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SUMMARY OF DOCTORAL THESIS

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Title: A genome-wide association study on lodging resistant related traits in the Ethiopian germplasm collections of teff (*Eragrostis tef*)

(エチオピアのテフ (*Eragrostis tef*) 遺伝資源における倒伏耐性関連形質に関するゲノムワイド関連解析)

Teff (*Eragrostis tef*) plays an important role in the food and nutrition security of about half of the population in Ethiopia. The crop is rarely known in the other world as a food crop for long time. Due to its gluten freeness and high in dietary fiber, however, it is attracting other consumers in the world and seen as a potential component of healthy food and beverage production in the future. In addition to the nutritional importance, teff has an ecological advantage over other cereal crops. Adaptiveness to extreme growing conditions particularly tolerant to water logging Vertisol areas where other cereals might fail is consistently mentioned as one of the top merits of the crop. On the other hand, teff is tolerant to storage pests such as weevils and has higher seed longevity even under traditional storage facilities. In Ethiopia where drought and climate variability affect crop production, teff continues one of the main cash crops as both the grain and straw fetch high price. Despite the merits, the productivity of teff is very low which is about 1.76 t/ha. Lodging is the major yield and quality limiting factor of teff production directly and it also hinders farmers from applying optimum fertilizer rate fearing it could aggravate lodging.

Efforts have been carried out to search and utilize dwarfing genes in teff lodging resistance cultivar development. The attempt however, was not successful mainly due to strong association of reduced plant height with weak culm and lower grain yield potential. On the other hand, the smaller floret size limits the efficiency of hybridization and trait inheritance studies. Consequently, mutation more recently TILLING (Targeting Induced Local Lesions in Genomes) becoming an option to source new variabilities for lodging resistance. Lack of scientific knowledge is the key problem in the breeding program of teff particularly sources of culm mechanical strength, the genetic diversity and responsible genomic regions that govern lodging resistant related traits is either limited or yet not explored. Phenotyping and genotyping studies were carried out using three hundred twenty teff genotypes under the field and screenhouse conditions with the objectives of i) to evaluate the yield potential and determine the variabilities of teff genotypes under lodging controlled and non-controlled growing condition, ii) to examine the variability of stem mechanical properties and agro-morphological traits with their associations with lodging, and iii) to explore the genetic diversity, population structure and trait-marker associations using RADseq derived SNP marks.

The first chapter outlines the general introduction of the thesis. It presents the botanical description, its origin and distribution, the importance, production constraints, the lodging effect, previous research undertakings and the statement of the problem and research gaps. The aims, specific objectives and the overall structure of the thesis are also included.

Chapter two presents the grain yield potential, heritability, and genetic advance under selection of diverse teff genotypes under intensive and field growing condition. It also outlined trait relationships at the phenotypic and genotypic levels. Under the intensive growing condition when lodging was artificially controlled with support, wider range of harvest index was observed than the field growing condition. On the other hand, high coefficient of variation, heritability and expected genetic advance

for grain yield were observed in both experiments. The harvest index showed strong positive relationship with grain yield under the intensive management but weak positive correlation with grain yield and a negative correlation with biomass under the field experiment, in which lodging was relatively higher. These suggests the presence of wide genetic potential in the teff gene pool and its opportunity to enhance the productivity.

The third chapter characterizes teff landrace accessions for lodging resistance in terms of the mechanical properties of the culm and lodging related agro-morphological traits using three hundred twenty teff genotypes. This study revealed the presence of wide variability in both biomechanical and agro-morphological traits among the accessions. It is also noted that lodging index, failure moment, pushing resistance and lodging related traits such as culm diameter had a strong positive correlation with plant height. This suggests the shorter the plant height the lower the material strength of the teff culm. In contrast, tiller number showed a significant negative correlation with lodging index. The peduncle–panicle length, which generally accounted for 59% of the plant height, should be a target when breeding for semi-dwarfism. Root system development, which reached a depth of more than 1 m in tall and 57 cm in dwarf teff accessions, signifies the presence of genetic variabilities for future root lodging studies in teff, and it may also explain why teff performs well in drought-prone areas of Ethiopia. The observations indicated that stem failure account more likely than root failure for lodging in teff. However, our observations that the tillers initially grew mainly laterally and start to hold upright later in the growth stage further implies space competition at the crown, and teff has a relatively narrow root–shoot jointing point (crown). Thus, root failure could not be ruled out and needs detailed investigation in the future.

The fifth chapter is about the general conclusions and future directions. The high grain yield performance and wider range of harvest index under the intensive growing condition and the associated moderate to high coefficient of genetic variation, heritability and genetic advance depicts the available genetic potential for further improvement. On the other hand, our study on the lodging resistance variation of teff germplasms indicated a strong positive correlation of lodging index with plant height. Identified genotypes could be a good sources of culm strength for lodging resistance breeding in teff. Significant marker-trait associations were also found for stem strength, stem diameter, and tiller number which could enhance the knowledge about molecular marker development and implementation of marker assisted selection in the teff breeding program. However, the strong positive correlation with plant height might continue a challenge until a mechanism to overturn the positive association of grain yield with plant height or the culm strength become strong enough to carry its self-weight. Thus, a strong crossing program is need to evaluate the mode of inheritance and pyramid the genes of interest. A reduce tiller number, wider stem diameter and higher stem strength with strong emphasis to enhance the grain yield of teff through increased harvest index could benefit the future teff breeding.

The fourth Chapter is omitted for certain reasons.

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