

POTENTIAL USE OF SHALLOTS SKIN EXTRACT AS SEED PRIMING TO INHIBIT DETERIORATION AND INCREASE VIABILITY OF SOYBEAN SEEDS

Maman Suryaman^{1,*} , and Yaya Sunarya¹ 

¹ Agrotechnology Department Faculty of Agriculture, Siliwangi University, Tasikmalaya West Java, Indonesia
Corresponding author email: mamansuryaman@unsil.ac.id

Article Info

Received: Jan 27, 2026

Revised: Marc 12, 2026

Accepted: Apr 25, 2026

OnlineVersion: Apr 30, 2026

Abstract

Soybean seeds, compared to other grain crops, deteriorate quite quickly, lose its vigor and yield. Therefore, proper measures are required to enhance seeds viability and prevent deterioration. The study is to investigate the potential of shallot skin extract in enhancing viability and preventing deterioration of soybean seeds. A factorial completely randomized design that was duplicated three times was employed in the study. The first factor was concentration of shallots skin extract of 0, 10, 20, and 30%, and the second factor was soaking time of 1, 3, and 6 hours. Electric conductivity, seed viability, vigor index, germination rate, and dry weight of sprouts were the observed data that were subjected to Analysis of Variance and Duncan's multiple range test at α 5%. The results indicated that soaking the seeds in 10% shallot skin extract for six hours showed the lowest level of electric conductivity. Compared to the control, the simple effect of increasing the concentration of shallot skin extract by 10, 20, and 30% enhanced the dry weight of sprouts, germination rate, vigor index, and seed vigor. In conclusion, soaking soybean seeds in shallot skin extract may preserve seed viability and prevent degradation, although the soaking time had no significant effect on seed viability. The shallot skin extract can be used as seed priming agent to improve viability of soybean seeds affordable to the farmers.

Keywords: Seed Priming, Shallot Skin, Soybean



© 2024 by the author(s)

This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

INTRODUCTION

Generally, soybean farmers have not yet fully implemented intensification method, one of which is the use of poor quality of seeds which results in low soybeans productivity (Ministry of Agriculture - Republic of Indonesia, 2024). High quality seeds are important for high productivity, which is characterized among others with high germination rate and vigor, that allows them to grow well even in suboptimal conditions. Soybean seeds belong to the orthodox seed group (Ebene et al., 2019), with quite high fat content (21.54%) (Nguyen et al., 2022) and which deteriorates relatively fast, especially in poor storage conditions.

The deterioration process is associated with physiological changes including lipids peroxidation, failure of protein synthesis, DNA damage and membrane damage (Chhabra et al., 2019; Basu & Groot, 2023). The deterioration process will induce an increase in respiration rate and cause an increase in the

production of excessive reactive oxygen species (ROS) (Ranganathan & Groot, 2023) which can cause the seeds to lose viability and vigor and even cause seed death (Selvi & Saraswathy, 2017; Ebone et al., 2019; Pinheiro et al., 2023). In addition, ROS causes fat peroxidation to increase, protein degradation and proteolytic enzyme activity also increase, while antioxidant activity decreases (Pinheiro et al., 2023). ROS including free radicals are unstable and reactive, can damage various cell components, nucleic acids, enzymes, chromosome abnormalities and DNA damage, and eventually result in cell death (Tiwari, 2018; Soundararajan et al., 2019; Liu & Yang, 2020; Zhang et al., 2021).

In general, there are two approaches to seed deterioration (seed aging), namely by natural storage but take a long time (months), or by providing high temperature and high humidity treatment in a short time (Pournik et al., 2019). One accelerated aging method is by providing 100% humidity treatment and a temperature of 40°C for 24 hours, this method is identical to natural storage for 3 months (Hillari et al., 2019). ROS are considered as the main cause of deterioration in seeds (Chhabra et al., 2019), but the destructive power of ROS can be counteracted with antioxidants (Tiwari, 2018; Choudhary et al., 2018). Plant cells use an antioxidant defense system to protect against oxidative damage by ROS (Tiwari, 2018). On the other hand, seed priming can increase germination, vigor index, plant growth and yield under stress conditions (Hussain et al., 2019). Seed priming can improve the antioxidant defense system in cells, improve germination and vigor and minimize the negative impact of stress (Haider et al., 2019).

Shallots skin extract can be used as seed priming materials. In 2023, shallot production in Indonesia reached 2 million tons (Directorate of Food Crops, 2025). Processing activities from harvesting until the shallots marketed produce waste, including the skin, which amounts to around 3-5% of the total weight (El Mashad et al., 2019). This means that in 2023 in Indonesia, the accumulation of shallots skin waste could reach around 100,000 tons. As waste, shallots skins harm human health and the environment, even though they contain various beneficial phytochemicals and bioactive compounds (Črnivec et al., 2021; Kumar et al., 2022). The concentration of phenolics and flavonoids contained in shallot skin is higher than in the tuber (Sagar et al., 2020; Kumar et al., 2022), and the extract shows strong antioxidant activity (Piechowiak & Balawejder, 2019) so it has the potential to provide protection from damage caused by ROS (Mobin et al., 2021).

The recently researches on onion skin restricted on its content of beneficial phytochemicals and bioactive compounds and its effect as antimicrobial and antioxidants. The novelty of this study is focused on the use of shallots skin extract as seed priming agent. Therefore, this study aims to investigate the potential of shallot skin extract as seed priming in enhancing soybean seeds viability and preventing its deterioration.

RESEARCH METHOD

Research Design

The research used a completely randomized design with a factorial pattern. There were 2 factors namely shallot skin extract (0%, 10%, 20%, and 30%), and soaking time (1 hour, 3 hours, and 6 hours), repeated 3 times. This research was carried out at the Seed Technology Laboratory of the Faculty of Agriculture, Siliwangi University, West Java Indonesia. The materials used was Deja 2 variety soybean seeds, were originated from Research Center for Legumes and Tuber Crops, distilled water (aquades) and 70% ethanol was obtained from chemical store (Brataco), and shallot skins were obtained from shallot-frying home industry.

Research Procedure

Preparing shallot skin extract as seed priming

Extraction of shallot skin follows the Črnivec et al. (2021) with modification. The maceration technique is used to produce shallot skin extract using 70% ethanol as the solvent. The shallot skin is washed and air-dried. Then, puree it with a blender, then the shallots skin is put in a macerator and ethanol is added and stirred until the shallot skin powder dissolves. Filtering is carried out to obtain the filtrate. The filtrate is put into a rotary evaporator to obtain a thick extract of shallot skin. The shallots skin extract is diluted into concentrations of 10, 20, and 30%. Then, seed priming is carried out by means of soaking the soybean seeds in shallot skin extracts for 1, 3, and 6 hours. The seeds are rinsed in running water and stored at room temperature for 24 hours, then the seeds are ready for accelerated aging.

Accelerated aging method

After the seeds are invigorated (soaked in the shallot skin extract), then obsolescence is carried out (accelerated aging) by placing the seeds in a bag and then storing them in a plastic box in 100% humid condition. The box was closed tightly and then placed in the oven at 40°C for a day. Accelerated aging method in this way is identical to a storage period of 3 months (Hillari et al., 2019). Next, the seeds are sown using paper media and put them into the germinator.

Instruments, Data Collection and Data Analysis Techniques

The data collected includes: (1) Electrical conductivity of seeds: Five seeds from each treatment were weighed and then soaked in a sealed plastic cup containing 50 ml of distilled water for 24 hours. The soaking water was then tested for its electrical conductivity using a digital EC meter. (2) Seed germination: The seed viability is calculated based on the number of seeds that germinated at the last day of observation divided by the number of seeds that germinated (100 seeds) multiplied by 100%. (3) Vigor index: The vigor index is calculated based on the number of normal sprouts that grow during the first observation (first count=5 days after germinated) divided by the number of seeds germinated (100 seeds) multiplied by 100%. (4) Growth rate: Germination rate is calculated from the increase in the number of sprouts everyday (24 hours = etmal) multiplied by 100%, starting from the first day after planting until the last day of observation (8 days). (5) Dry weight of sprouts: The sprouts are cleaned of dirt, then placed in paper bags, and then dried in an oven at 60°C for 2 x 24 hours. They are then removed from the oven and cooled, and then weighed using a digital scale. The observed data were then analyzed statistically using the analysis of variance (ANOVA) and followed with the Duncan's multiple range test (DMRT) at $\alpha = 0.05$ by using of SPSS.23.1 software.

RESULTS AND DISCUSSION

Electrical Conductivity of Seeds

Statistical analysis shows that shallot skin extract has a significant interaction effect with soaking time on the electrical conductivity (EC) of seeds (Table 1). Soybean seeds treated with 0 to 30% shallot skin extract with have a lower EC if soaked for a longer time. Soaking soybean seeds in shallots skin extract for 6 hours at a concentration of 10% shallots skin extract reduced the EC to 32.02 $\mu\text{S cm}^{-1}\text{g}^{-1}$ or 43.5% lower compared to soaking for 1 hour that reaches 59.67 $\mu\text{S cm}^{-1}\text{g}^{-1}$. Likewise, soaking for 6 hours at a concentration of 20% was significantly reduced seed EC by 37.6% to 39.34 $\mu\text{S cm}^{-1}\text{g}^{-1}$ compared to soaking for 1 hour. Meanwhile, at a concentration of 30%, the decrease in EC was not significant. The EC test is one of the seed vigor tests, which indicates the condition of cell membrane integrity (Nugraheni et al., 2023). Seed EC reflects the amount of electrolytes that move out from within towards the seed coat which can be detected by a conductivity meter (Suryaman et al., 2021). Oxidation of membrane lipids increases the risk of membrane leakage, hence aged seeds often show higher levels of EC (Basu & Groot, 2023). The higher the EC number, the higher the level of cell membrane damage (Nugraheni et al., 2023).

The damage of the cell membranes is usually accompanied by the movement of various nutrients towards the outside which can result in insufficient energy requirements for the germination and growth process, that results in the decrease in seed germination and vigor. On the other hand, the decrease in the electrical conductivity of seeds indicates that potential damage to cell components due to the destructive power of free radicals can be avoided or prevented. This condition relates with the role of phytochemical compounds such as phenolic compounds, flavonoids, anthocyanins, and quercetin contained in the shallot skins (Kumar et al., 2022), which seep into the seeds and act as strong antioxidants (Piechowiak & Balawejder, 2019). As a strong antioxidant, these compounds can reduce or even prevent damage of cell membranes by detoxifying free radicals which are often produced from the metabolic process of deteriorating seeds (Ebony et al., 2019), as a result the free radicals turn into non-reactive and harmless state (Mehla et al., 2017), as well as its destructive power decreases which results in the decrease in EC of the seeds. Whereas, Ranganathan & Groot (2023) stating that the repair of protein damage (membrane cell) is due to the reduction of methionine sulfoxide by methionine sulfoxide reductase.

Tabel 1. Effect of shallots skin extract and soaking time on the electrical conductivity of soybeans seeds ($\mu\text{S cm}^{-1}\text{g}^{-1}$)

Shallots skin extract	Soaking time		
	1 hour	3 hours	6 hours
0%	74.35 a A	53.93 a B	47.42 ab B
10%	59.67 b A	41.15 b B	32.02 c B
20%	63.01 b A	56.17 a A	39.34 b B
30%	56.94 b A	56.58 a A	52.05 a A

Description: Numbers followed by the same capital letter horizontally and the same lowercase letters horizontally vertical is not significantly different according to the Duncan's Multiple Range Test at $\alpha=0.05$.

Seed Germination And Vigor

Table 2 shows that the seed viability and vigor index were not significantly influenced by the interaction effect of shallot skin extract and soaking time, but the shallot skin extract independently showed significant effect. Shallot skin extract at various concentrations (10%, 20%, and 30%) significantly increased germination viability and vigor index compared to the control (0%). The increase in germination ranged from 44.2% to 59.3%, while the increase in vigor index ranged from 88.4% to 120.9% compared to the control. Soaking seeds in shallot skin extract is an invigoration or osmotic priming technique. The result is in relation with Haider et al. (2019) stating that the invigoration technique controls the seed hydration process and accelerates and increases seed germination; Selvi & Saraswathy (2017) stating that invigoration technique inhibits the deterioration process; and Piechowiak & Balawejder (2019) stating that since the extract contains various compounds which are categorized as strong antioxidants that can prevent cells from oxidative damage due to free radical attacks. Thus, soaking in shallot skin extract can stimulate and increase germination and seed vigor. Meanwhile, the soaking times did not cause a significant different in increasing germination and seed vigor. Soaking in shallot skin extract for 1 hour was able to control the seed hydration process which had an impact on improving and increasing the germination process.

Table 2. Effect of shallots skin extract and soaking time on germination power and vigor index of soybean seed

Treatments	Seed germination power (%)	Vigor index
Shallots skin extract		
0%	47.78 a	23.89 a
10%	68.89 b	45.00 b
20%	76.11 b	52.78 b
30%	69.44 b	47.22 b
Soaking time		
1 hour	66.25 a	43.75 a
3 hours	65.83 a	41.67 a
6 hours	64.58 a	41.25 a

Description: Numbers followed by the same lowercase letters horizontally vertical is not significantly different according to the Duncan's Multiple. Range Test at $\alpha=0.05$.

Growth Rate And Dry Weight Of Sprouts

Based on statistical analysis, the growth rate and dry weight of the sprouts were not significantly influenced by the interaction between shallot skin extract and soaking time. On the other hand, shallot skin extract independently significantly affected the growth rate and dry weight (Table 3). Shallot skin extract 10% to 30% significantly increased the growth rate and dry weight of sprouts compared to the

control (0%). The increase in growth rate was 45.4% to 62.5% compared to the control which only achieved a growth rate of 4.56% etmal^{-1} . The dry weight of the sprouts increased by 72.9% to 94.6% compared to the dry weight in control which only reached a weight of 0.37 g. The increase in growth rate and dry weight of the sprouts illustrates that the cell biosynthesis in the germination phase runs well and obstacles or disturbances that could potentially hinder the cell biosynthesis process can be avoided (Suryaman et al., 2021).

Such conditions are predicted to be closely related to the nature or role of the phytochemicals contained in shallot skin which are antioxidant (Kumar et al., 2022) and antimicrobial (Črnivec et al., 2021). The increase of free radicals (ROS) in deteriorating seeds has negative impact on the growth and cell biosynthesis (Ebony et al., 2019), but by administering shallot skin extract, oxidative damage can be prevented, such as reduced fat peroxidation, damage or disturbances to enzyme function can be prevented so that cell metabolic processes run normally (Piechowiak & Balawejder, 2019). The results is in relation with Corbineau (2024) stating that seed priming improves growth rates on seed of wheat and tomato. Apart from that, potential interference from biotic factors in the form of microorganisms can also be overcome (Črnivec et al., 2021). Shallot skin also contains minerals, such as potassium, calcium, magnesium, iron, zinc, and manganese (El Mashad et al., 2019), so that shallot skin extract can increase the availability of nutrients needed for continued growth and cell biosynthesis which has an impact on increasing the dry weight of sprouts. Meanwhile, the increase in growth rates and dry weight was not significantly influenced by the soaking time. It seems that even 1 hour soaking is appropriate for soybean seeds to absorb various phytochemical compounds which play a positive role in the germination process and cell biosynthesis, thereby influencing the growth rate and dry weight of the sprouts.

Table 3. Effect of shallots skin extract and soaking time on growth rate and dry weight of soybean sprouts

Treatments	Growth rate (% etmal^{-1})	Dry weight (g)
Shallots skin extract		
0%	4.56 a	0.37 a
10%	6.68 b	0.65 b
20%	7.41 b	0.72 b
30%	6.63 b	0.64 b
Soaking time		
1 hour	6.39 a	0.60 a
3 hours	6.35 a	0.58 a
6 hours	6.21 a	0.60 a

Description: Numbers followed by the same lowercase letters horizontally vertical is not significantly different according to the Duncan's Multiple. Range Test at $\alpha= 0.05$.

CONCLUSION

The application of shallot skin extract and soaking time significantly affected the electrical conductivity of soybean seeds. Soaking in 10 percent shallot skin extract for 6 hours resulted in the lowest electrical conductivity. The use of shallot skin extract has the potential to slower the rate of deterioration while simultaneously maintaining the viability and vigor of soybean seeds. Meanwhile, the soaking time did not significantly affect the rate of seeds deterioration. Therefore, shallot skin extract can be used as seed priming to maintain seed quality in storage.

ACKNOWLEDGMENTS

We grateful to Sasi Ramandanthi who helped carry out this research full time.

AUTHOR CONTRIBUTIONS

Conceptualization, Methodology, Analysis Data, Writing – Review & Editing; MS. Writing - Original Draft Preparation; YS .

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

REFERENCES

- Basu, S., & Groot, S. P. C. (2023). Seed vigour and invigoration. In M. Dadlani & D. K. Yadava (Eds.), *Seed Science and Technology: Biology, Production, Quality* (pp. 67–89). Springer Nature. <https://doi.org/10.1007/978-981-19-5888-5>
- Chhabra, R., Shabnam, & Singh, T. (2019). Seed aging, storage and deterioration: An irresistible physiological phenomenon. *Agricultural Reviews*, *40*(3), 234–238. <https://doi.org/10.18805/ag.r-1914>
- Choudhary, K. K., Chaudary, N., Agrawal, S. B., & Agrawal, M. (2018). Reactive oxygen species: generation, damage, and quenching in plants during stress. In V. P. Singh, S. Singh, D. K. Tripathi, S. M. Prasad, & D. K. Chauhan (Eds.), *Reactive Oxygen Species in Plants* (pp. 89–115). John Wiley & Sons Ltd.
- Corbineau, F. (2024). The effects of storage conditions on seed deterioration and ageing: How to improve seed longevity. *Seeds*, *3*(1), 56–75. <https://doi.org/10.3390/seeds3010005>
- Črnivec, I. G. O., Skrt, M., Šeremet, D., Sterniša, M., Farčnik, D., Štrumbelj, E., Poljanšek, A., Cebin, N., Pogačnik, L., Možina, S. S., Humar, M., Komes, D., & Ulrih, N. P. (2021). Waste streams in onion production: Bioactive compounds, quercetin and use of antimicrobial and antioxidative properties. *Waste Management*, *126*, 476–486. <https://doi.org/10.1016/j.wasman.2021.03.033>
- Directorate of Food Crops, H. and E. C. S. (2025). *Statistics of horticulture 2024* (T. H. Marpaung & U. Widiyantoro, Eds.; Vol. 6). BPS-Statistics Indonesia.
- Ebone, L. A., Caverzan, A., & Chavarria, G. (2019). Physiologic alterations in orthodox seeds due to deterioration processes. *Plant Physiology and Biochemistry*, *145*, 34–42. <https://doi.org/10.1016/j.plaphy.2019.10.028>
- El Mashad, H. M., Zhang, R., & Pan, Z. (2019). Onion and garlic. In *Integrated Processing Technologies for Food and Agricultural By-Products* (pp. 273–296). Elsevier. <https://doi.org/10.1016/B978-0-12-814138-0.00011-3>
- Haider, I., Akmal, M., Shakeel, M. T., Ahmad, S., Ahmad, N., Hussain, S., Bilal, M., & Ali, M. A. (2019). Improving antioxidant defense in plants through seed priming and seedling pretreatment. In M. Hasanuzzaman & V. Fotopoulos (Eds.), *Priming and Pretreatment of Seeds and Seedlings* (pp. 595–604). Springer Nature Singapore Pte Ltd. <https://doi.org/10.1007/978-981-13-8625-1>
- Hillari, O., Pramono, E., Kamal, M., & Agustiansyah. (2019). Viability of soybean seeds (*Glycine max* (L.) Merr.) varieties argomulyo and dena-1 due to the exposed on saturated steam or stored at low temperatures. *Jurnal Ilmiah Biologi Eksperimen Dan Keanekaragaman Hayati*, *6*(1), 55–61.
- Hussain, S., Hussain, S., Khaliq, A., Ali, S., & Khan, I. (2019). Physiological, biochemical, and molecular aspects of seed priming. In M. Hasanuzzaman & V. Fotopoulos (Eds.), *Priming and Pretreatment of Seeds and Seedlings* (pp. 43–62). Springer Nature.
- Kumar, M., Barbhai, M. D., Hasan, M., Punia, S., Dhumal, S., Radha, Rais, N., Chandran, D., Pandiselvam, R., Kothakota, A., Tomar, M., Satankar, V., Senapathy, M., Anitha, T., Dey, A., Sayed, A. A. S., Gadallah, F. M., Amarowicz, R., & Mekhemar, M. (2022). Onion (*Allium cepa* L.) peels: A review on bioactive compounds and biomedical activities. *Biomedicine and Pharmacotherapy*, *146*(112498), 1–15. <https://doi.org/10.1016/j.biopha.2021.112498>
- Liu, S., & Yang, R. (2020). Regulations of reactive oxygen species in plants abiotic stress: An integrated overview. In D. K. Tripathi, P. V Singh, S. K. Chauhan, S. Sharma, S. M. Prasad, N. K. Dubey, & N. Ramawat (Eds.), *Plant Life under Changing Environment: Responses and Management* (pp. 323–353). Elsevier. <https://doi.org/10.1016/B978-0-12-818204-8.00017-5>
- Mehla, N., Sindhi, V., Josula, D., Bisht, P., & Wan, S. H. (2017). An Introduction to antioxidants and their roles in plant stress tolerance. In M. I. Khan & N. A. Khan (Eds.), *Reactive Oxygen Species and Antioxidant Systems in Plants: Role and Regulation under Abiotic Stress* (pp. 1–23). Springer Nature. <https://doi.org/10.1007/978-981-10-5254-5>

- Ministry of Agriculture - Republic of Indonesia. (2024). *Agricultural statistics 2024* (V. S. Bonavia, P. H. Mulianny, R. Suryani, T. H. Astuti, V. J. Siagian, T. Agustina, B. Indra, S. N. Sholihah, N. I. Amzani, & D. Prasetyorini, Eds.). Ministry of Agriculture - Republic of Indonesia.
- Mobin, L., Haq, M. A., Ali, R., Naz, S., & Saeed, S. G. (2021). Antibacterial and antioxidant potential of the phenolic extract and its fractions isolated from *Allium ascalonicum* (onion) peel. *Natural Product Research*, 36(12), 3163–3167. <https://doi.org/10.1080/14786419.2021.1948040>
- Nguyen, T., Lapoin, W., Young, M., & Nguyen, C. H. (2022). Changes in fermented soybean nutritional content generated under the different fermentation conditions by *Bacillus subtilis*. *Waste and Biomass Valorization*, 13(1), 563–569. <https://doi.org/10.1007/s12649-021-01501-2>
- Nugraheni, N., Bambang, P., Samanhuji, S., & Sakya, A. T. (2023). Comparison between the electrical conductivity method and radicle emergence test as a rapid test of sorghum seed vigor. *Kultivasi*, 22(2), 200–209. <https://doi.org/10.24198/kultivasi.v22i2.46547>
- Piechowiak, T., & Balawejder, M. (2019). Onion skin extract as a protective agent against oxidative stress in *Saccharomyces cerevisiae* induced by cadmium. *Journal of Food Biochemistry*, 43(7), 1–9. <https://doi.org/10.1111/jfbc.12872>
- Pinheiro, D. T., Dias, D. C. F. D. S., da Silva, L. J., Martins, M. S., & Finger, F. L. (2023). Oxidative stress, protein metabolism, and physiological potential of soybean seeds under weathering deterioration in the pre-harvest phase. *Acta Scientiarum - Agronomy*, 45(e56910), 1–12. <https://doi.org/10.4025/actasciagron.v45i1.56910>
- Pournik, S., Abbasi-Rostami, M., Sadeghipour, H. R., & Ghaderi-Far, F. (2019). True lipases beside phospholipases contribute to walnut kernel viability loss during controlled deterioration and natural aging. *Environmental and Experimental Botany*, 164, 71–83. <https://doi.org/10.1016/j.envexpbot.2019.04.016>
- Ranganathan, U., & Groot, S. P. C. (2023). Seed longevity and deterioration. In M. Dadlani & D. K. Yadava (Eds.), *Seed Science and Technology: Biology, Production, Quality* (pp. 91–108). Springer Nature. <https://doi.org/10.1007/978-981-19-5888-5>
- Sagar, N. A., Pareek, S., & Gonzalez-Aguilar, G. A. (2020). Quantification of flavonoids, total phenols and antioxidant properties of onion skin: a comparative study of fifteen Indian cultivars. *Journal of Food Science and Technology*, 57(7), 2423–2432. <https://doi.org/10.1007/s13197-020-04277-w>
- Selvi, D. T., & Saraswathy, S. (2017). Seed viability, seed deterioration and seed quality improvements in stored onion seeds: a review. *The Journal of Horticultural Science and Biotechnology*, 93(1), 1–7. <https://doi.org/10.1080/14620316.2017.1343103>
- Soundararajan, P., Manivannan, A., & Jeong, B. R. (2019). Different antioxidant defense systems in halophytes and glycophytes to overcome salinity stress. In B. Gul, B. Böer, M. A. Khan, M. Clüsener-Godt, & A. Hameed (Eds.), *Tasks for vegetation science* (Vol. 6, pp. 335–347). Springer Nature. <https://doi.org/10.1007/978-3-030-04417-6>
- Suryaman, M., Hadiyah, I., & Nuraeni, Y. (2021). Mitigasi cekaman salinitas pada fase perkecambahan kedelai melalui invigorasi dengan ekstrak kulit manggis dan ekstrak kunyit. *AGROSAINSTEK: Jurnal Ilmu Dan Teknologi Pertanian*, 5(1), 18–26. <https://doi.org/10.33019/agrosainstek.v5i1.172>
- Tiwari, S. (2018). Reactive oxygen species and antioxidants: A continuous scuffle within the cell. In V. P. Singh, S. Singh, D. K. Tripathi, S. M. Prasad, & D. K. Chauhan (Eds.), *Reactive Oxygen Species in Plants* (pp. 187–203). Jhon Wiley & Sons Ltd.
- Zhang, K., Zhang, Y., Sun, J., Meng, J., & Tao, J. (2021). Deterioration of orthodox seeds during ageing: Influencing factors, physiological alterations and the role of reactive oxygen species. *Plant Physiology and Biochemistry*, 158, 475–485. <https://doi.org/10.1016/j.plaphy.2020.11.031>