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ABSTRACT OF DOCTORAL THESIS

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Title:

A Study of Continuous Monocropping Obstacles of Sesame (*Sesamum indicum* L.) for Sustainable Production on Upland Field Converted Paddy

（水田転換畑におけるゴマ（*Sesamum indicum* L.)の
持続的生産のための連作障害に関する研究）

Sesame is an important oilseed crop cultivated throughout the tropical and subtropical regions of the world for its use in foods and edible oil. However, the domestic production of sesame is still low in Japan. Sesame cultivation could be promoted through utilization of abandoned paddy fields. Given the profitability of sesame production, it is likely to increase from the utilization of these abandoned paddy fields and continuous monocropping is expected to become more popular. The objectives of this study were to determine the influence of continuous monocropping of sesame on upland field converted paddy on seed yield and mineral nutrient contents of sesame cultivars, determine the autotoxicity potentials of sesame cultivars, the seed fatty acid compositions in relation to yield of sesame, identify potentially limiting mineral nutrients, influence of additional nutrients on the seedling growth of sesame and the influence of rice husk biochar addition on the growth, seed yield, and seed mineral nutrient contents of sesame. In the first study, a field experiment was conducted from 2012 to 2014 to determine the effect of continuous monocropping on seed yield, crude protein and mineral nutrient contents of four sesame cultivars ('Maruhime', 'Nishikimaru', 'Gomazou', 'Masekin') and identify cultivars adaptable to continuous monocropping obstacle. The seed yield, crude protein and mineral nutrient contents were negatively affected in the second cropping: however, the level of response differed among the cultivars. The variation in the seed yield, crude protein and mineral nutrient contents in the second cropping reflected differences in the cultivar response to continuous monocropping that influence the seed composition. In the second study, another a field experiment was conducted with four sesame cultivars in 2018 on fields of 0, 1, 2, 3, 4, 5 and 6 years under continuous monocropping to analyse and identify phenolic compounds as allelochemicals in rhizosphere soils and decomposing roots of four sesame cultivars to understand the mechanisms of cultivar differences in responses towards continuous monocropping obstacle. Results revealed that decomposing sesame roots contained ferulic, *p*-hydroxybenzonic, caffeic, *p*-coumaric and vanaillic acids as the dominant phenolic compounds with 'Maruhime' showing significantly highest caffeic acid content compared to all cultivars and the total phenolic compounds was highest in 'Nishikimaru'. Phenolic compounds in the rhizosphere soil tended to decreased with increase in the duration of continuous. Although 'Gomazou' and 'Masekin' showed high phenolic contents in rhizosphere soils and high inhibition of germination and radicle growth in bioassay, their growth and yield are high under continuous monocropping in the field suggesting the allelochemical concentrations in the field are not sufficient to cause autotoxicity. The third study evaluated the fatty acid compositions in relation to yield decrease of from four fields A, B, C and D with sesame cropping history of 0, 1, 2 and 3 continuous monocropping years respectively from 2015 to 2016 under field conditions. Results showed that in both evaluation years, seed yield did not significantly differ among the fields although field A produced the highest mean seed yield and 1000-seed weight. 1000-seed weight showed significant differences between fields A and C. Seed saturated fatty acids lauric, and myristic decreased in only fields C and D whereas oleic, linoleic and linolenic acids increased in field D. Only field A produced the highest lauric and myristic acids. On the other hand, only field D produced the highest linoleic and linolenic acids. The soil total N and K tended to decrease as exchangeable Mg significantly increased on the fields with long

duration of cropping fields C and D. In the fourth study, sesame growth and yield, nutrient concentration and soil chemical properties were investigated on five fields with continuous monocropping history: non-continuous monocropping (Year 0) and durations of two, four, five and six years fields. Plant height significantly decreased in the long duration of continuous monocropping compared to Year 0. The plant leaf tissue N concentration significantly decreased in the Year 2, Year 4 and Year 6 fields compared to Year 0, whereas leaf tissue K concentration decreased in the Year 6 field. Soil analysis showed that soil pH, exchangeable Ca and Mg and CEC gradually increased in the long duration of continuous monocropping, whereas total N and C, exchangeable NH_4^+-N, urease, dehydrogenase and catalase activities decreased. It was suggested that the decrease in soil available N and enzyme activities, and decrease in K nutrition due to competitive ion effect as a result of increase in soil Ca and Mg could possibly contribute to the growth and yield decline of continuous sesame on upland field converted paddy. In the fifth study, a pot experiment was conducted under greenhouse condition of to determine effect of balancing cations of continuously monocropped soils of 1, 2 and 4-yrs on sesame growth. Results showed that balancing did not significantly affect growth and cation uptake in 1 and 2-yr soils but significant effect was observed in the 4-yr soils. Overall, plant height and dry weight increased for inorganic fertilizer and the rice husk biochar balancing. We suggested balancing with biochar was more beneficial than with inorganic fertilizers. The increase in growth in the 4-yr soil was attributed to increase in K uptake due to the decrease in the soil Ca/K and Mg/K ratios to acceptable levels as soil K saturation increased above 5% enhancing sesame growth. Therefore, sesame growth could be recovered through maintaining a balanced cation ratios of continuously monocropped soils through either additional K fertilizers or rice husk biochar. The sixth study was to assess the effect of biochar addition on sesame performance, with a specific emphasis on growth, yield, leaf nutrient concentration, seed mineral nutrients, and soil physicochemical properties in a field experiment. Rice husk biochar was added to sesame cropping at rates of 0, 20, 50 and 100 t ha^{-1} and combined with NPK fertilization in a first cropping and a second cropping field in 2017. Biochar addition increased plant height, yield and the total number of seeds per plant more in the first cropping than in the second cropping. The F+50B significantly increased seed yield by 35.0% in the first cropping whereas the F+20B non-significantly increased seed yield by 25.1% in the second cropping. At increasing biochar rates, plant K significantly increased while decreasing Mg whereas N and crude protein, P and Ca were non-significantly higher compared to the control. Soil porosity and bulk density improved with biochar addition while pH, exchangeable K, total N, C/N ratio and CEC significantly increased with biochar, but the effect faded in the second cropping. Overall, rice husk biochar addition was effective for increasing nutrient availability especially K for sesame while improving soil physicochemical properties to increase seed yield, growth and seed mineral quality. Overall, this research demonstrated that the growth and yield decrease under continuous monocropping of sesame depended on cultivars. The autotoxicity of phenolic compounds could not explain the growth and yield decline or continuous monocropping obstacles due to decrease in phenolics in rhizosphere soil with increase in the duration of continuous monocropping. On the other hand, the decrease soil available N and uptake of K negatively affected sesame growth and yield thereby causing continuous monocropping obstacles related to nutrient imbalance. Therefore, balancing soil nutrients in fertilizer management is important to increase availability of K and the adoption and use of rice husk biochar amendment to enhance K and N nutrition could be recommended for sustainable sesame production on upland fields converted paddy.

* In addition, some of the figures, etc., have been omitted.