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SYSTEM MANAGEMENT OF FORAGE PRODUCTION BY SIMULATING MILD DROUGHT PRIMING

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ABSTRACT

This study presents a case study analysis that examines the use of artificial intelligence and internet of things to enhance forage production. The study based on case study of Ngajum's Dairy Farm in Malang regency, which faces limitations in forage production during the dry season. Through a qualitative and quantitative investigation, this research aims to provide insights into the multifaceted effects of how the application of Artificial Intelligence and the Internet of Things modulate genetic imprinting in forage production. Mild drought priming involves subjecting plants to controlled, suboptimal water conditions for a short period. This technique triggers a series of physiological responses in plants, leading to increased stress tolerance and improved overall performance when exposed to subsequent drought stress. AI, with its data analysis capabilities, can process a vast amount of environmental data, including soil moisture levels, weather forecasts, and plant responses. IoT devices, equipped with sensors and actuators, provide the means to collect and transmit essential data from the field. The present results deduced that priming with mild drought using artificial intelligence and internet of things might effectively improve drought tolerance in forage, thus increasing the forage production to support dairy farmers in Indonesia.

Keywords : Mild Drought Priming, Drought Tolerance

ABSTRAK

Studi ini menyajikan analisis studi kasus yang meneliti penggunaan Artificial Intelligence and Internet of Things untuk meningkatkan produksi hijauan pakan ternak di peternakan sapi perah. Penelitian ini didasarkan pada studi kasus Peternakan Sapi Perah Ngajum di Kabupaten Malang, yang menghadapi keterbatasan produksi hijauan pakan ternak selama musim kemarau. Melalui penelusuran kualitatif dan kuantitatif, penelitian ini bertujuan untuk memberikan pemahaman tentang efek penerapan kecerdasan buatan dan Internet of Things dalam memodulasi pencetakan genetik pada produksi hijauan pakan ternak. Priming kekeringan ringan melibatkan tanaman pada kondisi air yang terkendali dan suboptimal dalam waktu yang singkat. Teknik ini memicu serangkaian respons fisiologis pada tanaman, yang mengarah pada peningkatan toleransi terhadap stres dan peningkatan kinerja secara keseluruhan ketika terpapar stres kekeringan berikutnya. AI, dengan kemampuan analisis datanya, dapat memproses sejumlah besar data lingkungan, termasuk tingkat kelembapan tanah, prakiraan cuaca, dan respons *tanaman. Perangkat IoT, yang dilengkapi dengan sensor dan aktuator, menyediakan sarana untuk mengumpulkan dan mengirimkan data penting dari lingkungan. Berdasarkan hasil penelitian ini, dapat disimpulkan bahwa priming dengan kekeringan ringan menggunakan Artificial Intelligence and Internet of Things dapat secara efektif meningkatkan toleransi hijauan pakan ternak terhadap kekeringan, sehingga dapat meningkatkan produksi hijauan pakan ternak untuk mendukung para peternak sapi perah di Indonesia.*

Kata kunci : *Priming Kekeringan Ringan, Toleransi Kekeringan*

Introduction

Indonesia is located in a region of the world with a tropical monsoon climate and is therefore extremely vulnerable to the El Nino Southern Oscillation (ENSO), a climate anomaly that extended the country's dry season and altered agricultural practices and economy (Mursidi & Sari, 2017). Drought is a major cause of land degradation and adversely affects the environment, natural resources, agriculture and the national economies (Sari & Kawashima, 2016). Drought in agriculture is associated with low soil moisture, which means that it cannot meet the needs of some plants for a certain amount of time over a large area (Mursidi & Sari, 2017). The erratic and restricted forage production brought on by the drought's onset has dire consequences for livestock productivity. This could jeopardize global food security along with the limited supply of agricultural products (Emadodin et al., 2021).

Limitations in forage production during drought and dry season are currently mitigated using an array of preservation and agricultural processing techniques, evidenced by what we've observed at Ngajum Village. However such methods that have been implemented still has major disadvantages. Forage preservation technologies are still burdened by high cost of production and their inefficiency (Bernardes et al., 2018). Other available solution in the form of agricultural by-product technology also did not solve the recurring problem; due to the fact that the output still has lower nutrition value (Imsya et al., 2018). Plants, or crops, are distinct from other organisms due to their immobility and ability to only change their growth and development patterns in response to external stimuli. Plants use their ability to rewire molecular machinery like transcription factors, stress-responsive proteins, and secondary messengers to mitigate stress by depending on the flexibility of their signal response network operation (Kambona et al., 2023). Priming is a novel technique for engineering drought-resistant plants, whereby potential future stress response can be regulated through manipulation of environmental signal that makes use of the formation of stress memory (Kambona et al., 2023). Plants create an imprint, known as genetic imprinting, as a result of their first stress exposure through priming. The aforementioned plant will be able to respond differently when confronted with the same stress later on thanks to this imprint, which will create stress memory—the capacity to store stress information upon exposure to stressors (Kambona et al., 2023). Muchlas et al. (2023) conducted a recent study and discovered that, as a result of the favorable outcomes in every test of the priming effect measurements, mildly drought-tolerant plants could effectively evolve drought resistance traits.

The lack of uniformity in conventional plant data monitoring resulting from the large number of samples are ineffective and at a disadvantage state. With the introduction of precision agriculture, cutting-edge technologies like artificial intelligence (AI) are taking the place of labor-intensive, traditional techniques for detecting drought stress. The agriculture sector has been greatly impacted by the rapid advancement of the Internet of Things (IoT) in recent years. IoT has been integrated into a number of agricultural applications, including the monitoring of crop growth and fertility, weather, pH, temperature, soil moisture, weed and pest identification, and irrigation control (Atalla et al., 2023). Farmers can reduce human labor and successfully enhance operational monitoring on their farms by employing IoT sensors. Remarkably, through communication channels, IoT sensors can transfer the acquired field status data into permanent and scalable data repositories (Atalla et al., 2023), and artificial intelligence (AI) will be used to process this mechanism further and enhance mild drought priming simulation in a more sophisticated and accurate way.

Methods

In a field survey, information is gathered through direct observation and interaction with people, groups, or locations in their natural environments (Ponto, 2015). In an interview, a researcher speaks with a participant or group of participants directly (Alshenqeeti, 2014). The state and difficulties faced by Ngajum dairy farmers during the start of the drought in the middle of the dry season serve as the sample under analysis in this paper.

A literature study is a fundamental research technique that entails a thorough inspection and evaluation of previous literature, scholarly books, articles, research papers, and other sources pertaining to a particular subject or research question (Ramdhani and Ramdhani, 2014). This paper focuses on the specific topics of priming, mild drought priming, stress memory in plants, and genetic imprinting in plants after external stressors induce a stress response.

Building physical or digital prototypes is known as "prototyping," and it entails creating a working, albeit temporary, proof of concept or functional model of a system, idea, or product (Harahap et al., 2020). Using sensors, actuators, WSN (Wireless System Network) components, and other crucial elements that effectively combine AI and IoT, the prototype described in this paper represents the first iteration.

Results and Discussion

Ngajum Village, nestled within the picturesque landscapes of the Malang Regency in Indonesia, has long been revered for its thriving agricultural endeavors, with a particular focus on the cultivation of forage crops and livestock farming. However, the village grapples with distinctive challenges when the dry season descends upon its tropical climes. These challenges cast a shadow over the well-being of their livestock and the sustainability of forage crop production, prompting us to embark on a comprehensive exploration through field surveys and interviews. Our findings reveal a myriad of issues that converge to create a multifaceted predicament during the dry season, including the following:

1. Water Scarcity
   The arid months in Ngajum Village are synonymous with a notable reduction in water supply. This dearth of moisture permeates the agricultural landscape, adversely affecting both the irrigation of forage crops and the availability of potable water for livestock. With irrigation channels running dry and water sources dwindling, the agrarian life that sustains the village is dealt a significant blow.
2. Decreased Forage Crop Yield
   The parched earth and relentless tropical sun conspire to create a hostile environment for forage crops during the dry season. Soil moisture levels plummet, and the intensity of sunlight exacts a toll on these vital crops. The result is a diminished yield of forage, which in turn adversely impacts the quantity and quality of feed available for the livestock. This dwindling resource base leaves both livestock and their caretakers in a precarious position. The shortfall in forage crops accentuates the vulnerability of the livestock, who depend on this primary source of sustenance for their well-being.
3. Nutritional Deficiency
   As the quality of forage dwindles during the dry season, livestock often find themselves grappling with nutritional deficiencies. This deficiency can manifest as reduced productivity, weight loss, and a host of health issues among the animals. The livestock, once robust and productive, become shadows of their former selves, struggling to maintain their vitality. This not only threatens the economic livelihood of the villagers, who rely on these animals for income and sustenance, but it also raises ethical concerns regarding the welfare of these sentient beings.

Priming, which is defined as pre-exposure to stress stimuli, could trigger a stress-induced genetic imprinting and/or biochemical modification that enables plants to react to later stress events (Tankari et al. 2021). Pre-exposure to mild drought (priming) has been known to alleviate the stress responses during subsequent drought period. Our previous research has demonstrated mild drought-induced hardening could efficiently induce drought resistance in plants, showing significant differences in priming effects in drought parameters.

During the subsequent drought period, mild drought-primed plants reduced the ROS (O2– and H2O2) accumulation and ROS signaling gene expressions (NADPH oxidase and OXI1), which, in turn, reduced the damages caused by oxidative stress. The lower accumulation of ROS in mild drought-primed plants enhanced the SA responses with an antagonistic depression of ABA responses. The enhanced SA-mediated GR1 activation and the expression of the redox-regulating genes (TAG1, GRXC9, and TRXh5) maintained the highly reducing potential of GSH-based redox with an antagonistic depression of GPOX7 in an ABA- dependent manner. As a result, the increased SA accumulation in mild drought- primed plants may be critical to the alleviation of severe drought damage (Muchlas et al., 2023).

Grass management with artificial intelligence and the internet of things is a groundbreaking system revolutionizing livestock forage management. Mild drought priming, a well-established scientific practice, involves the deliberate exposure of plants to controlled, suboptimal water conditions for a brief, strategic period. This procedure triggers a series of intricate physiological responses within the plants themselves, resulting in an improved capacity to endure stress and an overall enhanced performance when confronted with subsequent drought conditions. The synthesis of AI and IoT technologies offers the agriculture sector a dynamic tool to optimize the implementation of mild drought priming, enhancing the prospects of a more resilient and productive crop yield.

analysis capabilities. With the capacity to process a vast trove of environmental data, AI analyzes factors such as soil moisture levels, weather forecasts, and plant responses with remarkable precision. Through this analysis, AI deduces the ideal timing and intensity for mild drought priming. This ensures that the priming process is not only effective but also customized to suit the specific crop varieties and the prevailing environmental conditions. Moreover, AI algorithms are designed to maintain real-time surveillance of plant responses to priming, enabling swift adjustments to the process as conditions evolve. This real-time adaptability represents a paradigm shift in precision agriculture, where technology is harnessed to maximize crop resilience.

On the other hand, IoT devices, equipped with an array of sensors and actuators, furnish the indispensable infrastructure for collecting and transmitting critical data directly from the field. The incorporation of soil moisture sensors, weather stations, and remote-controlled irrigation systems, coordinated through IoT technology, empowers farmers with precise control over the mild drought priming process. Grass management with artificial intelligence and the internet of things has been thoughtfully designed to be accessible to a wide range of users, including farmers. An online interface, accessible through personal computers and smartphones, is equipped with a user-friendly interface that caters to the practical needs of those working in the agriculture sector. This accessibility empowers farmers to harness the potential of AI and IoT technologies in their day-to-day operations, ultimately leading to more resilient and productive forage management. The synthesis of AI and IoT technologies offers a multifaceted solution to the challenges posed by drought conditions, particularly through the implementation of mild drought priming.

The design is an automated mild drought priming simulation system for forage crops to increase drought tolerance, involves a combination of hardware and software components based on Artificial Intelligence (AI) and the Internet of Things (IoT).

- Automated Environmental Control
  IoT sensors and AI algorithms are employed to monitor and control environmental conditions in a simulated drought chamber. These systems continuously collect data on temperature, humidity, soil moisture, and light levels. AI can analyze this data to adjust conditions in real-time, ensuring the stress remains mild and controlled.
- Customized Stress Regimes
  AI can tailor the drought stress regime to the specific needs of different plant species and varieties. It can adjust parameters such as stress intensity, duration, and frequency to optimize drought priming for each type of plant.
- Remote Monitoring

With IoT, researchers and farmers can remotely monitor and control the simulation chamber via smartphones or computers. This allows for quick response to unexpected changes and ensures the priming process stays within the desired mild stress limits.

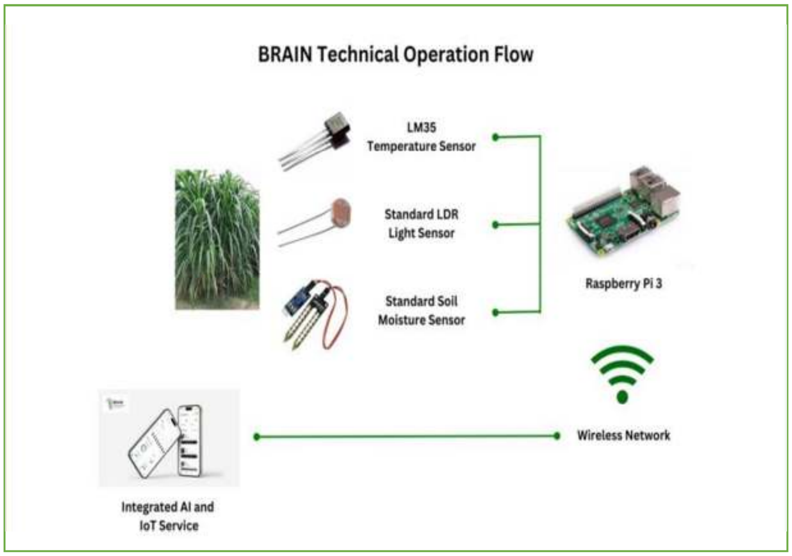

Figure 1. Technical Operation Flow

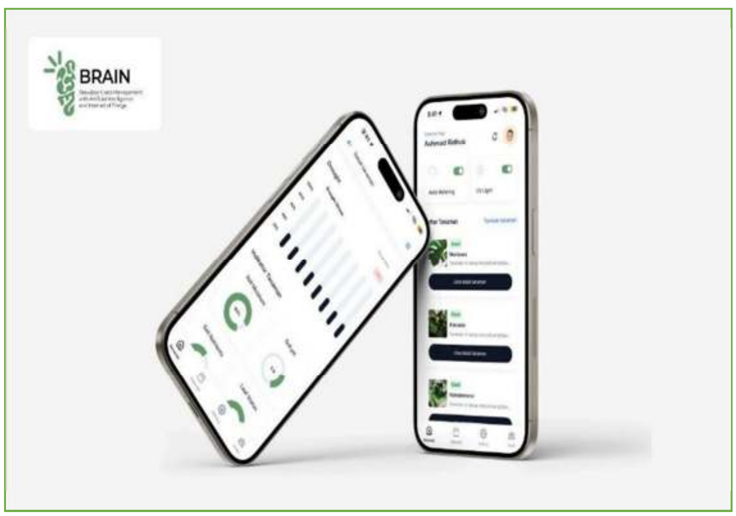

Figure 2. User Interface Design

We can propose the potential benefits such as:

a. Enhanced Drought Tolerance

By automating the simulation process, researchers or farmers alike can consistently induce mild drought stress, resulting in plants with enhanced drought tolerance. This makes them better equipped to withstand natural drought conditions.

b. Improved Crop Productivity
   Drought-tolerant plants cultivated through automated priming can contribute to higher crop yields, even in regions with unreliable rainfall patterns.
c. Reduced Resource Consumption
   The precise control enabled by AI and IoT reduces resource consumption in the priming process, including water usage. This aligns with sustainable agriculture practices.
d. Accelerated Research and Development
   Researchers or farmers alike can conduct experiments and management more efficiently, leading to accelerated discoveries and development to increase plant drought tolerance.

Conclusion

Since global warming has a negative impact on livestock production, Ngajum Village has experienced challenges during the dry season, including a shortage of water, a decline in forage yield, and a reduction in livestock numbers. There are still significant drawbacks to previous methods of reducing the yield limitation of forages during droughts, including high production costs, inefficiency, and low-quality nutrient contents. Current research indicates that by exploiting the development of stress memory and genetic imprinting mechanisms, mild drought priming may effectively form drought resistance traits on forage. Our proposal is based on this finding and is a novel data-driven and informatics-based forage management system that combines genetic engineering, AI, and IoT through controlled environment manipulation to induce mild drought priming in plants. In order to support dairy farmers in Ngajum Village with the possibility of future expansion and commercialization, we can infer from the analysis of related literatures and testing of the current prototype that priming with mild drought using artificial intelligence and the internet things may effectively improve drought tolerance in forage production.

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