Genotypic Variation in Yield Performance under Tropical Environments of Soybeans with Temperate and Tropical Origins

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Soybean [*Glycine max* (L.) Merr.] is largely predominant in temperate regions with cool to moderately warm climates. The increasing demand for soybeans in economically developing regions necessitates the rapid increase of production in the tropics. Soybean production in relatively high-temperature environments has also increased throughout temperate regions due to climate change, which has significant impacts on soybean production. The tropical environment with relatively higher temperatures may have the potential to be employed to study agronomic performance of soybean under high temperatures. Although the effects of temperature on plant or crop performance of soybean are increasingly documented, little is known about the genetic variability in soybean responsiveness to high temperature and, whether cultivars adapted to temperate and tropical regions differ in their adaptation to warm environments. To solve this question, I evaluated genotypic variation in yield performance under tropical environments using soybean cultivars originated from temperate and tropical regions.

Soybean yield is largely affected by length of growth duration that is determined by plant phenological development. But is not clear how growth duration is dominating to determine yield. Twenty-nine soybean cultivars divided into five groups with temperate (Japan and US) and tropical (Indonesia-old, Indonesia-modern and other tropical) origin were grown in 2014 and 2015 in a tropical environment at Banten, Indonesia. Temperate cultivars were earlier in

flowering and shorter in duration from R1 to R5. Temperate cultivars had low seed yield which was due to having lower values of pods, seed number and total dry weight (TDW). However, harvest index (HI) did not differ much between temperate and tropical cultivars, indicating that the process of biomass production may be involved in the yield difference. In addition, the occurrence of shriveling seed was considerably evident in Japanese cultivars. To account for the difference of growth duration, a maturity-corrected index for yield and relevant variables was calculated to consider the amount of incident solar radiation. The performance of temperate cultivars in yield, TDW and node number was poor even after a correction of data, suggesting that there is a genetic variation for adaptation to a tropical environment independent of growth duration. Additionally, there was considerable performance variation within temperate cultivars. Under the tropics, there is a large variation in yield performance, and temperate cultivars performed poor not only by short growth duration but also by factors independent of growth duration.

In order to identify crop physiological factors involved in genotypic difference of biomass productivity, twenty-nine (in 2014 and 2015) and 20 (in 2016) soybean cultivars of similarity different origin with the above experiment were grown in Banten (2014 and 2015) and in Bogor, West Java (2016), Indonesia. TDW at R5 (TDW_{R5}) of the temperate cultivars was one-third to one-fourth of that of the tropical cultivars. This was associated with less than half the amount of the cumulative intercepted radiation to R5 (CIR_{R5}) due to their short growth duration and low value of the mean fraction of canopy light interception till R5 (mean $F_{VE\text{-}R5}$). In addition, the radiation use efficiency (RUE) at R5 of the temperate cultivars was lower as compared to the tropical cultivars. The value of canopy temperature minus air temperature (CTd), as an indicator of relative transpiration activity, of temperate cultivars was markedly larger than that of the tropical cultivars, indicating lower transpiration activity in temperate cultivars, which was associated with the low RUE. Greater activity of transpiration in tropical cultivars was attributed to their higher stomatal conductance (g_s) and greater stomatal density (N_{stoma}) than that in those from the temperate regions. The low biomass production in temperate cultivars occurs not only due to less cumulative intercepted radiation in the canopy but also due to low RUE. The low RUE in temperate cultivars is associated with low gas exchange activity, in which leaf morphological traits are involved.

In order to explore useful genetic sources for better adaptation to tropical environment, diversity of soybean cultivars with different origins needs to be characterized in terms of performance under tropical environments. The yield and yield-related traits for 88 soybean cultivars, divided into eight groups with origins of temperate region (China, Korea, US and Japan) and tropical region (India, Indonesia, Nepal and Thailand) were evaluated at Khonkaen, Thailand in 2014, and at Bogor, Indonesia in 2015. The temperate cultivars were consistently inferior compared with tropical cultivars in seed weight, TDW, pod number and node number. The PCA highlighted the uniqueness of Japan group from not only tropical group but also other temperate groups. Further, stability of seed weight, TDW and HI were evaluated for 16 cultivars, and they were grown in the two above environments plus three other environments at Banten in 2014 and 2015 and at Bogor in 2016. A stability analysis showed that tropical cultivars were higher stable than temperate cultivars due to stability of HI rather than that of TDW. The cv.

Tidar is the highest in seed weight and has good stability, whereas cv. Tanbaguro is the smallest and less stable. HI tended to be lower under warmer environment. Among temperate cultivars, US cultivars have considerably better seed weight and stability than Japanese cultivars.

The performance in seed yield and biomass production of soybean cultivars from temperate regions was poor under a tropical environment compared to cultivars from the tropical region. Low biomass production in temperate cultivars occurs not only due to growth duration but also due to low crop physiological activity and hence RUE, in which leaf morphological traits are involved. Tropical cultivars also showed more stable performances as compared to temperate cultivars across environments, while the primary factor is formation of reproductive organs rather than biomass production. There also exists a genotypic variation in performance and its stability between cultivars within groups and this suggested that temperate cultivars, particularly Japanese ones, have potential to be improved for better adaptation to high temperature environment.

In conclusion, a large genotypic variation exists in soybean performance under tropical environments not only by growth duration but also by different crop physiological activity. Tropical cultivars produce greater yield than temperate cultivars and, within temperate cultivars, US cultivars exhibit better and stable HI than Japanese cultivars.