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Evaluasi Tren Iklim Jangka Pendek dan Kesesuaiannya untuk Pertanian Perkotaan di Palembang dan Jambi, Indonesia

Evaluating Short-Term Climate Trends and Suitability for Tropical Urban Agriculture in Palembang and Jambi, Indonesia

Strayker Ali Muda[1,2)*], Benyamin Lakitan[3)], Zulkarnain Zulkarnain[4)], Heripan Heripan[2,5)], Fitra Gustiar[3)], Fitra Fadhilah Rizar[6)], Fitri Ramadhani[3)], Lya Nailatul Fadilah[6)], Dora Fatma Nurshanti[7)], Rofiqoh Purnama Ria[3)]

[1)] Department of Agrotechnology, Faculty of Agriculture, Universitas Muhammadiyah Palembang, Palembang, 30139, South Sumatra, Indonesia
[2)] Center for Environment and Sustainable Development (CESD), Universitas Muhammadiyah Palembang, Palembang, 30139, South Sumatra, Indonesia
[3)] Department of Agronomy, Faculty of Agriculture, Universitas Sriwijaya, Indralaya, 30662, South Sumatra, Indonesia
[4)] Department of Agroecotechnology, Faculty of Agriculture, Universitas Jambi, Mendalo, 36361, Jambi, Indonesia
[5)] Department of Forestry, Faculty of Agriculture, Universitas Muhammadiyah Palembang, Palembang, 30139, South Sumatra, Indonesia
[6)] Department of Agroecotechnology, Faculty of Agriculture, Universitas Sriwijaya, Indralaya, 30662, South Sumatra, Indonesia
[7)] Department of Agrotechnology, Faculty of Agriculture, Universitas Baturaja, Baturaja, 32115, South Sumatra, Indonesia
[8)] Postgraduate of Plant Science, Faculty of Agriculture, Universitas Sriwijaya, Palembang, 30139, South Sumatra, Indonesia
[*]Penulis korespondensi: straykerali@gmail.com

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ABSTRAK

Perubahan iklim dan ketahanan pangan merupakan tantangan global pada era ini. Tren iklim berperan penting untuk menentukan karakteristik iklim dan rekomendasi kesesuaian pertanian di zona iklim tropis. Sebagai kawasan perkotaan tropis yang berkembang pesat, Palembang dan Jambi merupakan wilayah yang memerlukan perhatian khusus terkait tantangan perubahan iklim dan ketahanan pangan. Penelitian ini bertujuan untuk mengevaluasi perubahan iklim dan kesesuaian untuk pertanian perkotaan di Palembang dan Jambi. Penelitian ini menggunakan data sekunder curah hujan bulanan, suhu udara, kelembaban relatif, dan durasi sinar matahari untuk periode 2014-2018 dan 2019-2023. Data yang diperoleh kemudian dihitung rata-ratanya per bulan untuk setiap periode pengamatan. Selanjutnya, data tersebut dianalisis secara deskriptif. Hasil penelitian menunjukkan adanya perbedaan status iklim yang jelas antara Palembang dan Jambi, terutama terkait dengan curah hujan. Curah hujan di Palembang cenderung lebih tinggi dibandingkan dengan Jambi yang ditunjukkan dengan lebih banyak bulan basah (5-8 bulan di Palembang dan 3-6 bulan di Jambi). Sementara itu, musim kemarau di Jambi berpotensi lebih panjang daripada Palembang. Terdapat indikasi peningkatan suhu udara di kedua wilayah, yang terlihat dari suhu udara yang lebih tinggi pada periode 2019-2023 dibandingkan dengan periode 2014-2018 (kenaikan suhu setiap bulan di Palembang dan Jambi masing-masing 1.14% dan 0.93%). Meskipun demikian, suhu udara, kelembaban udara, dan durasi sinar matahari masih dalam rentang yang memungkinkan tanaman tropis untuk tumbuh dan produktif. Oleh karena itu, rekomendasi teknik budidaya yang sesuai di Palembang dan Jambi hampir serupa, yaitu pada bulan Maret-April dan November-Desember dengan teknik budidaya di bawah kondisi air berlebih, sedangkan pada bulan Juni-Agustus dengan budidaya tahan kekeringan atau irigasi minimum.

Kata kunci: budidaya dua cekaman; budidaya tropis; ketahanan pangan; pertanian perkotaan; variabilitas iklim.

ABSTRACT

Climate change and food security are global challenges on this era. Climate trends play a critical role in characterizing climatic conditions and informing agricultural suitability recommendations in tropical regions. As rapidly expanding tropical urban areas, Palembang and Jambi warrant particular attention regarding to climate and food security challenges. The study aimed to evaluate climate change and suitability for urban agriculture in Palembang and Jambi. The study used secondary data of monthly rainfall, air temperature, relative humidity, and sunshine duration for the 2014-2018 and 2019-2023 periods. The collected data were subsequently averaged on a monthly basis for each observation period. Thereafter, the data were analyzed using descriptive method. The results showed that there are obvious differences of climate status between Palembang and Jambi, especially related to rainfall. Rainfall in Palembang is higher than Jambi as represented by number of wet months (5-8 months on Palembang and 3-6 months on Jambi). Meanwhile, the dry season in Jambi is potentially longer than Palembang. There was an indication of increasing air temperature in both regions, as indicated by the higher air temperature in 2019-2023 compared to 2014-2018. The air temperature increases each month in Palembang and Jambi is 1.14% and 0.93%, respectively. Nevertheless, air temperature, air humidity, and sunshine duration were still within the range of tropical plants to grow and be productive. Therefore, the recommendation of suitable cultivation in Palembang and Jambi is almost similar,

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in March-April and November-December applying cultivation techniques under excess water condition, otherwise in June-August on drought-resistant or minimum irrigation cultivation.

Keywords: *climate variability; double-stress cultivation; food security; tropical cultivation; urban farming.*

INTRODUCTION

Climate change is an often-discussed issue nowadays. Human activities are the primary factor causing climate change. Thus, in some literature, the term anthropogenic climate change refers to climate change caused by human activities (Magnan et al., 2021; Ortiz-bobea, Ariel, Lobell, B. David, Ault, R.Toby , Carrillo, M. Carlos, Lobell, 2021). The CO_2 emissions and air pollution from greenhouse gases are among the many implications of human activities that contribute to climate change (Sadatshojaie & Rahimpour, 2020). Moreover, land cover change from vegetated to built-up land has contributed to more extreme climate change (Roy et al., 2022). Vegetation is a land component that plays an important role in carbon capture and storage (Nunes et al., 2020).

Urban areas are characterized by dense human activities and minimal vegetation. (Wang et al., 2022) revealed that urban energy activities such as industrial, transportation, residential, commercial sectors, and secondary energy consumption are the main factors causing increased carbon emissions, leading to climate change. Climate change has impacts on many sectors, among them related to food availability. (Malhi et al., 2021) stated that climate change has a negative effects on agriculture, starting from atmospheric conditions, such as rainfall and air temperature that are not suitable for optimal plant growth to an explosion of pest infestation which also causes yield loss. (Singh et al., 2023) emphasized that climate change will impact plant pathogens and food security, so we need to formulate a path forward.

Urban agriculture is an agricultural system practiced in urban ecosystems. Urban agriculture has the potential to provide food for urban communities sustainably (Zulfiqar et al., 2021). Several studies have confirmed that various types of plants can grow in urban ecosystems with certain treatments (Lakitan et al., 2022; Muda et al., 2023). Nevertheless, it needs to be studied more deeply, especially when linked to climate change and region-specific conditions.

Although many studies have examined the impacts of climate change on agriculture, research specifically focusing on urban agriculture in tropical regions, particularly in cities like Palembang and Jambi, remains limited. Most studies tend to focus on the effects of climate change on plant pathogens and food security in general ((Singh et al., 2023), while the specific conditions of rapidly growing tropical urban areas have not been adequately addressed. Furthermore, research on land suitability for urban agriculture in areas experiencing dynamic climate change is still scarce. While land cover changes and atmospheric conditions are known to affect agricultural productivity, their implications for urban agriculture in tropical regions like Palembang and Jambi have not been extensively studied.

Through this research is expected to be an important piece of information in formulating food security strategies in Palembang and Jambi by considering climate condition. The study aims to evaluate climate condition and suitability for urban agriculture in Palembang and Jambi.

MATERIALS AND METHODS

Research area

The study area covered Palembang and Jambi, Indonesia. Both selected locations are tropical lowland urban ecosystems located in Indonesia, an archipelagic country. As an urban area, the study area is dominated by built-up areas (Figure 1). Both regions have high population densities, namely 4317/km^2 (Palembang) and 3647/km^2 (Jambi) (Central Bureau of Statistics of Indonesia, 2023). The 1:50.000 resolution was chosen as it is adequate for spatial analysis without compromising important details.

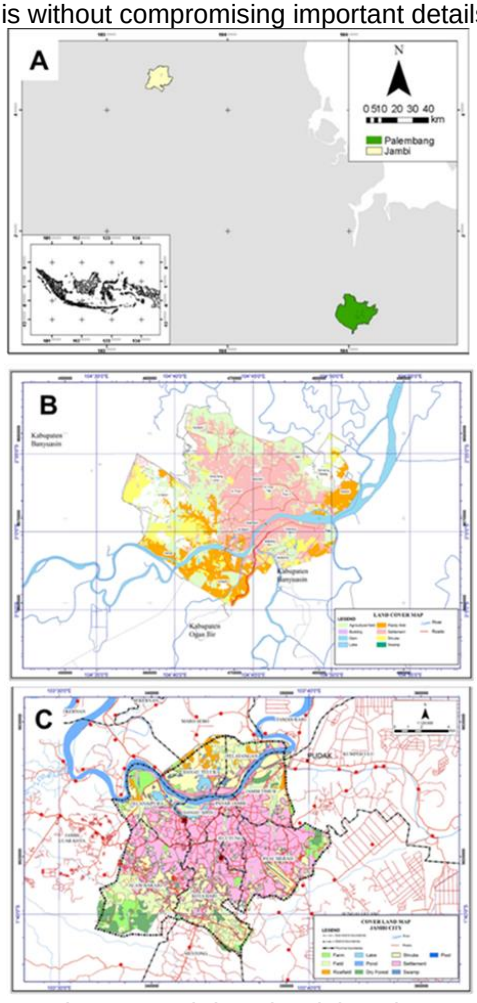

Figure 1. The research location (A) and comparison of land cover between Palembang (B) and Jambi (C). Source: Geospatial Information Agency of Indonesia

Datasets

The data collected were secondary data sourced from official institutions. The research location and land cover were obtained from the Geospatial Information Agency of Indonesia (https://tanahair.indonesia.go.id/map/). The raw spatial data of the research location and land cover used was 1:50.000. The 1:50.000 resolution was chosen as it is adequate for spatial analysis without compromising important details. The dataset used is highly reliable, sourced from verified providers, and commonly employed in similar studies, ensuring the necessary accuracy. Meanwhile, climate data such as rainfall, air temperature, relative humidity, and sunshine duration were obtained from the Meteorological, Climatological, and Geophysical Agency of Indonesia (https://dataonline.bmkg.go.id/). The Palembang climate station is located at 104°46'19" E, 2°55'38" S (8 masl), while in Jambi is located at 103°38'24" E, 1°38'1" S (27 masl). The analysis compares two distinct periods, namely 2014-2018 and 2019-2023. These periods were chosen to capture potential changes in climate patterns, especially given the growing significance of climate change discussions. The comparison will focus on anomaly analysis, assessing the differences in the average rainfall and temperature between the two periods. This approach helps to identify significant deviations from expected climate norms and trends.

Data Analysis

All data collected were provided in maps and graphs. The map was layout using ArcGIS software. Meanwhile, the climate data collected was organized to find monthly rainfall, average of air temperature and relative humidity, and average of sunshine duration. We used monthly average data to identify climate trends, which were then depicted in graphs to visualize the changes over time. For rainfall classification, we categorized months based on the average rainfall as follows: <100 mm was classified as dry months, 100-200 mm as humid months, and >200 mm as wet months. This classification helps in illustrating the rainfall patterns and climatic variability in the studied region. Climate data was processed using Microsoft Excel software. Furthermore, the collected data were analyzed descriptively and elaborated with relevant literature.

RESULTS AND DISCUSSION

Rainfall Characteristics and Implications for Urban Cultivation

The monthly rainfall of Palembang and Jambi was confirmed to follow a two-peak equatorial pattern, with March-April as the first peak and November-December as the second one. This pattern occurs throughout the year. Meanwhile, June-August is the dry season period, as represented by lower monthly rainfall compared to the other months. Based on the monthly rainfall collected, Palembang is indicated to be wetter than Jambi, mainly when comparing the first (321.16 mm in March during 2014-2018) and second rainfall peaks (347.18 mm in March during 2019-2023). Based on monthly rainfall, we divided wet months, humid months, and dry months which are indicated by >200 mm, >100-200 mm, and <100 mm of rainfall, respectively (Wandayantolis, W., Budianta, D., Yakup, Y., & Gunawan, 2024). The results showed that Palembang experiences higher rainfall than Jambi, with higher monthly rainfall peak as indicated by the greater number of wet months in Palembang (5-8 months) compared Jambi (3-6 months) (Figure 2). Rainfall determines the availability of water for urban agriculture. The number of wet months and high rainfall peaks in Palembang need to be considered to avoid a submerged environment that causes hypoxia conditions in plant.

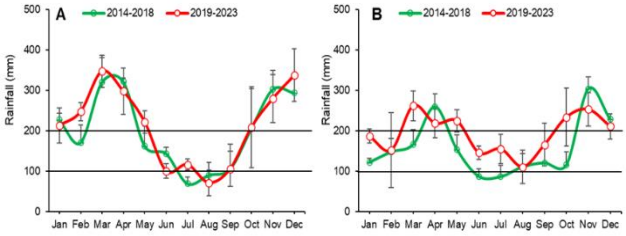

Figure 2. Average of monthly rainfall collected in 2014-2018 and 2019-2023 in Palembang (A) and Jambi (B).

Hypoxia is a condition where plants lack oxygen and has a negative impact on plant growth and development (Zahra et al., 2021). At the cellular level, hypoxia reduced respiration and adenosine triphosphate (ATP) production (Loreti & Perata, 2020). Under prolonged conditions, hypoxia will negatively affect plant growth and yield. (Jia et al., 2021) summarized the changes in physiology, morphology, and anatomy due to hypoxia condition. Given the longer wet-month duration and higher rainfall peaks in Palembang (Figure 2), urban agriculture should focus on selecting crops tolerant of transient waterlogging and root hypoxia (e.g., species with aerenchyma-forming capacity) and strengthening water-management practices, including raised beds, improved drainage, and well-aerated porous growing media. In contrast, Jambi's shorter wet period suggests a comparatively lower risk and duration of waterlogging, permitting a wider range of vegetables and herbs. Accordingly, management in Jambi should emphasize minimizing short-term ponding during peak rainfall months through drainage channels and flexible planting schedules.

There are some plants that are able to survive in submerged conditions characterized by having aerenchyma tissue. The aerenchyma tissue plays a role as oxygen transportation and plant ventilation (Striker, 2024). Thus, for high-rainfall settings such as Palembang, should prioritize crops with strong aerenchyma-forming capacity, such as *Luffa cylindrica* (Shimamura et al., 2007) and balsam pear (Li et al., 2022).

There was a similar pattern of monthly rainfall trend in Palembang and Jambi, either in 2014-2018 or

2019-2023. According to the monthly rainfall of these two periods, the difference in the beginning and end of the rainy season was only one or two months. However, we specifically highlight that there is a potential for a long dry season in Jambi at least in June-August, as happened in the 2014-2018 (June: 86.44 mm; July: 85.92 mm; August: 110.16 mm), and 2019-2023 (June: 145.50 mm; July: 154.88 mm; August: 110.42 mm). During this dry season, water availability is a major consideration in urban cultivation activities. Water deficiency will reduce the performance of plant growth and yield. Water is an important component in plant metabolism including photosynthesis. Plant under water stress was confirmed to exhibit low photosynthetic rate, thus affecting plant growth and yield (Zhao et al., 2020). In addition, water plays an important role in nutrient solubility. The water-deficient growing medium causes the nutrients contained within it to be unavailable to the plant (Marschner & Rengel, 2023).

Regarding urban cultivation practices in the dry season, the selection of relevant plant species and cultivation technique in Palembang and Jambi needs to be considered. Some plant species were indicated to be able to adapt under minimum irrigation conditions, such as eggplant (*Solanum melongena*) maintain growth and productivity at 80% field capacity (Mohawesh, 2016) and tomato (*Solanum lycopersicum*) performs well under 70% irrigation (Hashem *et al*., 2018). Meanwhile, modification of planting media through the addition of organic matter can also be done to overcome the lack of water availability. (Lal, 2020) stated that organic matter can increase the water holding capacity. Furthermore, a mixture of manure (Hosseinzadeh et al., 2021; Kadhim, 2021) and biochar (Mansoor et al., 2021) can be used as an alternative to anticipate water deficiencies.

Air Temperature and Relative Humidity Dynamics

The atmospheric condition that impacts urban agricultural activity is air temperature and air humidity. The sun's apparent motion will affect both of these atmospheric conditions. Palembang and Jambi were identified to experience two peaks in air temperature in May and November. Palembang has a higher average air temperature than Jambi. In both regions, there was obviously an increase in average air temperature in the 2019-2023 compared to the 2014-2018. This increase can be an indicator of global warming. On the other hand, air humidity follows the dry and rainy season which has affected the amount of water vapor in the atmosphere. The average humidity in Palembang is recorded higher than Jambi, as well as the monthly rainfall. Interestingly, there was a period of high air temperature followed by an increase in air humidity. This phenomenon was due to the increasing air temperature causing water on the earth's surface to evaporate which accumulated in the atmosphere, thus increasing the air humidity (Figure 3).

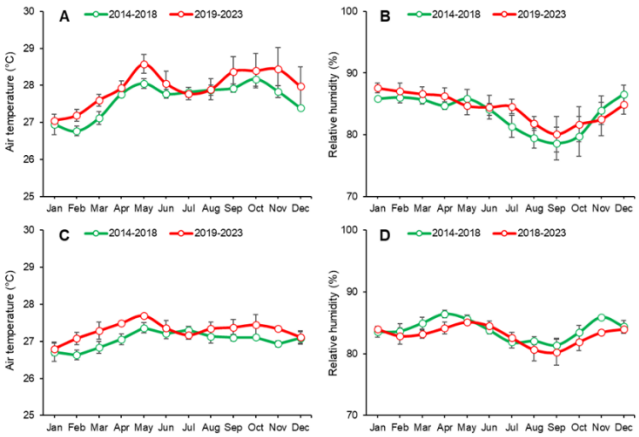

Figure 3. Average of air temperature and relative humidity collected in 2014-2018 and 2019-2023 in Palembang (A-B) and Jambi (C-D).

Based on this research, air temperature in Palembang was confirmed to be higher than Jambi. The denser population density in Palembang led land conversion from vegetated to built-up areas. Land conversion into built-up areas will have an impact on increasing air temperature. Land dominated by building was confirmed causing an increase in air temperature, while if it is dominated by vegetation, air temperature will be maintained (Halder et al., 2021).

Air temperature is a factor that affect plant growth. Extreme high temperature causes plants to experience heat stress. (dos Santos et al., 2022) revealed that heat stress causes membrane and protein damage, and disrupt plant metabolism. More specifically related to the photosynthesis sequence, heat stress affects chlorophyll biosynthesis, photochemical reactions, electron transport, and CO_2 assimilation (Hu et al., 2020). Each plant has a different air temperature tolerance threshold. (Hwang et al., 2018) reported that pak-choi (*Brassica campestris* subsp. *chinensis*) experienced declining growth at 32°C, conversely edible amaranth (*Amaranthus tricolor*) experienced better growth at the same temperature. Meanwhile, 'lollo rosso' lettuce (*Lactuca sativa*) experienced inhibited growth at 33°C when compared to 25°C (Sublett et al., 2018). The results of this study showed that the air temperature of Palembang and Jambi was still in the range of 26-28.5°C. Therefore, these crops are recommended for urban cultivation in Palembang and Jambi.

Sunshine Duration and Crop Growth Potential

As tropical region, the sunshine duration in Palembang and Jambi is relatively long-term. There was no dramatically change in sunshine duration in 2014-2018 to 2019-2023, although there was a decrease in June of the 2014-2018. The peak sunshine duration in Palembang and Jambi occurred in August and then slowly declined until December. The sunshine duration in Palembang was identified to be slightly shorter than that in Jambi. Higher rainfall in Palembang caused the atmosphere to be cloudy more

often than Jambi. This condition has an impact on decreasing the sunshine duration (Figure 4).

Based on the collected data, the sunshine duration in Jambi is slightly longer than Palembang. Despite Palembang being cloudier, the Jambi's position nearer to the equator also determines sunshine duration. This difference is reflected in latitudinal positions, with Jambi located at 1°30′–1°41′ S and Palembang at 2°52′–3°05′ S. Those areas that are nearer to the equator zone are proven to have a longer sunshine duration. Meanwhile, the more distant from the equator, the sunshine duration is shorter, such as in the Western of Africa (Philippon et al., 2022). The overall sunshine duration in the study area is sufficient. The sufficient sunlight allows a wide selection of plant species that can be grown in Palembang and Jambi. (Kulyakwave et al., 2020) stated that sunshine duration is a climatic factor that determines plant growth and yield. Sunshine duration plays an important role mainly related to photosynthetic metabolism. (Song & Jin, 2020) reported that a decrease in sunshine duration caused a decrease in plant growth and yield.

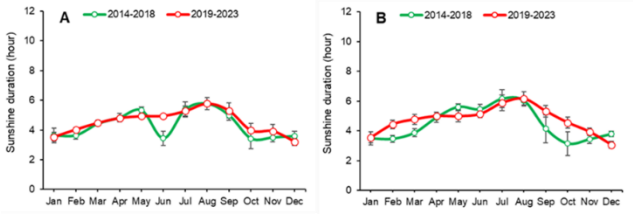

Figure 4. Average of sunshine duration collected in 2014-2018 and 2019-2023 in Palembang (A) and Jambi (B).

CONCLUSION

Across 2014-2023, the air-temperature data indicate a warming signal in both cities, while Palembang consistently exhibits higher monthly rainfall and more wet months than Jambi. Accordingly, cultivation during the main rainfall peaks (March-April and November-December) should prioritize excess-water management, whereas the drier period (June-August) should emphasize water-saving strategies and irrigation planning. This assessment is descriptive and based on monthly mean data over a relatively short time span, so future research should use longer and higher-resolution records to quantify variability and extremes and validate crop-specific recommendations through field trials.

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REFERENCES

dos Santos, T.B., Ribas, A.F., de Souza, S.G.H., Budzinski, I.G.F., and Domingues, D.S. 2022. *"Physiological Responses to Drought, Salinity, and Heat Stress in Plants: A Review*". Stresses. 2(1): 113–135. https://doi.org/10.3390/stresses2010009

Halder, B., Bandyopadhyay, J., and Banik, P. 2021. *"Monitoring the effect of urban development on urban heat island based on remote sensing and geo-spatial approach in Kolkata and adjacent areas, India*". Sustainable Cities and Society. 74(103186). https://doi.org/10.1016/J.SCS.2021.103186

Hashem, S., El-Abedin, T.Z, and Al-Ghobari, H.M. 2018. *"Assessing effects of deficit irrigation techniques on water productivity of tomato for subsurface drip irrigation system*". International Journal of Agricultural and Biological Engineering. 11(4): 137–145. https://doi.org/10.25165/j.ijabe.20181104.3846

Hosseinzadeh, M.H., Ghalavand, A., Boojar, M.M.A., Modarres-Sanavy, S.A.M., and Mokhtassi-Bidgoli, A. 2021. *"Application of manure and biofertilizer to improve soil properties and increase grain yield, essential oil and ω3 of purslane (Portulaca oleracea L.) under drought stress*". Soil and Tillage Research. 205(104633). https://doi.org/10.1016/J.STILL.2020.104633

Hu, S., Ding, Y., and Zhu, C. 2020. *"Sensitivity and Responses of Chloroplasts to Heat Stress in Plants*". Frontiers in Plant Science. 11(April): 1–11. https://doi.org/10.3389/fpls.2020.00375

Hwang, S.G., Chao, H.C., and Lin, H.L. 2018. *"Differential responses of pak choi and edible amaranth to an elevated temperature*". HortScience. 53(2): 195–199. https://doi.org/10.21273/HORTSCI12667-17

Jia, W., Ma, M., Chen, J., and Wu, S. 2021. "*Plant morphological, physiological and anatomical adaption to flooding stress and the underlying molecular mechanisms*". International Journal of Molecular Sciences. 22(3): 1–24. https://doi.org/10.3390/ijms22031088

Kadhim, A.J. 2021. *"Effect of biofertilizers and animal manure on morphophysiological characteristics and amount of coriander (Coriandrum sativum L.) essential oil under drought stress conditions*". IOP Conference Series: Earth and Environmental Science. 735(1). https://doi.org/10.1088/1755-1315/735/1/012047

Kulyakwave, P.D., Xu, S., and Yu, W. 2020. Impact of meteorological factors on rice growth stages and yield". Pertanika Journal of Science and Technology. 28(3): 1009–1026.

Lakitan, B., Rizar, F.F., and Muda, S.A. 2022. *"Morphological Characteristics and Growth Behavior of Ridge Gourd [Luffa acutangula (L.) Roxb.] in Tropical Urban Ecosystem*". Journal of

Tropical Life Science. 12(3): 367–376. https://doi.org/10.11594/jtls.12.03.10

Lal, R. 2020. "*Soil organic matter and water retention*". Agronomy Journal. 112(5): 3265–3277. https://doi.org/10.1002/AGJ2.20282

Li, W.J., Yao, M.H., Peng, Y.Q., Xu, L.T., and Zhu, J. 2022. *"Effects of grafting on the morphology, physiology, and aerenchyma of balsam pear aboveground under waterlogging stress*". Notulae Botanicae Horti Agrobotanici Cluj-Napoca. 50(3); 1–12. https://doi.org/10.15835/nbha50312132

Loreti, E., and Perata, P. 2020. *"The many facets of hypoxia in plants*". Plants. 9(6): 1–14. https://doi.org/10.3390/plants9060745

Magnan, A.K., Pörtner, H.O., Duvat, V.K.E., Garschagen, M., Guinder, V.A., Zommers, Z., Hoegh-Guldberg, O., and Gattuso, J.P. 2021. *"Estimating the global risk of anthropogenic climate change*". Nature Climate Change. 11(10): 879–885. https://doi.org/10.1038/s41558-021-01156-w

Malhi, G.S., Kaur, M., and Kaushik, P. 2021. *"Impact of climate change on agriculture and its mitigation strategies: A review*". Sustainability. 13(3): 1–21. https://doi.org/10.3390/su13031318

Mansoor, S., Kour, N., Manhas, S., Zahid, S., Wani, O.A., Sharma, V., Wijaya, L., Alyemeni, M.N., Alsahli, A.A., El-Serehy, H.A., Paray, B.A., and Ahmad, P. 2021. "*Biochar as a tool for effective management of drought and heavy metal toxicity"*. Chemosphere. 271(129458). https://doi.org/10.1016/J.CHEMOSPHERE.2020.129458

Marschner, P., and Rengel, Z. 2023. *"Nutrient availability in soils. Marschner's Mineral*" Nutrition of Plants. 499–522. https://doi.org/10.1016/B978-0-12-819773-8.00003-4

Mohawesh, O. 2016. "Utilizing deficit irrigation to enhance growth performance and water-use efficiency of eggplant in arid environments". Journal of Agricultural Science and Technology. 18(1): 265–276.

Muda, S.A., Lakitan, B., Wijaya, A., and Susilawati. 2023. *"Influence of growing systems and non-fertilizer ameliorants on microclimate and growth of Brazilian spinach*. Pesquisa Agropecuaria Tropical. 53: 1–11. https://doi.org/10.1590/1983-40632023v5375742

Nunes, L.J.R., Meireles, C.I.R., Gomes, C.J.P., and Ribeiro, N.M.C.A. 2020. *"Forest Contribution to Climate Change Mitigation: Management Oriented to Carbon Capture and Storage*". Climate. 8(2). https://doi.org/10.3390/CLI8020021

Ortiz-Bobea, A., Ault, T.R., Carrillo, C.M., Chambers, R.G., and Lobell, D.B. 2021. *"Anthropogenic climate change has slowed global agricultural productivity growth*". Nature Climate Change. 11(4): 306–312. https://doi.org/10.1038/s41558-021-01000-1

Philippon, N., Ouhechou, A., Camberlin, P., Trentmann, J., Fink, A.H., Maloba, J.D., Morel, B., and Samba, G. 2022. *"Characterization of Sunshine Duration in Western Equatorial Africa: In Situ Measurements versus SARAH-2 Satellite Estimates*". Journal of Applied Meteorology and Climatology. 61(2): 185–201. https://doi.org/10.1175/JAMC-D-21-0072.1

Roy, P.S., Ramachandran, R.M., Paul, O., Thakur, P.K., Ravan, S., Behera, M.D., Sarangi, C., and Kanawade, V.P. 2022. *"Anthropogenic Land Use and Land Cover Changes—A Review on Its Environmental Consequences and Climate Change*". Journal of the Indian Society of Remote Sensing. *50*(8): 1615–1640. https://doi.org/10.1007/S12524-022-01569-W

Sadatshojaie, A., and Rahimpour, M.R. 2020. *"CO2 emission and air pollution (volatile organic compounds, etc.)–related problems causing climate change*". Current Trends and Future Developments on (Bio-) Membranes: Membranes in Environmental Applications. 1–30. https://doi.org/10.1016/B978-0-12-816778-6.00001-1

Shimamura, S., Yoshida, S., and Mochizuki, T. 2007. *"Cortical aerenchyma formation in hypocotyl and adventitious roots of Luffa cylindrica subjected to soil flooding*". Annals of Botany. 100(7): 1431–1439. https://doi.org/10.1093/aob/mcm239

Singh, B.K., Delgado-Baquerizo, M., Egidi, E., Guirado, E., Leach, J.E., Liu, H., and Trivedi, P. 2023. *"Climate change impacts on plant pathogens, food security and paths forward*". Nature Reviews Microbiology. 21(10): 640–656. https://doi.org/10.1038/s41579-023-00900-7

Song, L., and Jin, J. 2020. *"Effects of sunshine hours and daily maximum temperature declines and cultivar replacements on maize growth and yields*". Agronomy. 10(12). https://doi.org/10.3390/agronomy10121862

Striker, G.G. 2024. *"Oxygen Transport and Plant Ventilation*". Responses of Plants to Soil Flooding. 139–156. https://doi.org/10.1007/978-981-99-9112-9_9

Sublett, W.L., Casey Barickman, T., and Sams, C.E. 2018. *"Effects of elevated temperature and potassium on biomass and quality of dark red 'lollo rosso' lettuce*". Horticulturae. 4(2). https://doi.org/10.3390/horticulturae4020011

Wandayantolis, W., Budianta, D., Yakup, Y., and Gunawan, D. 2024. *"Assessing the Change of Agroclimatic Suitability for Rice Cultivation in South Sumatra, Indonesia*". AGRIVITA Journal of Agricultural Science. 46(2): 229–237.

Wang, Y., Niu, Y., Li, M., Yu, Q., and Chen, W. 2022. *"Spatial structure and carbon emission of urban agglomerations: Spatiotemporal characteristics and driving forces*". Sustainable Cities and Society. 78(103600). https://doi.org/10.1016/J.SCS.2021.103600

Zahra, N., Hafeez, M.B., Shaukat, K., Wahid, A., Hussain, S., Naseer, R., Raza, A., Iqbal, S., and

Farooq, M. 2021. *"Hypoxia and Anoxia Stress: Plant responses and tolerance mechanisms*". Journal of Agronomy and Crop Science. 207(2): 249–284. https://doi.org/10.1111/JAC.12471

Zhao, W., Liu, L., Shen, Q., Yang, J., Han, X., Tian, F., and Wu, J. 2020. *"Effects of water stress on photosynthesis, yield, and water use efficiency in winter wheat*". Water. 12(8): 1–19. https://doi.org/10.3390/W12082127

Zulfiqar, F., Shang, J., Yasmeen, S., Wattoo, M.U., Nasrullah, M., and Alam, Q. 2021. *"Urban agriculture can transform the sustainable food security for urban dwellers in Pakistan*". GeoJournal. 86(5): 2419–2433. https://doi.org/10.1007/S10708-020-10208-1/METRICS