CHAPTER VII

GENERAL DISCUSSION AND CONCLUSION

Paddy fields occupy approximately 65% of arable areas in Northeast Thailand, with both under rainfed and irrigated conditions. A double cropping system in rainfed paddy fields and a triple cropping system in irrigated paddy fields in fallow land during the dry-wet transition period utilizing sweet sorghum would increase land use efficiency. This would allow small holder farmers to access huge agro-bioethanol markets and ultimately improve their income. In addition, with the high competition for current biofuel feedstock i.e. cassava and sugarcane molasses, with other well-established industries such as sugar, animal feed and cassava flour, the shortage of raw materials causes inefficiency in the industry because factories can be operated only four to six months a year. The production of sweet sorghum as a pre-rice crop could increase additional biofuel feedstock without negatively impacting food crops or other traditional crops and fill the gap during this shortage of feedstock, thereby improving the efficiency of the industry. For these reasons, development of sustainable farming systems in paddy ecosystems by means of introducing sweet sorghum as a pre-rice crop is essential not only to secure income for farmers but also to ensure national bio-energy stability.

Results of our field experiments have shown that sweet sorghum could be successfully grown as a pre-rice crop both under rainfed and irrigated conditions (Chapter VI). The most productive strategies were shown to be early planting and using a high stalk yielding cultivar with relative waterlogging tolerance. The results showed that early planting increased plant height, LAI, stem diameter and consequently resulted in high stalk and estimated ethanol yields.

At early planting date, even though crops were subjected to waterlogging twice, at vegetative stage and mid-reproductive stage, the capacity to withstand flooding stress found in greenhouse experiments may elevate these detrimental effects. Under greenhouse conditions (Chapter V), the results indicated that a flood-free period of at least 30 DAE was required to sustain growth and stalk yield of sweet sorghum. Early planting under field conditions successfully avoids extended flooding duration from this critical growing period under both rianfed and irrigated fields. The results also revealed that sweet sorghum could withstand flooding beginning from 45 DAE until harvest without significantly affecting growth and yield. The flooding tolerance in sweet sorghum was contributed by the development of nodal and lateral roots in water and interconnection of aerenchyma spaces in roots at flooded soil and water above soil surface, and plant's axes and stalks above water level (Chapter V). In addition, even the results of our greenhouse experiment indicated that sweet sorghum was most susceptible to waterlogging at early vegetative growth stage. Periodic flooding occurring under field conditions for 7 d at vegetative stage had no effect on growth and yield at final harvest. This may be due to sweet sorghum's capacity to recover from adverse effects of flooding by sharply increasing leaf growth, plant height and stalk diameter (Chapter IV). It also implies that sweet sorghum could withstand a short-term waterlogging. Furthermore, pre-anoxic conditions of the first flooding incident may induce flooding tolerance in sweet sorghum such as reported in maize (Zaidi et al., 2003).

Late planting, particularly under rainfed field conditions, markedly reduced harvested stalk number per m^2 and stalk yield. This was contributed to severe flooding in mid-rainy season. Plants grown at late planting date suffered from continuous flooding starting at soft dough stage (about 75 DAE) in PD2 and flowering stage (60 DAE) in PD3. Even results from the greenhouse experiment (Chapter V) indicated that growth and stalk yield were less affected by flooding initiated at late growth stage. Strong wind and heavy rains at mid-rainy season resulted in lodging problems and creating problem for harvesting and giving high possibility for flooding susceptibility under field conditions.

Our findings (Chapter III) indicated that there was a variation in flooding tolerance among studied sorghum cultivars when evaluated by using youngest leaf elongation rate (YLER), root growth, dry matter partition and leaf gas exchange parameters. The results showed that there was no relationship between growth and leaf photosynthetic traits in sweet sorghum under waterlogging conditions. This information will be useful for further study in sweet sorghum responses under anoxic conditions. Under greenhouse conditions, no significant interaction in shoot growth response between flooding treatment and cultivar was found. However, averaging across flooding treatments, cv. Bailey had lowest stalk yield reduction, followed by cv. Wray with lowest in cv. Keller. Results from the greenhouse experiment indicated that cv. Bailey developed the highest nodal root in all flooding treatments. It also formed extensive aerenchyma spaces in plant axes in relation to the control (Chapter V). This may indicate that cv. Bailey is a relatively flooding tolerant cultivar. Consequently, it produces significantly high stalk and estimated ethanol yields under filed conditions.

In addition to high growth and stalk yield production, sweet sorghum production mainly focuses on juice quality or sugar content in the stalk. Results from greenhouse experiment indicate that Brix value, sucrose content and total sugar content of juice were not affected by flooding (Chapter IV and Chapter V). This indicates that sucrose synthesis and transportation of sweet sorghum are not affected by flooding stress. This may be due to the preferential sink for photosynthates of the stalk or the acclimation capacity of sweet sorghum under anoxic conditions. Unaffected juice quality under flooding conditions further indicates the possibility of growing sweet sorghum before rice or in waterlogging prone areas.

Fresh stalk obtained, ranging 29-35 t ha^{-1}, at early planting date is similar to that produced in upland areas within the same region during early planting date, February, 30 t ha^{-1}, (Jaisil et al. 2007). This confirms that growing sweet sorghum before rice is a viable strategy to increase supplemental feedstock for ethanol production in the future. Early planting and using high stalk yielding cultivar with relative flooding tolerance will provide economical viability for this bio-energy feedstock production. In addition, due to the limited fallow period in rainfed and irrigated paddy fields, sweet sorghum cultivar harvested not later than 103 DAE is desirable. In addition to waterlogging, sweet sorghum grown as a pre-rice crop suffered from a periodic drought, particularly at vegetative stage. With its high adaptability to drought stress, sweet sorghum productivity under field conditions in our experiments was practical. However, further studies are needed to improve growth and yield under drought stress. Simulation models to predict the optimum time of sowing by using rainfall and other climatological data may support a long-term plan for commercial ethanol production. Additional studies are needed to determine the impact of this new cropping system on the environment as well as succeeding rice.