Drought Resistance of NERICA Compared with Asian Rice, African Rice and Millets in the Field with Different Fertilization Levels

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Abstract

Recently NERICA (New Rice for Africa) was developed by a crossing between African rice (*Oryza glaberrima* Steud.) with Asian rice (*Oryza sativa* L.) in West Africa, and is considered to be drought resistant, but it is not clarified enough about the difference in reactions under dry condition. In this research, NERICA, Asian rice, African rice and millets were cultivated in the field under drought condition with different fertilization levels to compare dry matter production, stomatal and leaf characteristics and water absorbing characteristics to comfirm the characteristics of NERICA under drought condition. Fertilization levels were 6gN/m^2 in standard fertilization level and 2gN/m^2 in low fertilization level. Stomatal conductance was measured by porometer and soil water contents at individual depths (0-60cm) were measured by TDR method. Leaf thickness was measured by micrometer and and SPAD value was determined with SPAD meter. In standard fertilization level under drought condition, top dry weight at harvest was high in Dular, drought resistant Asian rice cultivar. Dry weight at harvest in low fertilization level tended to be higher than that grown in standard fertilization level. In low fertilization level one of NERICA showed high dry weight. Dry weight of g*laberrima* parent of NERICA was high in both standard and low fertilization levels, but proportion of dead leaf was high. In standard fertilization level, Dular showed highest stomatal conductance followed by *sativa* parent of NERICA and one of NERICA. In low fertilization level *sativa* parent of NERICA, Dular and one of NERICA showed high stomatal conductance and it tended to be higher than in standard fertilization level. *Glaberrima* parent of NERICA showed low stomatal conductance in both fertilization levels. Average soil water content at 0-60cm depth before harvest in standard fertilization level was low in Dular followed by g*laberrima* parent of NERICA. In low fertilization level soil water content was maintained highest in one of NERICA. Soil water content at 0-20 cm depth in standard fertilization level was low in g*laberrima* parent of NERICA. There was large cultivar differences in soil water content at 40-60 cm depth and soil water decreased significantly in Dular in standard fertilization level. On the contrary it was maintained highest in one of NERICA in low fertilization level. Dry weight was high in Dular, but soil water content decreased especially in the standard fertilization level. On the contrary, dry weight was high in one of NERICA and soil water content was maintained high especially in low fertilization level and at deep soil layer (40-60 cm depth). There was a significant correlation (r=0.907**) between average stomatal conductance and dry weight at harvest except g*laberrima* parent of NERICA. In low fertilization level stomatal conductance and dry weight at harvest tended to be larger than in standard fertilization level. There was a significant correlation (r=0.892**) between average leaf thickness and dry weight at harvest except g*laberrima* parent of NERICA and cultivar with thick leaf tended to maintain high dry matter production. There was a significant correlation (r=0.828**) between average leaf thickness and SPAD value in rice. In one of NERICA leaf thickness and SPAD value were higher in low fertilization level than in standard fertilization level. SPAD value tended to be low in Dular. High leaf thickness and SPAD values seem to be effective to maintain dry matter production under limited water condition with high water use efficiency. NERICA seems to be appropriate for the cultivation under drought condition with the effective use of limited water for the sustainable crop production especially in low fertilization level.

Keywords: drought resistance, fertilization levels, NERICA, soil water content, stomatal conductance

Introduction

Global water shortages are getting worse and drought is the major constraint to the crop production (Blum, 2009, Boyer, 2010, Serraj *et al*., 2011). Recently NERICA (New Rice for Africa)

was developed by a crossing between African rice (*Oryza glaberrima* Steud.) with Asian rice (*Oryza sativa* L.) in West Africa, and is considered to be drought resistant, but it is not clarified enough about the difference in reactions under dry condition. In this research, NERICA, Asian rice, African rice and millets were cultivated in the field under drought condition with different fertilization levels to compare dry matter production, stomatal and leaf characteristics and water absorbing characteristics to confirm the characteristics of NERICA under drought condition.

Materials and Methods

Plant Materials and Cultivation

In this study two NERICA lines which showed superior drought resistant in our previous reports (Fujii *et.al*, 2004, 2008) and their two parent cultivars were used. Cultivars WAB450-24-3-P3-1-HB, WAB450-I-B-P-82-2-1, *sativa* parent: WAB56-104, *glaberrima* parent: CG14. Rice cultivars of *O. sativa* L. (Koshihikari (japonica, lowland, Japan), Dular (indica, lowland-upland, India) and IRAT13 (japonica, upland, Cote d'Ivoire)) and common millet (*Panicum miliaceum* L.) were also used. Plants were seeded in paper pots on May 31, 2007 and seedlings were planted at upland field in the vinyl house of Shizuoka University on June 21. Sides of vinyl house were kept open. Irrigation was applied on June 21, 27 and July 10, and after that no irrigation was applied. Plots were fertilized by compound fertilizer at the rate of 6 g/m^2 as nitrogen in standard fertilization plots and 2 g/m^2 in low fertilization plots individually.

Measurements

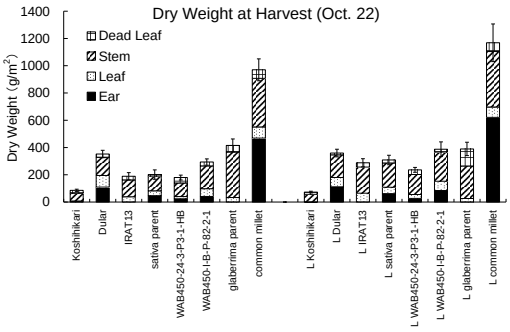
Plants were sampled on June 25, July 31, September 13 and October 22 at the harvesting time. After dividing into organs, dry weight was measured after desiccating in the drying oven. Stomatal conductance was measured at the center of abaxial side of topmost three leaves by dynamic diffusion porometer (AP4, Delta-T Devices Ltd., Cambridge, UK) on sunny days during the daytime. Measurements were made on August 7, 13 and 20. Soil water contents at individual depths were measured by TRIME-T3 tube access probe system (IMKO micromodultechnik, Ettlingen, Germany) by TDR method. Measurements were made at intervals of 10cm depth on August 6, 17, 30 and September 11.

Leaf thickness was measured by micrometer (No.193-111, Mitutoyo, Kawasaki, Japan) at the middle length of topmost fully extended leaves avoiding midrib on August 10, 17, 22, 30 and September 12. SPAD value was measured by SPAD meter (SPAD502, Konica Minolta, Tokyo, Japan) on August 10, 17, 22, 30 and September 10. Both measurements were replicated 10 times in each plot.

Results and Discussion

Top Dry Weight

In standard fertilization level under drought condition, top dry weight at harvest was high in Dular, drought resistant cultivar in Asian rice (Figure1). Dry weight at harvest in low fertilization level tended to be higher than in standard fertilization level. In low fertilization level one of NERICA showed high dry weight. Dry weight in g*laberrima* parent of NERICA was high in both standard and low fertilization levels, but proportion of dead leaf was high and heading was not observed.



Bars show standard errors.

Figure1. Top dry weight of individual organs at harvest, Oct. 22.

Stomatal Conductance

In standard fertilization level Dular showed highest stomatal conductance followed by *sativa* parent of NERICA and one of NERICA (Figure 2). In low fertilization level *sativa* parent of NERICA, Dular and one of NERICA showed high stomatal conductance and it tended to be higher than in standard fertilization level. *Glaberrima* parent of NERICA showed low stomatal conductance in both fertilization levels.

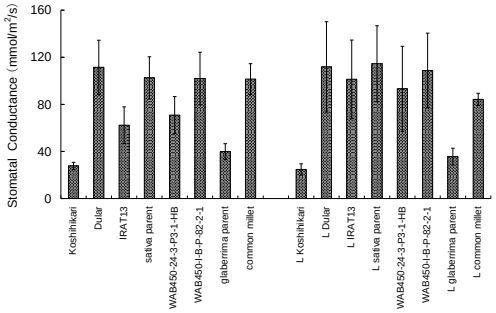


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Figure 2. Average stomatal conductance from August 7 to 20.

Soil water content

Average soil water content at 0-60 cm depth before harvest in standard fertilization level was low in Dular followed by g*laberrima* parent of NERICA. In low fertilization level soil water content was maintained highest in one of NERICA. Soil water content at 0-20 cm depth in standard fertilization level was low in g*laberrima* parent of NERICA (Figure 3). There was large cultivar differences in soil water content at 40-60 cm depth and soil water decreased significantly in Dular in standard fertilization level (Figure 4). On the contrary it was maintained highest in one of NERICA in low fertilization level.

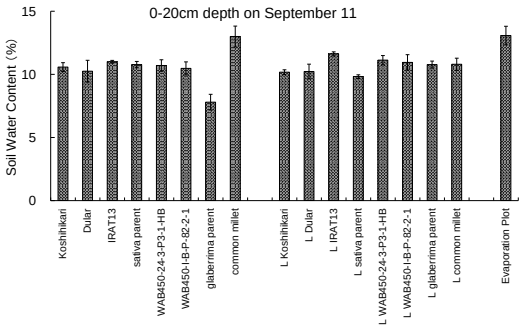

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Figure 3. Soil water content at 0-20 cm depth on September 11.

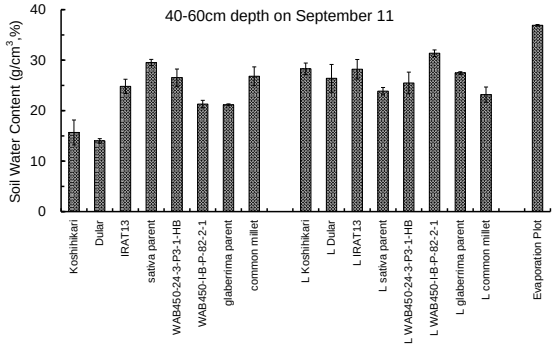

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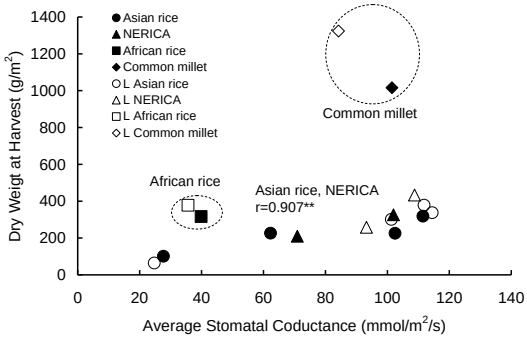
Figure 4. Soil water content at 40-60cm depth on September 11.

Relationship between stomatal conductance and dry weight

There was a significant correlation (r=0.907**) between average stomatal conductance and dry weight at harvest except g*laberrima* parent of NERICA (Figure 5). In low fertilization level stomatal conductance and dry weight at harvest tended to be larger than in standard fertilization level.



**: significant at 1%

Figure 5. Relationship between average stomatal conductance from August 7 to 20 and top dry weight at harvest on Oct. 22.

Relationship between leaf thickness and dry weight

There was a significant correlation (r=0.892**) between average leaf thickness and dry weight at harvest except g*laberrima* parent of NERICA and cultivar with thick leaf tended to maintain high dry matter production (Figure 6).

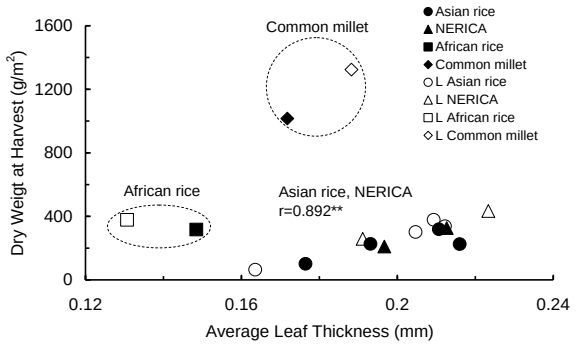


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Figure 6. Relationship between average leaf thickness from August 10 to September 12 and top dry weight at harvest on Oct. 22.

Relationship between leaf thickness and SPAD value

There was a significant correlation (r=0.828**) between average leaf thickness and SPAD value in rice (Figure 7). In one of NERICA leaf thickness and SPAD value were higher in low fertilization level than in standard fertilization level. SPAD value tended to be low in Dular.

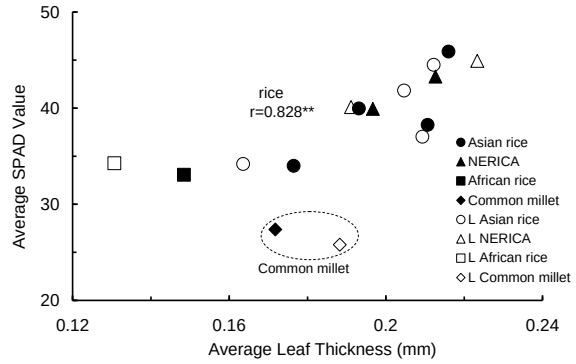

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Figure 7. Relationship between average leaf thickness from August 10 to September 12 and average SPAD value from August 10 to September 10.

Conclusions

Dry weight was high in Dular, but soil water content decreased especially in the standard fertilization level. On the contrary dry weight was high in one of NERICA and soil water content was maintained high especially in low fertilization level and at deep soil layer. High leaf thickness and

SPAD values seem to be effective to maintain dry matter production under limited water condition with high water use efficiency. Condon *et al.* (2004) showed cultivar differences in water use efficiency in wheat. In rice, NERICA seems to be appropriate for the cultivation under drought condition with the effective use of limited water for the sustainable crop production especially in low fertilization level.

Acknowledgements

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