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SUMMARY OF DOCTORAL THESIS

Name: Wacal Cosmas

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 (*Sesamum indicum* L.) is an oilseed crop cultivated throughout the tropical and subtropical regions of the world. Although Japan's sesame production is still low, its 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; (1) determine the influence of continuous monocropping (obstacles) of sesame on upland field converted paddy on seed yield and mineral nutrient contents of sesame cultivars, (2) determine the autotoxicity potentials of sesame cultivars, (3) determine the seed fatty acid compositions in relation to yield of sesame, (4) identify potentially limiting mineral nutrients, (5) determine influence of additional nutrients on the seedling growth of sesame on continuously monocropped soils and (6) determine influence of rice husk biochar addition on the growth, seed yield, and seed mineral nutrient contents of sesame. In Chapter two, 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. Seed yield, crude protein and mineral nutrient contents were negatively affected in the second cropping: however, the level of response differed among the cultivars. Averaged over years, seed yield was significantly lowest in 'Maruhime' and 'Nishikimaru' compared with 'Gomazou' (588.3 kg ha^{-1}) and 'Masekin' (450.3 kg ha^{-1}). Averaged across cultivars, seed the crude protein and N, P, Fe, Zn and Mn decreased by 7.5, 10.0, 19.4, 14.7, and 13.6% in second cropping compared with first cropping. 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 chapter three, 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 indicated 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. In chapter four, a field 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. Compared with 2015, all fields in 2016 had higher contents of MUFA (mono-unsaturated fatty acids) and oleic acid while, in 2016, lauric, myristic and palmitic acids were lower in all fields. The high in the oleic, linoleic and linolenic acids were attributed to high soil Mg in field D whereas 1000-seed weight, lauric and myristic acids due to the high soil K in field A. In chapter five, 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 by 18.8%, 15.2%, and 13.6% in the Year 4, Year 5 and Year 6 fields, respectively, compared to Year 0. 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. The increase in duration of continuous monocropping years gradually altered soil chemical properties. 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. This study 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 chapter six, 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 of soil cation ratios improved the soil chemical properties increasing nutrient concentration K, K uptake and growth of sesame plants more in the 4-yr soils than the 1 and 2-yr soils suggesting balancing the soil cations is beneficial in long term continuous monocropping. Decreasing the Ca/K and Mg/K ratios led to significant increase in the soil K saturations indicating that increased growth of sesame in continuous monocropping can be achieved when soil cation ratios are balanced bringing the K saturations above 5% to increase its availability that could be achieved through adding more K fertilizer or rice husk biochar. Finally chapter seven was designed 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. Conversely exchangeable Mg and its plant tissue concentration decreased due to competitive ion effect of high K from the biochar. Biochar addition is effective for increasing nutrient availability especially K for sesame while improving soil physicochemical properties to increase seed yield, growth and seed mineral quality. This study demonstrated that continuous monocropping of sesame on upland field converted paddy is detrimental to sesame growth, yield and seed mineral contents but improved seed fatty acid quality in terms of high oleic, linoleic and linolenic contents. Growth and yield declines depend on cultivars indicating the magnitude of continuous monocropping obstacles vary with sesame cultivars attributed to resistance to autotoxicity of phenolic compounds and disease occurrence under field conditions. In addition, decreasing soil available N and uptake of K negatively affected sesame growth and yield. Therefore, balancing soil cations to increase availability of K and use of rice husk biochar amendment to enhance K and N nutrition could mitigate and boosts sesame productivity on upland field converted paddy. However, further research should focus on increasing N availability and appropriate use of dolomite lime without causing competitive ion effect and research to uncover the mechanism of disease pathogens interacting with phenolic compounds is necessary.