The pots were kept in a glasshouse chamber for 10 days without watering. Soil moisture sensors were used to monitor the drought level. From day 7, soil moisture went down to level 1.5 indicating the soils were in drought condition (Figure 5). The experiment was harvested on day 10 and the roots of the control seeds and seed-treated nanoparticles were compared (Figure 6).

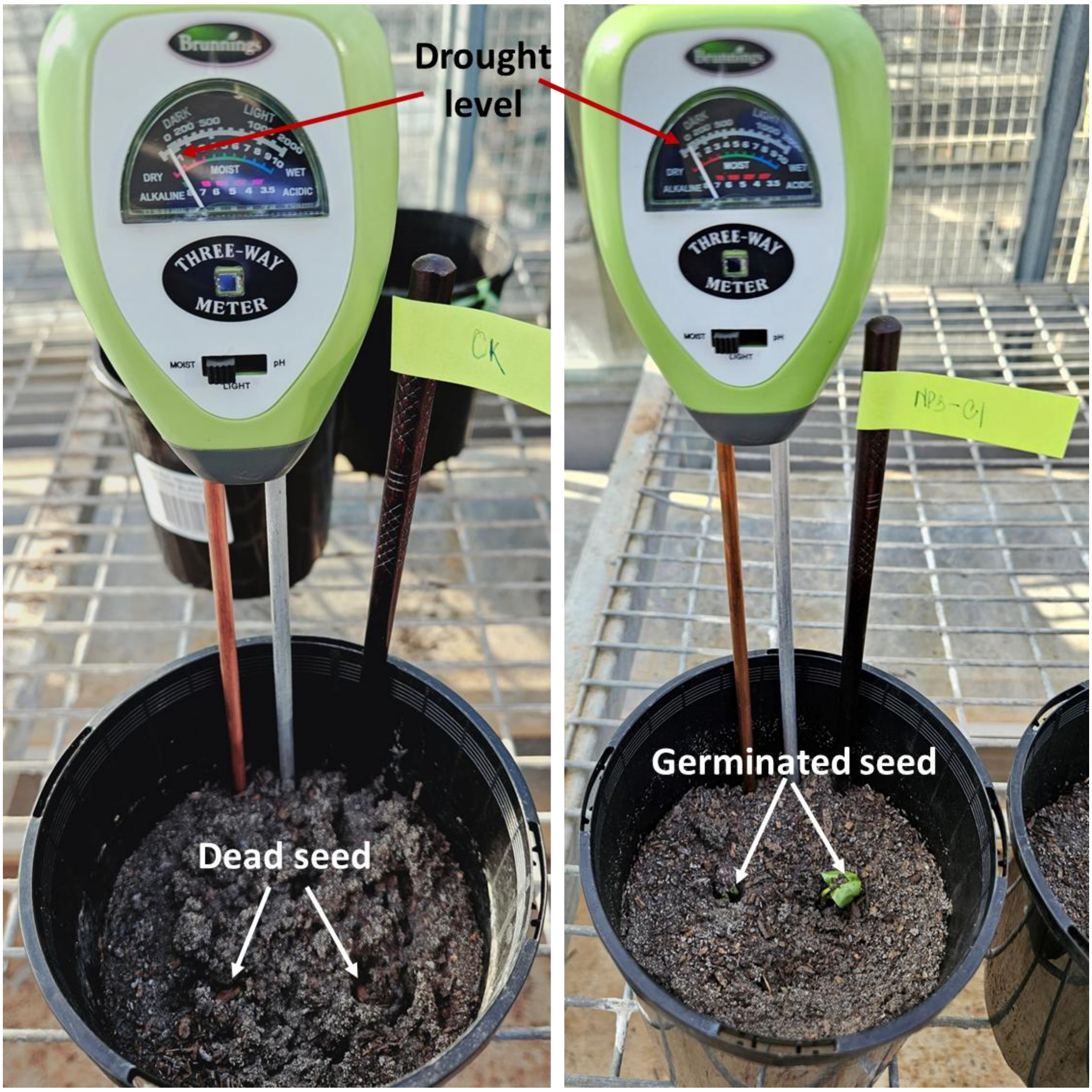


Figure 5. Experiment demonstrating the drought stress tolerance of seeds-treated nanoparticles.

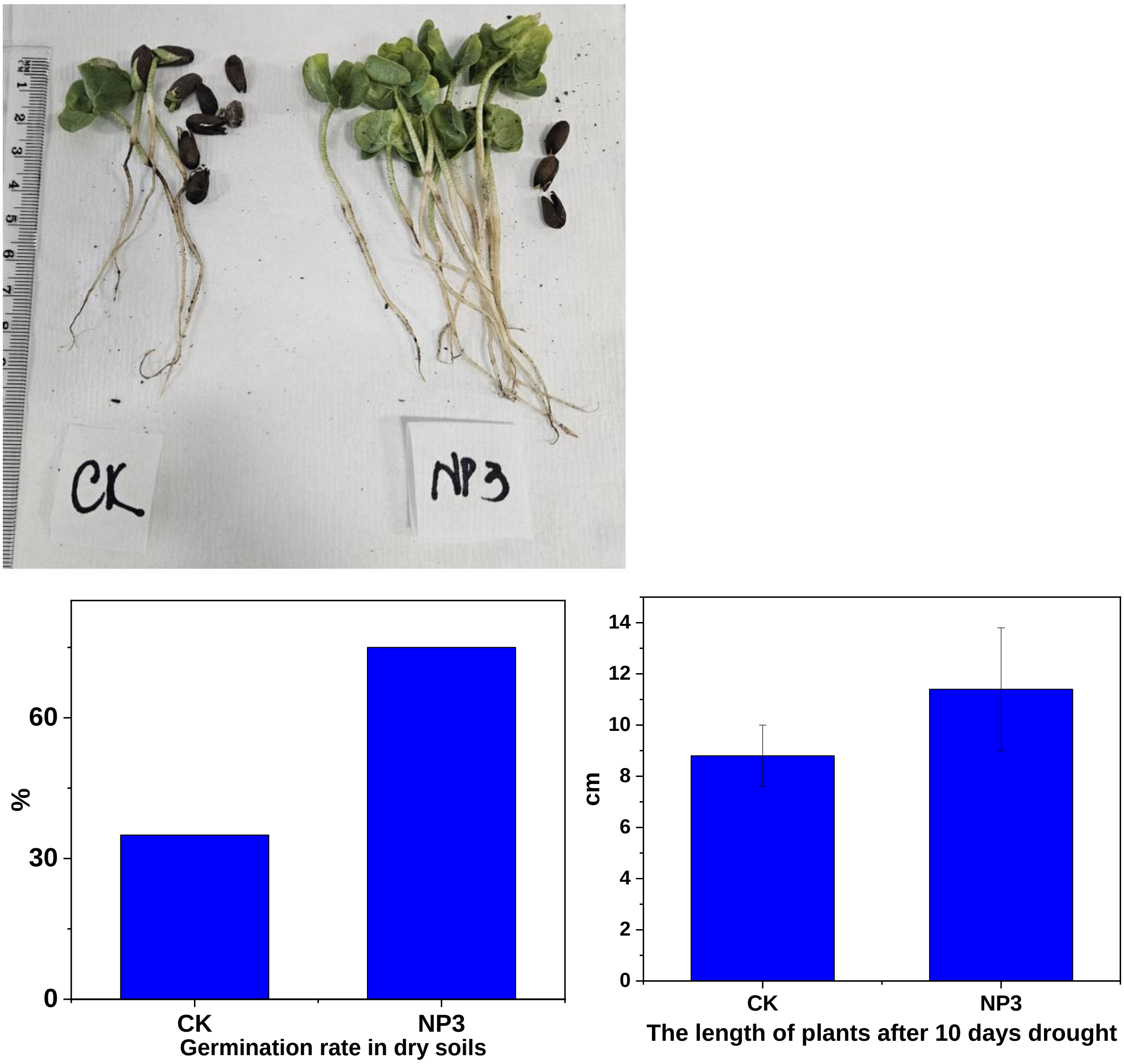


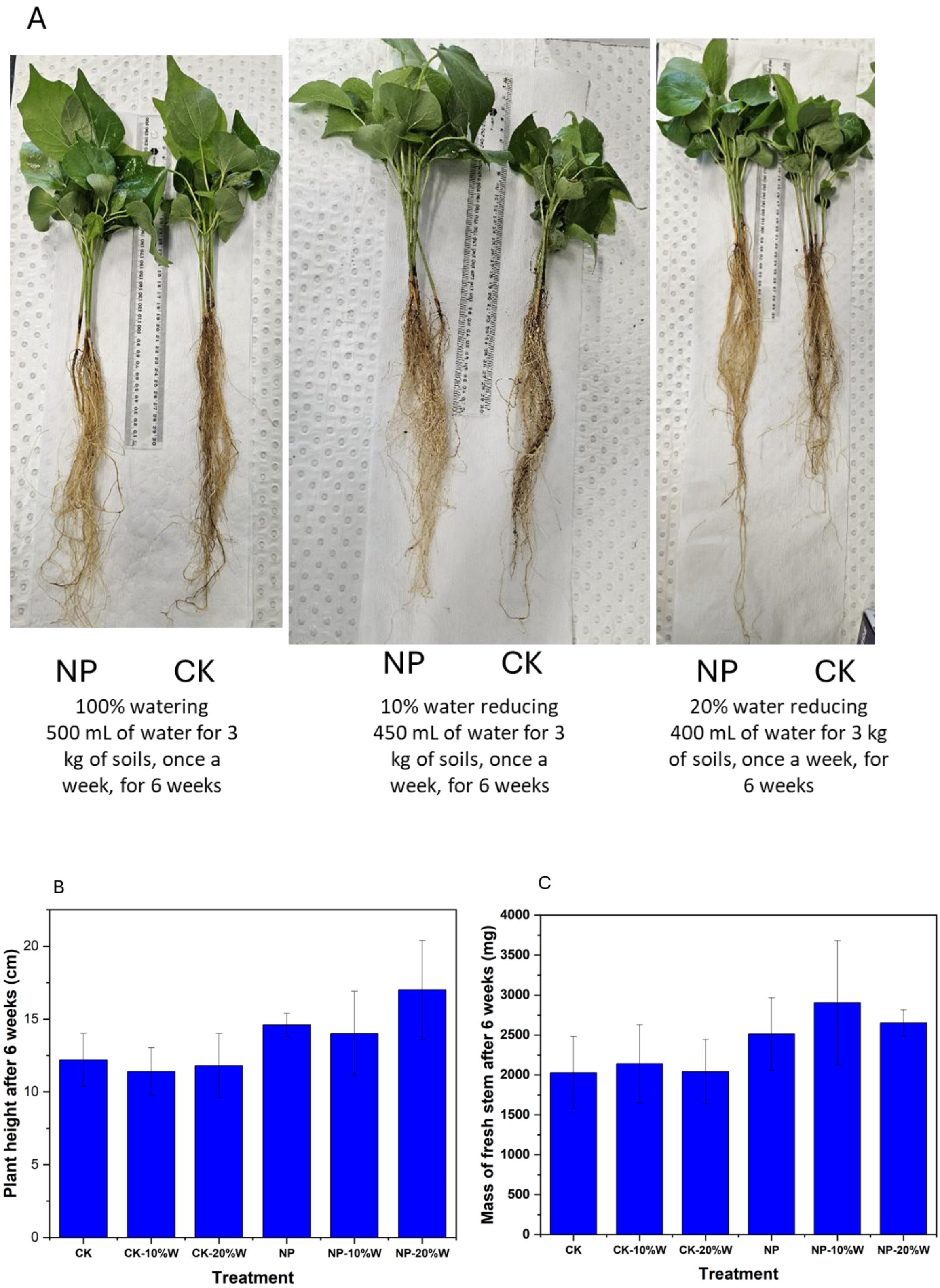
Figure 6. Control seeds and seeds coated with nanoparticles were sown in pre-irrigated soils for 10 days without watering. Control seeds could germinate in pre-irrigated soils but only about 35% of the germinated seeds could survive until day 10. About 70% of the seeds coated nanoparticles germinated and developed into plants. The roots of seed coated nanoparticles are significantly longer than control seeds.

Application of silica nanoparticles

Background of silica uses in agriculture: silica or silicon dioxide or sodium silicate have been widely used as a fertiliser and bio stimulation for plants. Some examples of silica in the market are CropSIL, Silica Blast, and CYCO Silica. The claimed benefits of these silica fertiliser are increased plant cell wall strength, increased vigor and stress resistance, improved crop quality and rooting, increased nutrient uptake.

What makes silica nanoparticles from NanoSoils different from others: Originally, we used silica nanoparticles for biomedical applications, particularly for anticancer drug delivery. Both humans and plants need silica. For human silica strengthens bone, hair and nails. For plants silica supports plant cell wall strength. As mentioned, there are various forms of silica such as sodium silicate, silicon dioxide; however, the only useful and bioavailable form of silica for both plants and humans is ortho silicic acid. In other words, silica needs to be dissolved into the bioavailable form- ortho silicic acid.
NanoSoils has developed a new class of silica nanoparticles that can dissolve in both pH<4 and pH>10. This is interesting because most silica nanoparticles dissolve in base pH. However, the pH environment for practical uses of silica is mostly acid (in human stomach, soils, inside the plant).

It is hypothesized that the silica nanoparticles of NanoSoils could help the roots of cotton seed treated nanoparticles grow stronger under drought stress condition; therefore, cotton seed treated silica nanoparticles grows better than the control seeds under water stress.
To clarify this hypothesis, cotton seed treated with nanoparticles and without nanoparticles were sown in soil pot with different watering amounts: 100% water (500 mL of water per 3 kg of soils); 10% of water reduction (450 mL of water per 3 kg of soils); and 20% of water reduction (400 mL of water per 3 kg of soils). The pots were watered once a week, and the plants were harvested after 6 weeks (Figure 7).


A
NP CK
100% watering
500 mL of water for 3 kg of soils, once a week, for 6 weeks
NP CK
10% water reducing
450 mL of water for 3 kg of soils, once a week, for 6 weeks
NP CK
20% water reducing
400 mL of water for 3 kg of soils, once a week, for 6 weeks
B
Plant height after 6 weeks (cm)
0
5
10
15
20
CK
CK-10%W
CK-20%W
NP
NP-10%W
NP-20%W
Treatment
C
Mass of fresh stem after 6 weeks (mg)
0
500
1000
1500
2000
2500
3000
3500
4000
CK
CK-10%W
CK-20%W
NP
NP-10%W
NP-20%W
Treatment

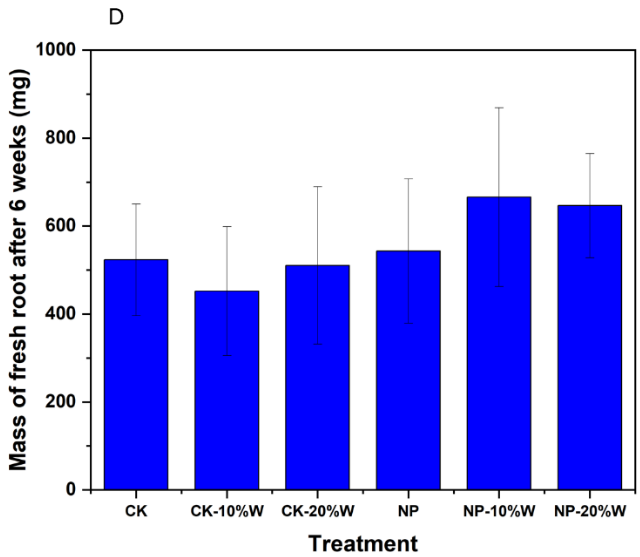


Figure 7. (A) Cotton seed treated with nanoparticles (NP) and without nanoparticles (CK) were sown in soil in the pot with different watering amounts for 6 weeks. The third picture of (A) has been zoomed out to see the whole root length. The ruler in the middle shows the scale. (B) Comparison of the plant height. (C) Comparison of mass of fresh stem. (D) Comparison of mass of fresh root of cotton.

When nanoparticles-treated and control plants were fully watered (500 mL per pot), the nanoparticles showed little impact compared to the control (Figure 7). However, when the water was reduced to 20%, the root of the nanoparticles treated seeds grew longer. The mass of the roots of 10% and 20% irrigating water reducing treatments were almost the same. The mechanism of how silica nanoparticles impact on cotton root under drought stress is unclear. It could be because silica nanoparticles trigger some hormones to help root go deeper to get water when the plants are under drought stress (20% water reduction). More extending work is needed to investigate on the mechanism and expand the trials from seedling until harvest to see how much water silica nanoparticles could totally reduce in glasshouse and in the field.

4. **Benefits to industry** Describe how your industry will benefit from your project results. Have there been any steps already taken with industry, or plans to engage stakeholders? Are you working with your Award sponsor to reach industry stakeholders?

Practical use of silica nanoparticles for cotton growers in future: reduce irrigating water to make the root grow stronger and deeper. In the future once the nanoparticles are widely used as a seed coating, deeply-rooted cotton (Figure 8) to replace shallow-rooted ones is proposed as a promising natural solution for mitigating the effect of drought and improving soil health.

Figure 8. An example of deeply-rooted cotton from the nanoparticles treated seeds and 20% water reducing treatment.

The award directly or indirectly helps NanoSoils to be reached by potential collaborators.

Nanoparticles were found to have a positive impact on various crop beside cotton (Figure 9). Meat and Livestock Australia (contacted with Joshua Whelan) is interested in the potential application of nanoparticles for pasture seeds.

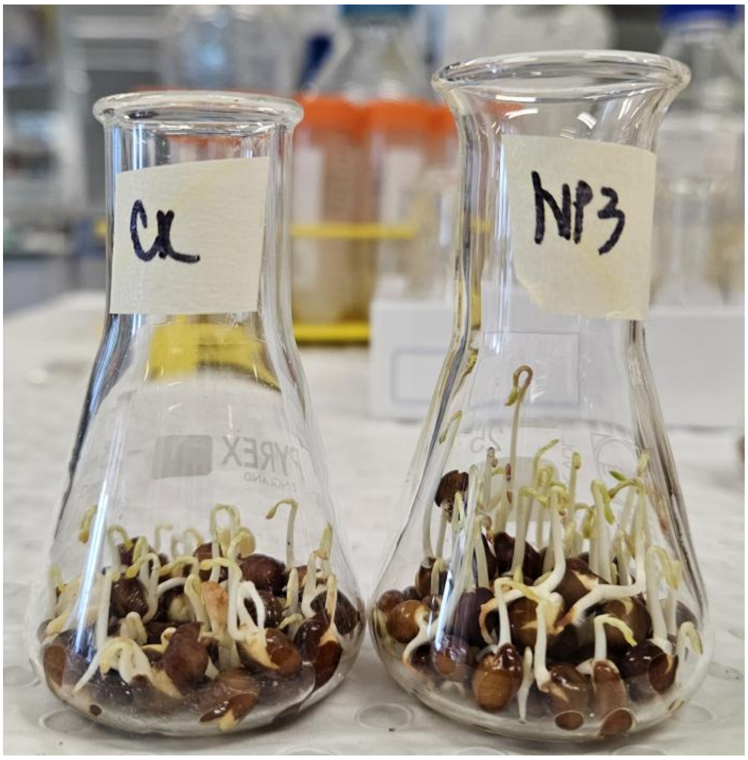


Figure 7. Pasture seeds without nanoparticles (left image) and coated with nanoparticles (right image)

5. **Budget expenditure** How has your grant funding been expended? (Refer to the budget from your grant agreement and your six-month report). Include details of any unspent funds. A financial acquittal is required at the conclusion of your project. Refer to page one of this report for advice.

6. **Dissemination** Describe the communication activities you have undertaken (eg speaking at external events and seminars, media coverage, contributions to newsletters, journals or published articles etc). How effective were these activities in raising awareness of your project?

International level:

The work that NanoSoils is doing, a part of the CRDC sponsor for 2023 Science and Innovation Awards for Young People in Agriculture, Fisheries and Forestry, is known by the chair of two conferences in America. NanoSoils is invited to attend the conference and present a poster "Application of nanotechnology for Australian cotton" at the conference.

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In addition to this, Dr Cong Vu is selected to be one of the 30 Sustainability Stars globally, recognized by American Chemical Society (ACS). ACS invites him to attend the 28th Annual Green Chemistry & Engineering Conference (gcande.org) which also happens in June 2024 in USA. Below is their announcement.

American Chemical Society
212,076 followers
1mo • Edited •

Congrats to Cong Vu, an #ACSSustainabilityStar!

As Founder and CEO of NanoSoils BIO, Cong is driven by a mission to combat climate change impacts on agriculture. Inspired by Sydney's bushfires, he developed silica nanoparticles to help plants survive drought stress. Now, his startup focuses on innovative solutions to reduce irrigation water usage by elongating root length and enhancing plant resilience. Cong's commitment to net-zero carbon emissions and sustainable practices ensures Nano Soils Bio's products are environmentally friendly.

Thank you Cong for your dedication to sustainable agriculture and mitigating climate change effects.

Are you an #ACSSustainabilityStar? Nominate yourself today at https://brnw.ch/21wIISr

National level:

2024 evokeAG showcase at Starup Alley sponsored by Syngenta.

Communication activities: pitched at Sparklabs Cultiv8 showcase in Orange on 1st November.

Media interviews: Is nanotechnology the next big R&D breakthrough for cotton? | Farm Online | Farmonline

7news: 1st November: Post | Feed | LinkedIn

7. **Career and personal benefits** What benefits has this Science Award grant provided you? (eg assisted in career or skills development? Made new industry connections? Collaboration opportunities for future projects? presentation skills and opportunities? to continue working in your chosen field of research?)

The scope of this project is mainly focusing on drought stress tolerance; however, other benefits of silica nanoparticles for cotton on the roots that could maximize fertiliser uptake and enhance disease resistance are unexplored. The silica nanoparticles can also deliver pesticides (insecticide, fungicide) to protect the seeds.

We aim to provide a nanoparticle formulation that could (1) stretch the first irrigation time to help the root develop stronger; (2) because of the stronger root system, nanoparticles can help plants get water and fertiliser more effectively, in other words, the nanoparticles could potentially reduce the use of irrigating water and fertiliser (nitrogen and phosphate); (3) the nanoparticles can precisely deliver pesticide to protect the seeds from pests.

Indirect saving and carbon credit for cotton growers

Saving water, reducing the use of nitrogen fertiliser and reducing spray drift are direct and indirect bringing the benefit for the cotton industry. These positive impacts can be converted into carbon credit for cotton growers.

Expand the technology to other crops:

Pasture and wheat are the next two crops NanoSoils is interested in now.

8. **Future work** Have you identified any future work opportunities to build on your project outcomes? What will you do in your career over the next 12 months?

We are looking for the funding to expand the trials.

7. Contact with your Award sponsor Have you maintained contact with your Award sponsor during your project? Do you intend to continue this contact in the future?

Yes, please. We are looking to expand the trials and commercialise the nanoparticles.

8. Declaration and signature

Australian Government
Department of Agriculture, Fisheries and Forestry

I certify that the information presented in this report is an accurate statement of my project for the 2022 Science and Innovation Awards for Young People in Agriculture, Fisheries and Forestry.

If not included with this final report, I confirm that a financial acquittal and a signed statutory declaration will be provided within one month of this final report submission.

Signature:	Dr Cong Vu. CEO of NanoSoils Bio
Date:	02/06/2024

Return the completed report to the Community Grants Hub.

For enquiries contact Maree Finnegan, Science Awards Manager, ABARES, GPO Box 858, Canberra, ACT, 2601; Ph: 02 6272 2260 / 0417 689 567 / scienceawards@ariculture.gov.au

Congratulations on completing your Science Awards project. We hope that you have found your involvement in the 2023 Science and Innovation Awards to be a valuable and worthwhile experience, and wish you success in the next stages of your career.