（学位第３号様式）

学 位 論 文 要 旨

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題　目	Mitigating Environmental Impact of Sugarcane Cultivation: A Comprehensive Study on Nitrate Leaching from Sugarcane Fields, Water Footprint Assessment, and Process-Based Crop Modeling for Sustainable Utilization of Ground Water Resources. サトウキビ栽培の環境影響の軽減:サトウキビ畑からの硝酸塩浸出、水フットプリント評価、地下水資源の持続可能な利用のためのプロセスベースの作物モデリングに関する包括的研究。

Although sugarcane cultivation uses heavy fertilization, the maximum recovery of applied N fertilizer is just over 60% by the crop and soil. Excess fertilizers, especially urea, readily dissolve in soil water causing leaching and runoff and contaminate water resources. Controlled-release fertilizer (CRF) can potentially reduce N leaching from cropping systems. Although CRF's efficiency has been tested for yield enhancement, there are limited studies on its potential to reduce groundwater pollution. This study focused on field studies aimed at CRF's effectiveness in reducing nitrate leaching and a modeling approach using the APSIMX-Sugarcane to quantify nitrate balance affecting parameters.

Two lysimeter experiments (Exp-1 and Exp-2) were conducted using four treatments: (1) bare land (BL), (2) P and K fertilization without N (N-free), (3) urea, and (4) CRF application in Japan. In Exp-1 CRF increased sugarcane dry weight (CDW) compared to urea in plant cane and ratoon. In Exp-2, CRF led to higher CDW in ratoon than urea and, lower CDW in plant cane compared to urea, potentially attributed to typhoon damage. Nitrate-N leaching, particularly during the plant cane of both experiments was lower with CRF than urea demonstrating the environmental benefits of CRF. Conversely, during the ratoon, nitrate-N leaching was higher with CRF than urea in both experiments, potentially due to increased leaching events that occurred in CRF. Importantly, the total sugarcane water footprint (WF) for the CRF was lower in Exp-1, (plant cane: 192.33m^3/t, ratoon: 190.47m^3/t) compared to urea (plant cane: 233.47m^3/t, ratoon: 237.59m^3/t). In Exp-2, ratoon resulted in lower WF for CRF (149.25m^3/t) than for urea (172.32m^3/t), while that of plant cane was higher in CRF (438.57m^3/t) than for urea (318.77m^3/t). The elevated WF for CRF in the plant cane occurred due to lower pollutant load and reduced yield compared to the urea. The lower pollutant loads that occurred for CRF in both experiments signify its reduced impact on groundwater pollution compared to urea.

Addressing challenges in direct nitrate balance monitoring, the study conducted a modeling approach using APSIMX-Sugarcane to quantify the influential parameters on nitrate balance. A treed Gaussian process (tgp) based global sensitivity analysis was conducted for nitrate uptake and leaching under three conditions: (1) BL, (2) N-free under radiation use efficiency (RUE) ranges (i) 1.2–1.8 [N-free(a)] and (ii) 1.8–2.5 [N-free(b)], and (3) urea. Meta-models generated using the tgp method showed good accuracy. The most influential parameters were: for leached nitrate-N in BL: SWCON of all soil layers; for nitrate uptake and leached nitrate-N in N-free(a) and urea: RUE of phenological stage (PS) 3 (RUE3) and 4, *tt_emerg_to_begcane*, *green_leaf_no*, and *y_n_conc_crit_leaf* of PS 4 (NCL4); in N-free(b): RUE3, NCL4, and SWCON of soil layers 0–15cm; 15–30cm, which confirmed that influential parameters were depended on N-stress. This modeling approach enhances our understanding of the complex interactions affecting nitrate balance in sugarcane cultivation.

The combined findings offer insights into sustainable sugarcane cultivation, emphasizing the practical application of CRF to minimize nitrate leaching and integrating modeling techniques to improve accuracy in assessing the impact on groundwater.