氏　　名	NGUYEN THI THANH HIEN
授与した学位	博　士
専攻分野の名称	農　学
学位授与番号	博甲第　　７１５７　　号
学位授与の日付	２０２４年　９月　２５日
学位授与の要件	環境生命科学研究科　　農生命科学専攻 （学位規則第４条第１項該当）
学位論文の題目	Water use properties contributing to the maintenance of plant biomass and grain production in NERICA upland rice subjected to dry soils （NERICA 陸稲における乾燥土壌下のバイオマス生産と収量維持に寄与する水利用特性の解明）
論文審査委員	教授　豊田和弘　　教授　平井儀彦　　教授　福田文夫　　准教授　田中佑

学位論文内容の要旨

Drought is one of the major factors causing yield reduction in rice. NERICA upland rice, a hybrid of *Oryza sativa* L. and *Oryza glaberima* Steud. is a crop with high-production potential in sub-Saharan rainfed regions of Africa. Objectives of the thesis aimed to determine the water use properties that strongly contribute to maintaining the plant biomass (BY) and grain (GY) production in NERICA subjected to dry soils. The relationship between GY and water use by plants is indicated by GY=BY×HI where HI is harvest index and furthermore, BY=WUE×T/VD where WUE is water use efficiency, T is transpiration and VD is vapor water deficit. The research to analyze these directly processes from water absorption to the plant and grain productions has never been.

In chapter 1, the contribution of transpiration and WUE to BY production in 29 cvs. including 16 upland NERICA, 3 lowland NERICA, 4 parents of NERICA and 6 *Oryza sativa* was examined. Plants were grown in 4-L pots, and subjected to soil moisture treatments of 100, 40 and 10% of the field capacity (FC) for 14 days after the flag leaf appeared. There was scarcely difference in WUE indicated by a liner regression between BY and T/VD among cvs. across soil moisture treatments, although the variation might have resulted from large fluctuations of humidity during treatment. Cultivars with higher transpiration had higher BY. Hence, the effect of soil drying on WUE was smaller.

In chapter 2, selected five upland NERICA cvs., Dular (drought resistant), Nipponbare (sensitive) and Hokuriku 193 were used to examine the relationship between WUE and carbon isotope discrimination (CID) under different field water capacity soils. There was a significant difference in CID between cvs. ($p<0.05$), but not between soil desiccation treatments. When same cvs. were grown in well-watered 12-L pots, CID was different among cvs. In both results, there was no significant relationship between CID and WUE or the ratio of photosynthetic and transpiration as WUE on the leaf gas exchange level. Therefore, CID would not be reflected the biomass and gas exchange level WUE.

In chapter 3, the differences between upland rice cvs. in high root penetrating ability under drought conditions were compared. Upland cvs. (Terishirazu, Hitachihatamochi, and NERICA 1) and lowland cv. Koshihikari were grown in PVC pots of 0.85 m height. Drought treatment by stopping irrigation was imposed approximately 10 days before the heading. Soil moisture content (SMC) monitored with a profile probe in all layers was lower than 0.1 m^3m^{-3}, and soil below 60 cm kept the highest SMC. When the absorbed soil water after treatment was calculated from the SWC, NERICA 1 absorbed the largest amount of water among the cvs. across all soil layers. The root length density (RLD) decreased with increasing soil depth in all cvs. Cultivars with a high RLD, such as NERICA 1, absorbed high amounts of water from the deep soil layers after withholding water. RLD was able to be well regressed by a quadratic regression line of soil depth in all cvs.

In chapter 4, the water use properties that strongly contribute to maintaining BY and GY in upland NERICA was determined. Five NERICA upland and 3 *Oryza sativa* cvs. were grown in 4- and 12-L pots. Treatment started after the flag leaves emerged. In 4-L pots with soil moisture levels of 100, 40 and 10% of FC for 14 days, the relationship between BY and T/VD was well fitted by a line irrespective of cvs., and hence, when by a subscript 0 for moist soils, $BY/BY_0 = WUE/WUE_0 \times T/T_0$, WUE/WUE_0 was approximately stable during the soil-drying cycles. For 10 days treatment of withholding water in 12-L pots, T/T_0 was indicated by a single logistic-equation of the fraction of transpirable soil water (FTSW) regardless of the cvs. and hence FTSW influenced BY/BY_0 through T/T_0. Four positions (-5, -20, -60 and -80 cm) of irrigation along the soil depth were set in 100 cm depth pots grown NERICA 1, NERICA 4 and Nipponbare. The average FTSW, FTSW estimated from both root distribution and SWC in different soil depths in NERICA cvs. was higher to maintain BY, grain weight and harvest index.

It was concluded that the most important property for maintaining biomass and grain production in NERICA upland rice subjected to desiccated soils is not the high WUE but transpiration maintenance and escaping the effect of root dehydration on harvest index depending on deep root distribution in moist soils. Furthermore, cv. differences in the average FTSW under desiccated soils among NERICA upland rice and superiority of the trait to *Oryza sativa* cvs. should be investigated.

論文審査結果の要旨

ネリカ陸稲は高い生産性を有するアジアイネと環境耐性の高いアフリカイネとの交雑種であり、アフリカのサハラ以南の天水栽培地域で高い潜在的生産力が期待されている。本論文の目的は、乾燥土壌で栽培されたネリカ陸稲において、バイオマス収量（BY）および子実収量（GY）の維持に大きく寄与する水利用特性を明らかにすることである。BYとGYは次の式で示される。BY=WUE×T/VD（WUEは水利用効率、Tは蒸散量、VDは飽差）、GY=BY×HI（HIは収穫指数）。第1章ではネリカ陸稲16品種を含む29品種について、土壌乾燥下でのBYへのTとWUEの寄与を調べた。蒸散量の多い品種は BYが高く、WUEのBYへの寄与も認められた。第2章では、ネリカ陸稲を含む5品種を用い、WUE と炭素同位体分別能（CID）の関係を調べた。しかし、CID とバイオマスおよびガス交換レベルのWUEとの関係はなく、CIDはWUEの指標としては用いられなかった。第3章では、干ばつ条件下における根の伸長能力を85 cmの高さの深底ポットで栽培したアジアイネとネリカ陸稲品種間で比較した。ネリカ陸稲は根長密度が高く、灌水停止後に土壌深層から多量の水を吸収した。第4章では、ネリカ陸稲を含む8品種をポット栽培し、土壌水分レベルを3段階に処理した場合、BY と T/VDは、品種に関係なくBY=WUE×T/VD+b （bは定数）の直線関係で回帰されたためWUEは土壌水分にかかわらずほぼ変化しなかった。ポット栽培した同品種に10 日間の止水処理を行った結果、T/T_0（$_0$は湿潤条件）は品種に関係なく、蒸散可能土壌水分率（FTSW）のロジスティック曲線で回帰された。ネリカ陸稲を含む3品種を深さ100 cmのポットで栽培し、4つの灌水土壌深度（−5, −20, −60, −80 cm）を設定した。その結果、NERICA1、NERICA4は、根の分布とFTSWから決定される平均的FTSWが高く、BY、GYおよびHIを維持することができた。

$BY/BY_0=WUE/WUE_0\times T/T_0$（$_0$は湿潤条件）として表した場合、ネリカ陸稲の$WUE/WUE_0$ は土壌乾燥処理によらずほぼ安定していたこと、T/T_0はFTSWの低下によって大きく減少したこと、FTSWは根の分布が強く影響することから、BY/BY_0が乾燥土壌条件下で高く保たれるためにはFTSWが高い必要があった。また、高いFTSWはHIも高く維持した。以上から、乾燥土壌下でネリカ陸稲のバイオマスおよび子実収量を維持するために最も重要な特性は、WUEではなく、Tを維持し脱水によるHIの低下を回避できる深根性であると結論した。ネリカ陸稲の乾燥下におけるFTSWの品種間差が耐乾性ネリカ品種を選抜するために有効であることを示唆した本論文は高く評価される。

以上の理由により、博士（農学）の学位を授与するに十分値するものと認める。