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学位論文題目	Biomass Production and Environmental Load of Forage Rice Cultivation under Different Levels of Animal Manure （堆肥施用水準が異なる飼料イネ栽培水田におけるバイオマス生産量と環境負荷）
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学位論文の要旨

Effect of long term nitrogen (N) animal manure application was observed to estimate N balance on forage rice cultivation in 2 years in pot and 4 years in field experiment. Repeated application of animal manure will probably affect gross N dynamic in paddy soils in long term and high biomass production of forage rice plant. Much of the N applied to submerged rice fields, resulting in increased N losses such as nitrate (NO_3) leaching. Forage rice is grown intensively with the application of large amount of animal manure and tolerates higher N loading than as staple food varieties of rice. Thus, collaboration is feasible between rice growers and livestock farmers in usage of animal waste as fertilizer. Furthermore, appropriate N management is required to improve soil fertility and forage crop production while minimizing N losses.

Chapter 1. The general introduction and literature review about N-cycling process in forage rice cultivation and animal manure effects on the paddy rice cultivation.

Chapter 2. Field experiment was conducted on the biomass production and N quality as effects of the long-term of N-animal manure application in a paddy field planted with forage rice (*Oryza sativa* L. cv Tachisuzuka, Kusanohoshi) during four years rice-growing seasons. Growing forage rice as whole crop silage would be a step forward towards

self-sufficiency in feed. The results study indicated that the increasing of N-animal manure application tended to increase of biomass production, and in average of biomass yield was higher in 14 g N m^{-2} throughout 4 years cropping rice. The biomass production tended extremely to increase gradually over the cropping season within a year and increase year after year. Forage rice plants (Tachisuzuka) can produce a lot of biomass and can take up a lot of nutrient in the highest of N application (28 g N m^{-2}), however this is considered to be more effectively by reduce and minimize loading of N in 14 g N m^{-2} application rate to maintain the soil fertility and environmental pollution. High N application was also higher to the nutrient content by plant and the nutrient content in the remained soil at harvest time during 4 years rice cropping season.

Chapter 3. Pot Experiment was conducted to estimate N balance of forage rice (*Oryza sativa* L. cv. Tachisuzuka) Applied with animal manure. Result indicated that increasing levels of N input improved forage rice growth characteristics (plant height, tiller number and SPAD value). Higher N inputs resulted in greater plant N content, N-uptake by plant and biomass production in all treatments, with the greatest increase being observed for the 28 g N m^{-2} treatment. We found that increasing N input increases N leaching loss. In addition, we found that N leaching loss was greatly enhanced in the absence of rice plants. Ratio of N leaching losses for selected treatments was 20.3% (N14-planted), 29.1% (N14-unplanted), 23.4% (N28-planted), and 33.5% (N28-unplanted). Excess application of N was shown not only inefficient for biomass production, but also increase N leaching out and harmful for environment.

Chapter 4. Leaching behaviour of N in forage rice (*Oryza sativa L.* cv. Tachisuzuka.) cultivation that applied with animal manure was conducted in field experiment. The result showed that NO_3-N leaching was higher than NH_4-N leaching in the percolation water during the cultivation of forage rice periods. The highest NO_3-N leaching was found in 28 g N m^{-2} (6.3 $mg.L^{-1}$), that it was indicated on the polluted levels. Highest of the biomass production was in 28 g N m^{-2}, but the biomass production was nearly similar result in 14, 21 and 28 g N m^{-2}. It is concluded that best of application of N-fertilizer in N14 because it was greatly to enhance of N-use efficiency, and decreased steadily of NO_3-N leaching in the environment of the groundwater.

Chapter 5. Rice growth, N uptake, and biomass production as effect of N animal manure compost applied in the forage rice (*Oryza sativa* L.) cultivation was conducted in pot and field experiment. The result showed that high N application was higher significant of the growth characteristic rice, the N uptake by plant, and the biomass production

in all of treatment, in all of rice cultivated, and in the pot and field experiment. In forage rice cultivation, Tachisuzuka was perfective prospects for forage rice plant as whole crop silage (WCS) due to the Tachisuzuka is the first rice cultivar in which highest straw biomass production, and suitable for feed production of rice WCS of advanced quality compared by Kusanohoshi and Hinohikari. In N14 (14 g N m^{-2}) of N-manure application was considered effective of N-use efficiency to higher productivity for forage rice and using forage rice are useful for the reduction of N loading in the environment.

General Conclusions: Forage rice can produce a lot of biomass and a lot of nutrient uptake in the highest of N-animal manure application. Excess application of N was shown not only inefficient for biomass production, but also increase N leaching out and harmful for environment. It was concluded that application of N-animal manure in 14 g N m^{-2} increased N-fertilizer efficiency at higher produce of biomass and decreased steadily N leaching pollution in the groundwater. Using of forage rice are useful for the reduction of N loading in the environment.

審査の結果の要旨

中山間地域の休耕田や耕作放棄地等で生産が推奨されている飼料イネの栽培において、農業系の有機性廃棄物である家畜糞尿を原料とする堆肥を施用した場合の影響を、バイオマス生産量と窒素収支の観点で評価した。研究は、ガラス温室内での２年間のポット試験と４年間の水田試験により行った。

ポット試験では、広島県で栽培が進められている飼料イネの１品種であるタチスズカやクサノホシ等を用い、窒素施肥量を変化させた栽培試験を実施し、土壌、土壌透過水と作物の部位ごとのバイオマス中の窒素を化学形態別に分析することによって、窒素収支を検討した。その結果、窒素施肥量が高いほどバイオマス量は増加したものの、土壌透過水として未利用のまま流出する窒素量も増加したことから、投入窒素の効率的な利用と地下水環境への窒素負荷低減の観点に立つと、14g-N/m2 の窒素施肥が最適の施肥条件であると判断された。

また、４年間にわたる窒素施肥量の異なる反復施肥による水田試験では、栽培前後の土壌、栽培中の土壌水と作物の部位ごとのバイオマス中の窒素を化学形態別に分析することによって、実際の栽培環境中での窒素収支を把握した。これらの結果、14 から 28g-N/m2 の窒素施肥では栽培バイオマス量に大きな差が生じないことが実栽培においても確認されるとともに、土壌水ではアンモニア性窒素よりも硝酸性窒素の濃度が高かった。また、28 g-N/m2 の窒素施肥条件下で最大 1.6mg/L の硝酸性窒素濃度が測定されたことから、過剰の窒素施肥が地下水汚染の原因に繋がる可能性を指摘した。

なお、学位論文題目の和訳に誤訳があり、その修正を指摘した。

以上のように、本論文は、備北地域において農業系の有機性廃棄物である家畜糞尿を原料とする堆肥を利用して飼料作物を栽培する上で、環境負荷の少ない最適の試料イネの作物種や栽培方法について必要かつ有益な知見を得ている。この成果は、酪農地域の循環型社会の形成を図る上で有益な情報であると判断される。よって、本論文は博士（生命システム科学）の学位に値するものと認められる。