



PRINT ISSN 1119-8362
Electronic ISSN 2659-1499

Full-text Available Online at
<https://www.ajol.info/index.php/jasem>
<https://www.bioline.org.br/ja>

J. Appl. Sci. Environ. Manage.
Vol. 30 (3) 826-831 March 2026

Effects of Organic and Inorganic Fertilizers on Oxidative Stress Biomarkers and Antioxidant Enzyme Activity in Sesame (*Sesamum indicum* L.) Plants obtained from Abraka, Delta State, Nigeria

*¹OKPEWHO, OP; ²AKPORIDO, UE; ¹EDOKPIAWE, S; ¹UDO, WM; ²IRIVWIERI, AU

¹*Department of Botany, ²Department of Biochemistry, Faculty of Science, Delta State University Abraka, Delta State, Nigeria

*Corresponding Author Email: pokpewho@delsu.edu.ng

*ORCID ID: <https://orcid.org/0009-0007-8776-1046>

*Tel: +2348066433574

Co-Authors Emails: akporidoufuoma61@gmail.com; sedokpiawe@delsu.edu.ng; wudo@delsu.edu.ng; irivwieriacquit81@gmail.com

ABSTRACT: Fertilization management can influence plant oxidative balance and antioxidant defense systems, and it has a close relationship with stress tolerance and crop quality. This study evaluated the effects of organic manure and inorganic fertilizer on oxidative stress biomarkers and antioxidant enzymes activities in (*Sesamum indicum* L.) Sesame plants obtained from Abraka, Delta State, Nigeria using various standard methods. The results suggested that a moderate application of organic manure could decrease the lipid peroxidation level but enhance the antioxidant enzyme activity, and therefore improving redox balance, but at higher concentrations increased stress-related enzyme responses. Inorganic fertilizer exhibited the same pattern, where moderate levels decreased oxidative damage and high levels elevated stress markers. These results suggest that a balanced fertilizer use can maintain redox stability in sesame and may be helpful for nutrient and functional qualities by antioxidant regulation.

DOI : <https://dx.doi.org/10.4314/jasem.v30i3.24>

License: **CC-BY-4.0**

Open Access Policy: All articles published by **JASEM** are open-access and free for anyone to download, copy, redistribute, repost, translate and read.

Copyright Policy: © 2026. Authors retain the copyright and grant **JASEM** the right of first publication. Any part of the article may be reused without permission, provided that the original article is cited.

Cite this Article as: OKPEWHO, O. P; AKPORIDO, U. E; EDOKPIAWE, S; UDO, W. M; IRIVWIERI, A. U. (2026). Effects of Organic and Inorganic Fertilizers on Oxidative Stress Biomarkers and Antioxidant Enzyme Activity in Sesame (*Sesamum indicum* L.) Plants obtained from Abraka, Delta State, Nigeria. *J. Appl. Sci. Environ. Manage.* 30 (3) 826-831

Dates: Received: 30 January 2026; Revised: 19 March 2026; Accepted: 29 March 2026; Published: 31 March 2026

Keywords: *Sesamum indicum*; Stress tolerance; Oxidative stress; Antioxidant enzymes; Lipid peroxidation.

Plants play a central role in sustaining life and human well-being, providing essential resources such as food, bioactive medicinal compounds, and raw materials for numerous products used in daily life (Akporido and Okoro, 2022). The variation of bioactive secondary metabolites in medicinal plants has attracted considerable scientific interest (Halder and Jha, 2023). Increased antioxidant activities of the plant tissues do not only provide information about response to stress condition, but also can enhance the bioactive compounds in crop plants that promote human health by decreasing oxidative stress in

human cells caused by Reactive oxygen species (ROS), which is particularly associated with chronic diseases like cancer, cardiovascular diseases, and neurological disorders Sarker and Oba, 2018). Reactive oxygen species (ROS) consist of a number of oxygen-containing molecules with high intrinsic reactivity and are involved in many plant physiological processes, especially stress responses. ROS are endogenously produced during aerobic metabolism and are involved in various plant growth, development and adaptation process. In the ideal scenario, plant antioxidant system can maintain redox

*Corresponding Author Email: pokpewho@delsu.edu.ng

*ORCID ID: <https://orcid.org/0009-0007-8776-1046>

*Tel: +2348066433574

homeostasis through regulating ROS production and detoxification. However, antioxidant system can be affected by biotic and abiotic stress which disrupts balance between production and elimination of ROS and consequently resulting in superfluous accumulation of ROS and oxidative burst. To suppress oxidative damage, plants set up a complex antioxidative defense network including both enzymatic and nonenzymatic parts to work collaboratively to scavenge ROS and protect cellular biomolecules (Zheng *et al.*, 2025).

Sesamum indicum L. (sesame) is an important oilseed crop cultivated in regions including China, India, Sudan, Japan, Mexico, West and Central Africa, and Central America (Yaseen *et al.*, 2021). It is widely valued for its characteristic aroma, mellow flavor and diverse culinary applications such as the production of sesame oil, paste as well as garnishing of foods. The nutritional and medicinal value status of sesame seed was established formally in 2002 when they were included in the list of medicinal and food ingredients by the former Chinese Minister of Health (Wei *et al.*, 2022).

Sesame is prized for superior quality of its oil and protein hence the poetic lable "Queen of Oilseeds". Sesame is highly nutritious, boasting a high oil content of 38-54% and protein content of 18-25% and the seeds are widely used as toppings for burgers, breads and cakes as well as other food products. Sesame seeds have been associated with digestive, rejuvenative, and anti-aging properties. Their nutritional profile includes vitamin E, essential minerals like phosphorus, copper, iron, calcium magnesium, zinc and potassium, high levels of unsaturated fatty acids (linoleic acid) and tocopherols, contributing to the high dietary and functional value of sesame (Tizazu *et al.*, 2019). The growing reliance on the use of inorganic fertilizers in agriculture has prompted concerns about their potential effect on environmental sustainability and human health and given that sesame occupies an evident role in the human diet, alteration of antioxidant enzymes activities through fertilizer management could have a direct impact on nutritional and functional properties of sesame seeds by modifying bioactive antioxidant profile, therefore increasing suggested health benefits beyond conventional nutritive value (Jote, 2023).

The effects of fertilizers on growth and yield in sesame have been previously studied, but the effect of different fertilizer sources on osmotic adjustment and enzymatic antioxidant defense has not been established. Therefore, the objective of this paper is

to evaluate the organic and inorganic fertilizer on oxidative biomarkers and antioxidant enzyme activities in (*Sesamum indicum*) Sesame plants obtained from Abraka, Delta State, Nigeria.

MATERIALS AND METHODS

Study Area: The study was carried out in a screen house at the Botanical garden of the Department of Botany, Delta State University, Abraka, Delta State, Nigeria. Between latitudes 5°00 and 6°30'N and longitudes 0°00 and 6°45'E, roughly, is where Delta State is located. Its total land area is 16,842 square kilometers. Delta State is bordered to the north by Edo, to the northwest by Ondo, to the east by Anambra, and to the southeast by Bayelsa and the Rivers. Abraka is located in Latitude 5.74745° or 5° 44' 51" north and Longitude 6.12794° or 6° 7' 41" east. Figure 1 is a map of Delta State showing Abraka.

Sample collection, planting duration and soil treatment: Soil samples of loamy texture were sourced from a vegetation area within the university premises deemed free from contamination. White sesame seeds were bought from Abraka market, organic manure comprising poultry droppings were collected from local farmers in Abraka and inorganic fertilizer (NKP 15:15:15) bought from Abraka main market, Ethiope-East Local Government Area, Delta State, Nigeria. For the experiment, 2kg of soil was treated with 0, 5, 10, 15 and 20 percent organic manure and inorganic fertilizer. The manure-soil and fertilizer-soil mixture were turned thoroughly and left for 2 days to allow for proper mixing. The sesame seeds were planted into twenty seven (27) experimental pots, watered twice every two days and left for a total duration of four weeks (1 month) the whole plant was used for the assays. The soil was treated and planted using a split-plot design and replicates thrice.

For the organic manure; Control = Soil (2 kg) + (0 %), Treatment 1 (T1) = Soil (2 kg) + organic manure (5%), Treatment 2 (T2) = Soil (2 kg) + organic manure (10%), Treatment 3 (T3) = Soil (2 kg) + organic manure (15%), Treatment 4 (T4) = Soil (2 kg) + organic manure (20%).

Inorganic fertilizer: Treatment 1 (T1) = Soil (2 kg) + inorganic fertilizer (5%), Treatment 2 (T2) = Soil (2 kg) + inorganic fertilizer (10%), Treatment 3 (T3) = Soil (2 kg) + inorganic fertilizer (15%), Treatment 4 (T4) = Soil (2 kg) + inorganic fertilizer (20%).

Sample Analysis Methodologies: *Malondialdehyde (MDA) content:* Malondialdehyde content was

OKPEWHO, O. P; AKPORIDO, U. E; EDOKPIAWE, S; UDO, W. M; IRIVWIERI, A. U.

quantified using the 2-thiobarbituric acid (TBA) assay as described by Wang *et al.* (2014). MDA concentration was calculated in nmol g^{-1} fresh weight (FW) by measuring absorbance at 450, 532, and 600 nm using a spectrophotometer.

Catalase (CAT) activity: Catalase activity was analyzed following the method of Aebi (1984) by monitoring the decomposition of hydrogen peroxide (H_2O_2) as a decrease in absorbance at 240 nm over a

3 min interval. Enzyme activity was expressed as $\text{mmol H}_2\text{O}_2$ decomposed $\text{min}^{-1} \text{mg}^{-1}$ protein.

Superoxide dismutase (SOD) activity: Superoxide dismutase activity was determined spectrophotometrically at 560 nm using a modified nitroblue tetrazolium (NBT) reduction assay as described by Beyer and Fridovich (1987). The results were expressed as units in mg^{-1} protein.



Fig 1: map of delta state showing abiraka (Ofomola *et al.*, 218)

Statistical analysis: Data collected was subjected to analysis of variance (ANOVA) where significant differences exist; treatment means compared at $P < 0.05$ significant level using Duncan's new Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

The results in table 1 showed that the variations in the enzymatic antioxidant system observed in sesame plants treated with different concentrations of organic manure reflect a significant physiological response to nutrient-induced oxidative stress. The presence of organic manure at varying concentrations influenced the activities of key antioxidant enzymes malondialdehyde (MDA), catalase (CAT), and superoxide dismutase (SOD) which serve as biochemical markers for oxidative stress and defense regulation in plants. Malondialdehyde content varied across treatment where the highest malondialdehyde (MDA) content was recorded in T2, while T1 and T4 showed same malondialdehyde content and the lowest content was observed in T3 which indicates that reduced lipid peroxidation and lower oxidative stress, suggesting the plant's cellular membranes are relatively intact and the plant is experiencing less stre

ss(Sofa *et al.*, 2004). Catalase activity was also markedly different between treatments. However, CAT activity was significantly enhanced with the increase in manure application level, which suggests that H_2O_2 scavenging systems would be upregulated due to elevated ROS accumulation. The high CAT activity was also found in T3 and the lowest one in T1. The high CAT activity in T4 indicates great oxidising power, which could be due to the enhanced microbial activity and nutrient mineralization in rhizosphere. Catalase is an important enzyme involved in the detoxification of hydrogen peroxide to water and oxygen, and its upregulation generally represents a stronger antioxidant defense mechanism (Gill and Tuteja, 2010).

Superoxide dismutase (SOD) activity also showed a similar pattern. The most significant SOD activity was observed in T4, suggesting a strong defense mechanism against superoxide radicals. It was significantly higher than in the control, which had the lowest SOD activity. The high SOD activity detected from plants in higher treatments of manure application might be attributed to increased metabolic rate accompanying large ROS content, therefore

OKPEWHO, O. P; AKPORIDO, U. E; EDOKPIAWE, S; UDO, W. M; IRIVWIERI, A. U.

requiring stronger antioxidant responses. The control plants, lacking organic inputs, likely experienced slower growth and less oxidative challenge, resulting in lower enzymatic activity. The trend revealed in this study indicates that although organic manure does increase the growth of plants and metabolic processes, its concentration is decisive in terms of whether the plant response remains beneficial or it turns more to stress-induced defense mechanisms. T3 seems to maintain a good equilibrium, in promoting oxidative growth with little oxidative damage, which

is indicated by relatively low MDA and moderate CAT and SOD. T4 on the other hand, although it also stimulated enzyme activities, indicating a stress response to superfluous nutrient supply and its application through time may compromise plant health. These results are similar to other reports indicating that organic amendments can alter the activities of antioxidant enzymes. Chen *et al.* (2025) showed that organic fertilization can improve microbial-mediated nutrient release, influencing plant oxidative metabolism.

Table 1: The effect of organic manure on the antioxidant enzyme activity of sesame

Treatment	Antioxidant enzyme activity		
	MDA (nmol/g tissue)	CAT ($\mu\text{mol}/\text{min}/\text{g}$ tissue)	SOD (unit/g tissue)
Control (0%)	0.115 $\pm$ 0.26 ^a	15.07 $\pm$ 1.20 ^a	4.81 $\pm$ 0.26 ^a
T1 (5%)	0.135 $\pm$ 0.42 ^b	13.18 $\pm$ 1.20 ^a	6.10 $\pm$ 0.26 ^a
T2 (10%)	0.144 $\pm$ 0.32 ^c	19.20 $\pm$ 0.20 ^a	7.51 $\pm$ 0.24 ^a
T3 (15%)	0.104 $\pm$ 0.05 ^d	20.25 $\pm$ 0.09 ^a	11.20 $\pm$ 0.01 ^b
T4 (20%)	0.135 $\pm$ 0.59 ^b	32.08 $\pm$ 0.94 ^b	18.50 $\pm$ 0.61 ^b

Keys: T1 = Treatment 1; T2 = Treatment 2; T3 = Treatment 3; T4 = Treatment 4. Values are presented in Mean. Values with different superscript are significantly different using Duncan's Multiple Range Tests (DMRT).

Table 2: The effect of inorganic fertilizer on the antioxidant enzyme activity of sesame

Treatment	Antioxidant enzyme activity		
	MDA (nmol/g tissue)	CAT ($\mu\text{mol}/\text{min}/\text{g}$ tissue)	SOD (unit/g tissue)
Control (0%)	0.115 $\pm$ 4.02 ^a	15.07 $\pm$ 2.11 ^b	4.81 $\pm$ 1.16 ^a
T1 (5%)	0.112 $\pm$ 1.85 ^a	21.19 $\pm$ 0.13 ^a	12.10 $\pm$ 0.95 ^b
T2 (10%)	0.108 $\pm$ 0.07 ^b	25.08 $\pm$ 0.44 ^a	13.22 $\pm$ 0.06 ^b
T3 (15%)	0.144 $\pm$ 0.51 ^c	22.56 $\pm$ 0.85 ^a	18.11 $\pm$ 0.23 ^c
T4 (20%)	0.129 $\pm$ 1.59 ^c	30.37 $\pm$ 0.89 ^a	17.27 $\pm$ 0.97 ^c

Keys: T1 = Treatment 1; T2 = Treatment 2; T3 = Treatment 3; T4 = Treatment 4

Values are presented in Mean. Values with different superscript are significantly different using Duncan's Multiple Range Tests (DMRT).

The results presented in table 2 showed that malondialdehyde activity, a biochemical marker of lipid peroxidation and membrane damage, was highest in T3 at 0.144 $\pm$ 0.51 nmol/g tissue. This elevated MDA level suggests that plants in T3 experienced a higher degree of oxidative stress compared to other treatments. T4 followed, while the lowest MDA level was recorded in T2. The differences in MDA activity imply that the dosage or formulation of inorganic fertilizer used in Tr3 may have induced a level of metabolic stress that resulted in increased ROS generation and subsequent membrane lipid degradation. Conversely, T2 appears to have provided a nutrient environment that minimized oxidative damage, likely due to a more balanced uptake and assimilation of nutrients without inducing excessive ROS accumulation. Catalase activity followed a similar trend of variation among treatments. T4 exhibited the CAT activity increased with fertilizer concentration. The elevated levels of catalase activity in T4 and T2 suggest that an

enzymatic removal of H₂O₂, a typical ROS produced under intensive metabolism, was active. This enzymatic reaction indicates that these treatments caused an oxidative burden great enough to induce up-regulation of antioxidant defense in plants. The lower CAT activity in T1 may imply a lower level of oxidative stress or a reduced ability to activate the enzymatic defense system possibly due to suboptimal nutrient availability at this fertilizer concentration. Superoxide dismutase activity showed a significant response to the inorganic fertilizer treatments. The highest SOD activity was observed in T3 and the lowest was in the control. The significant increase in SOD activity for T3 indicates a high generation of superoxide radicals (O₂⁻) and demanding the need for strong antioxidative response. This suggests that while Treatment 3 may have supported active plant metabolism and growth, it also led to the accumulation of ROS, which the plant overcame through increased SOD activity. The control group, which did not receive inorganic fertilizer, maintained

basal SOD levels, thus this group may have suffered less or no oxidative stress attributed to marginal growth and metabolism.

In general, the results showed that different concentrations of inorganic fertilizer treatments caused significant changes in the antioxidant enzyme system of sesame plants. T3, while potentially promoting high metabolic activity, also induced elevated oxidative stress, as evidenced by high MDA and SOD activities. T4 similarly showed signs of oxidative activity but with a slightly better balance between ROS production and antioxidant defense, as indicated by the high CAT activity.

Treatment 2 appear to represent a favourable status under inorganic fertilization, with very low oxidative stress level (low MDA), yet high CAT activity, indicating an efficient ROS detoxification without excessive stress induction. This result is also consistent with existing studies, which demonstrated that excessive levels of inorganic fertilizer might disrupt nutrient absorption and cause oxidative damage. Sharma *et al.* (2012) suggested that excessive application may open the potential for enhanced ROS formation in plant tissue due to nitrogen and phosphorus, thus additional antioxidant enzyme activity is required. Similarly, Hernández *et al.* (2001) found that the activity of SOD and CAT could be affected by inorganic nitrogen sources with different level of deficiency, as well as growth stage.

Therefore, while inorganic fertilizers are effective in promoting plant growth, their application must be carefully managed to avoid oxidative damage and maintain physiological stability. In comparing the antioxidant enzyme activity of sesame planted in both organic manure and inorganic fertilizer, the results showed that moderate organic manure (T3) minimized oxidative stress (lowest MDA) while maintaining high CAT and SOD activity, promoting plant vigor. Excessive manure (T4) caused elevated CAT and SOD levels, indicating higher oxidative stress. For inorganic fertilizer, moderate application (T2) achieved low MDA with high antioxidant activity, whereas higher levels (T3) increased MDA and SOD, signaling greater oxidative burden.

Overall, the results showed that fertilizer regime and the rate of application ad a significant effect on inducing oxidative stress and antioxidant defense mechanism in *Sesamum indicum*. Since both organic manure and inorganic fertilizers had the potential to increase the activity of antioxidant enzymes, there is need for moderate applications in order to effectively maintain redox homeostasis and minimizing lipid

peroxidation. However the excess application of fertilizer especially the inorganic fertilizer, enhanced oxidative stress as was indicated by an increase in MDA accumulation and increases in enzymatic defense responses.

The findings are indicative of the importance of the balanced management of nutrient supply, in order to avoid metabolic disorders which result from increased production of ROS. Furthermore, the observed enhancement of antioxidant defense under optimal fertilization suggests potential downstream benefits for the biochemical and functional attributes of sesame, and given the relationship that exists between plant redox regulation and the accumulation of health-promoting phytochemicals. Therefore it is important to adopt appropriate fertilizers treatments which may not only improve crop performance and stress resilience but may also contribute to the nutritional and functional value of sesame-derived products

Conclusion: The type of fertilizer used and the rate of application had a significant effect on the antioxidant enzyme activity and oxidative stress in *Sesamum indicum*. It was observed from the findings that moderate organic manure improved antioxidant defense while inhibiting lipid peroxidation, whereas excess application of fertilizer especially the inorganic fertilizer showed elevated oxidative stress markers, emphasizing the need for balanced nutrient management to maintain redox homeostasis in sesame plant and suggest that optimized fertilization may also support the crop's nutritional and functional quality.

DECLARATION

Ethical Approval: This study did not involve human participants or animals experimentation and therefore did not require formal ethical approval. All procedures involving data handling and analysis were conducted responsibly and in accordance with standard academic and institutional guidelines.

Disclaimer (Artificial Intelligence): Author(s) hereby declare that no generative Artificial Intelligence (AI) technologies such as large language models (ChatGPT, COPILOT, XLNet, Ernie 3.0 Titan etc) and text-to-image generators have been used during writing or editing of this manuscript.

Declaration of Conflict of Interest: The authors declare that no known conflict of interest or personal relationships that have influenced the work reported in this paper.

Declaration of Data Availability: Data are available upon request from the first author.

REFERENCES

- Aebi, H. (1984). Catalase in vitro. *Methods Enzymol.* 105: 121–126. DOI: [https://doi.org/10.1016/S0076-6879\(84\)05016-3](https://doi.org/10.1016/S0076-6879(84)05016-3)
- Akporido, UE; Okoro, IO. (2022). Influence of Geographical Location on Key Nutritional Properties of Watermelon (*C. lanatus*) Pulp. *J. Appl. Sci. Environ. Manage.* 26 (12): 2039-2044. DOI: <https://dx.doi.org/10.4314/jasem.v26i12.18>
- Beyer Jr, WF; Fridovich, I. (1987) Assaying for Superoxide dismutase activity: Some large consequences of minor changes in conditions. *Annals. Biochem.* 161: 559–566. DOI: [http://dx.doi.org/10.1016/0003-2697\(87\)90489-1](http://dx.doi.org/10.1016/0003-2697(87)90489-1)
- Chen, L; Fang, H; Cheng, S; Wang, H; Guo, Y; Shi, F; Pu, H. (2025). Organic Fertilization Enhances Microbial-Mediated Dissolved Organic Matter Composition and Transformation in Paddy Soil. *Agriculture.* 15(23): 2412. DOI: <https://doi.org/10.3390/agriculture15232412>
- Gill, SS; Tuteja, N. (2010). Reactive oxygen species and antioxidant machinery in abiotic stress tolerance in crop plants. *Plant. Physiol. Biochem.* 48(12): 909–930. DOI: <http://dx.doi.org/10.1016/j.plaphy.2010.08.016>
- Halder, M; Jha, S. (2023). Medicinal plants and bioactive phytochemical diversity: a fountainhead of potential drugs against human diseases. *Med. Plants Biodivers. Biotechnol. Conserv.* (pp. 39-93). Singapore: Springer Nature Singapore. DOI: https://doi.org/10.1007/978-981-19-9936-9_2
- Hernández, JA; Ferrer, MA; Jiménez, A; Barceló, AR; Sevilla, F. (2001). Antioxidant systems and O₂/ H₂O₂ production in the apoplast of pea leaves: its relation with salt-induced necrotic lesions in minor veins. *Plant. Physiol.* 127(3): 817–831. DOI: <https://doi.org/10.1104/pp.010188>
- Jote, CA. (2023). The impacts of using inorganic chemical fertilizers on the environment and human health. *Org. Med. Chem. Int. J.* 13(3): 555864. DOI: <https://doi.org/10.19080/OMCIJ.2023.13.555864>
- Ofomola, MO; Iserhien-Emekeme, RE; Okocha, FO; Adeoye, TO. (2018). Evaluation of Subsoil Competence for Foundation Studies at Site III of Delta State University, Nigeria. *J. Geophys. Eng.* 15: 638 - 657. DOI: <https://doi.org/10.1088/1742-2140/aaa073>
- Sarker, U; Oba, S. (2018). Drought stress enhances nutritional and bioactive compounds, phenolic acids and antioxidant capacity of Amaranthus leafy vegetable. *BMC. Plant. biol.* 18(1): 258. DOI: <https://doi.org/10.1186/s12870-018-1484-1>
- Sharma, P; Jha, AB; Dubey, RS; Pessarakli, M. (2012). Reactive oxygen species, oxidative damage, and antioxidative defense mechanism in plants under stressful conditions. *J. Bot.* 217037. DOI: <https://doi.org/10.1155/2012/217037>
- Sofo, A; Dichio, B; Xiloyannis, C; Masia, A. (2004). Effects of different irradiance levels on some antioxidant enzymes and on malondialdehyde content during rewatering in olive tree. *Plant Sci.* 166(2): 293-302. DOI: <https://doi.org/10.1016/j.plantsci.2003.09.018>
- Tizazu, Y; Ayalew, D; Terefe, G; Assefa, F. (2019). Evaluation of seed priming and coating on germination and early seedling growth of sesame (*Sesamum indicum* L.) under laboratory condition at Gondar, Ethiopia. *Cogent Food Agric.* 5(1): 1609252. DOI: <https://doi.org/10.1080/23311932.2019.1609252>
- Wang, Y; Pan, F; Wang, G; Zhang, G; Wang, Y; Chen, X; Mao, Z. (2014). Effects of biochar on photosynthesis and antioxidative system of *Malus hupehensis* Rehd. seedlings under replant conditions. *Sci. Hortic.* 175: 9–15. DOI: <https://doi.org/10.1016/j.scienta.2014.05.029>
- Wei, P; Zhao, F; Wang, Z; Wang, Q; Chai, X; Hou, G; Meng, Q. (2022). Sesame (*sesamum indicum* L.): A comprehensive review of nutritional value, phytochemical composition, health benefits, development of food, and industrial applications. *Nutrients.* 14(19): 4079. DOI: <https://doi.org/10.3390/nu14194079>
- Yaseen, G; Ahmad, M; Zafar, M; Akram, A; Sultana, S; Ahmed, SN; Kilic, O. (2021). Sesame (*Sesamum indicum* L.). *Green Sustain. Process Chem. Environ. Eng. Sci.* (pp. 253-269). DOI: <https://doi.org/10.1016/B978-0-12-821886-0.00005-1>
- Zheng, Y; Sun, K; Sun, X; Li, Y; Xiao, P; He, C. (2025). Quality differences in sea buckthorn (*Hippophaë rhamnoides* L.) berries of major varieties in China based on key components and antioxidant activity. *Food Chem.* 465: 142139. DOI: <https://doi.org/10.1016/j.foodchem.2024.142139>