Jour. Agri. Res. China (中華農業研究) 39(4) : 259~268 (1990)

Study of Leaf Area as Functions of Age and Temperature in Rice (*Oryza sativa* L.)[1]

Chwen-Ming Yang[2] and James L. Heilman[3]

Abstract : Correlations between the measured and the estimated leaf areas of rice plants as functions of age and temperature were studied. The results showed that as the plant advances area can be estimated from leaf dimensions in a controlled-environment. When temperature treatment is imposed, causes that alter leaf length/width ratio may change the measured values. Different sets of regression analysis, therefore, may be needed for leaf area estimation when temperature stress occurs.

Key Words : Leaf area, Age, Temperature, Rice, *Oryza sativa* L., Leaf dimensions

Introduction

Leaf area is one of the observed characters of plant growth in favor of quantitative description. When the productivity of crops or an ecosystem in nature is concerned, the performance of leaf area per unit of ground area, namely, leaf area index (LAI), is frequently used as a measure of this expression (Beadle, 1985 ; Watson, 1947). However, the destructive nature of sampling technique in growth analysis makes it difficult for future inquiry and study. The non-destructive approach for leaf area measurement, therefore, has an important advantage since the same plants can be repeatedly sampled and the variability of individuals and populations may be eliminated (Beadle, 1985).

By this approach, the charactersitics related to leaf area, i.e., the length and width of leaves, must be measured and the relationship between length and width and leaf area must be established from harvested samples. The gain and loss of leaf area can then be derived from regression equations relating leaf area to the characteristics measured. Accurate measurements of leaf dimensions are essential to avoid unnecessary variation.

In this study, the objective is focused on the linear regressions of the measured and the estimated leaf areas. Such correlations as functions of age and temperature effects are also investigated. The information is particularly useful for studies of parameters related to leaf production in controlled environments and growth analysis (Beadle, 1985 ; Hunt, 1982).

1. Contribution No. 1533 from Taiwan Agricultural Research Institute.
2. Agronomist, Department of Agronomy, TARI, Wufeng 41301 Taichung, Taiwan, ROC.
3. Associate professor, Department of Soil & Crop Sciences, Texas A&M University, College Station, Texas 77843, USA.

Materials and Methods

Plants of rice variety LEMONT (Bollich et al., 1973, 1984, and 1985) were grown in opaque plastic containers (.25 m diameter, .20 m height), three plants per pot with even space, filled with fritted clay and irrigated with nutrient solutions. The composition of nutrient solution and the schedule of watering are listed in Tables 1 and 2, respectively. Physical properties of fritted clay has been tested by van Bavel et al. (1978). They were grown as groups in a controlled-environmnent chamber circulated with ambient air (day /night temperature 30°C/20°C ; relative humidty 50−70%/90−100% ; CO_2 concentration 330—430 ppm). The daylength was 12 hours with PPFD about 650 μmole m^{-2} s^{-1}. When reaching the appropriate test stages (Table 3), some plants were moved to an assimilation cabinet for 8-day temperature treatments. At the end of treatments, half of the plants were sacrificed and the rest were grown in the growth chamber until harvest.

Table 1. The composition of nutrient solution (full strength, X).

Element	Concentration (mg l^{-1})	Element	Concentration (mg l^{-1})
Nitrogen (N)	320	Iron (Fe)	3.0
Phosphorus (P)	210	Sodium (Na)	2.3
Potassium (K)	320	Manganese (Mn)	1.0
Calcium (Ca)	280	Copper (Cu)	0.6
Magnesium (Mg)	40	Zinc (Zn)	0.4
Sulfur (S)	180	Boron (B)	1.0
Cloride (Cl)	3.5	Molybdenum (Mo)	0.1

The pH value is adjusted to 6.8 with 1 N sodium hydroxide (NaOH) solution.

Table 2. Schedule of watering nutrient solutions.

Stage	Strength
Seeding to Transplanting	1/32 X
Transplanting to Leaf 3 stage	1/16 X
Leaf 4 stage to Leaf 5 stage	1/8 X
Leaf 6 stage to Heading	1/4 X
Heading to R-2 stsge	1/8 X
R-3 stage to Harvest	1/16 X

Table 3. The design of temperature treatments.

Symbol	Treatment	Description
V25	25 C at vegetative stage*	Collected after treatment
VH25	25 C at vegetative stage	Collected at harvest
V35	35 C at vegetative stage	Collected after treatment
VH35	35 C at vegetative stage	Collected at harvest
G25	25 C at grain-filling stage **	Collected after treatment
GH25	25 C at grain-filling stage	Collected at harvest
G35	35 C at grain-filling stage	Collected after treatment
GH35	35 C at grain-filling stage	Collected at harvest

*Leaf 7 stage
**From the 8th day to the 15th day from heading.

Every 7 days and 3 days, the pots were flushed with distilled water to avoid salt accumulation during the vegetative and the reproductive stages, respectively. They were rotated periodically to ensure uniformity within the chamber.

The assimilation cabinet was set for a photoperiod of 12 hours and a constant day/night temperature and absolute humidity. The average value of PPFD at the top of the cabinet was about 1300 μmole m^{-2} m^{-1}.

The area of leaf was determined by area meter (LI-3000, LI-COR, Inc., Nebraska, USA), while the estimated leaf area was the product of leaf length and leaf width. Leaf dimensions were taken before plants were harvested. The relations between the measured and the estimated values were analyzed by the linear regressions. Of the whole plant, only dead tissues were excluded from the measurements.

The leaf stage (plant age) was assessed by the emergence of the primary leaf on the main culm (Yoshida, 1981). When the 8th primary leaf emerges from the main culm, the plant is said to be at Leaf 7 stage ; the Heading stage is from the first day to the 7th day from heading, the R-1 stage is from the 8th to the 14th day from heading, and so on.

Results and Discussion

Age Effect

The linear regressions were calculated between stages from Leaf 5 stage until the harvest. The leaf area estimated from dimensions against the measured values are plotted in Fig. 1. The results showed that as the plant age advanced the relationship between the estimated and the measured leaf areas remain unchanged, which implies that a constant proportion of leaf length/leaf width may be maintained under the experimental conditions. Changes of leaf area can therefore be estimated from leaf dimensions from Leaf 5 stage throughout the life cycle of rice plant in a controlled environment.

Temperature Effect

When Figs. 2 and 3 were compared, the results indicated that a short term (8 days) temperature treatment at the vegetative stage may affect leaf dimensions, the lenght/width ratios, to some extent. But this effect may not be distinguished between treatments

at harvest, if the treated plants are allowed to grow to maturity. Also, such treatments may somewhat alter the uniformity of the length/width ratio within the same treatment as the plants continually develop (Figs. 4 and 5). A prallel fashion was shown from young plants to matured plants. Different sets of regression analysis, thus, may be needed for leaf area estimation when temperature stress is imposed. The relationship determined for the plant in the early age may not be used for the matured one, and vice versa.

In addition, short term temperature variations at grain-filling stage will also influence leaf dimensions (Figs. 6 and 7). It suggests that the tillering capability and the emergence rate of leaf, and hence leaf age and leaf number, are affected by temperature treatments. As a result, leaf area may not be estimated from data obtained in previous conditions but rather from new environment. Further, as shown in Figs. 8 and 9, the ratios of length/width of newly produced leaves may also be altered within the same treatment as the plant ages.

The study reveals that under a controlled environment leaf area may be estimated from the calculation of leaf dimensions in rice plants. However, when the growth conditions are changed either at vegetative or grain-filling stage, due to temperature or other factors, different regression analyses should be made to excldue the variation from plant growth and development. Such enviromnental fluctuations are often the case in the field that may significantly interfere plant growth. Accordingly, the measured rater than the estsimated leaf area should be used.

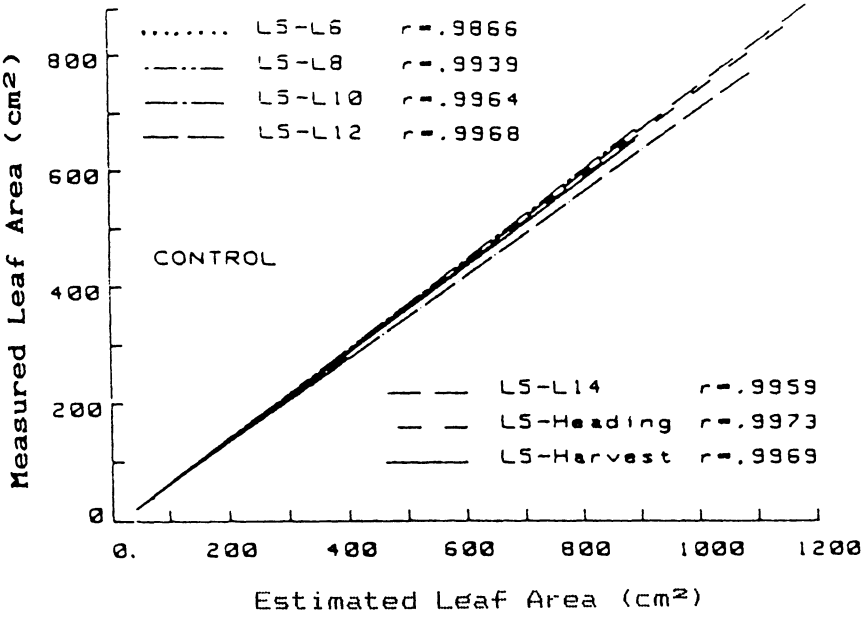


Fig 1. Regression analysis of the correlation between the estimated and the measured leaf areas as a function of leaf stage (plant age) under controlled environment conditions. L5-L6 represents the areas of leaf that were measured/estimated from Leaf 5 stage to Leaf 6 stage, and so on. The values of r are the correlation coefficients.

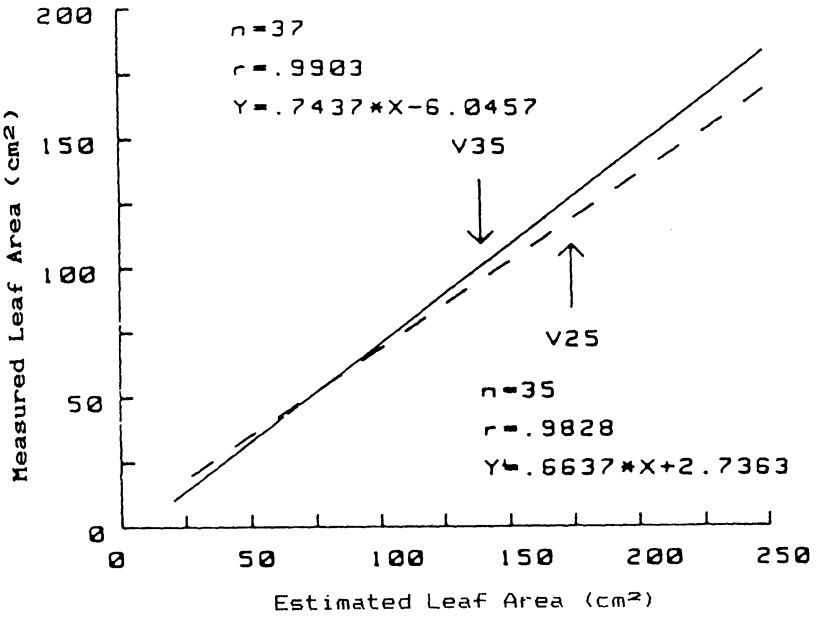


Fig 2. Temperature effects on the linear regressions of the estimated leaf areas to the measured values after treatments in the vegetative stage. The values of X are the estimated leaf areas and the values of Y are the measured leaf areas. V25 and V35 were the 25 C and 35 C treatments at the Leaf 7 stage, respectively.

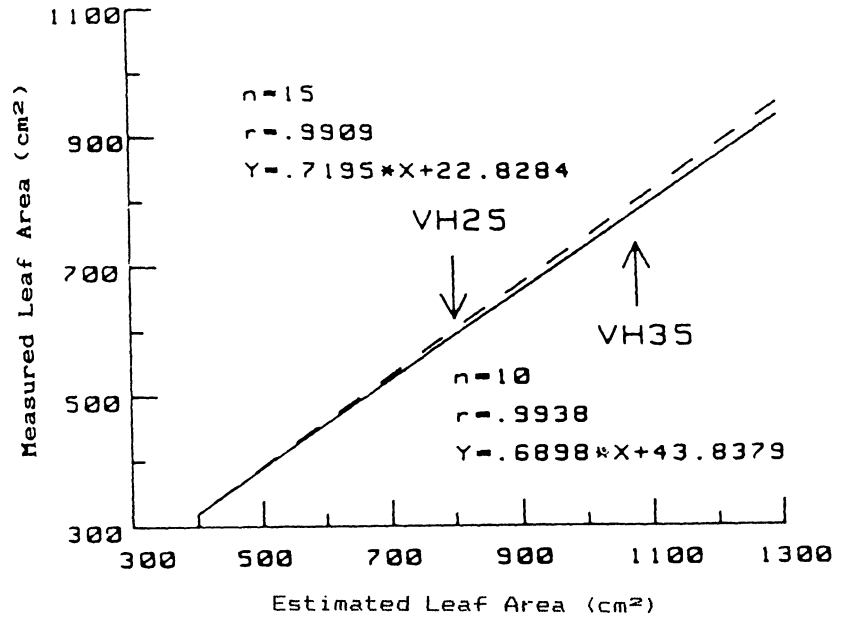


Fig 3. Temperature effects on the linear regressions of the estimated leaf areas to the measured values at harvest. The values of X are the estimated leaf areas and the values of Y are the measured leaf areas. VH25 and VH35 were the 25 C and 35 C treatments at the Leaf 7 stage and collected at harvest, respectively.

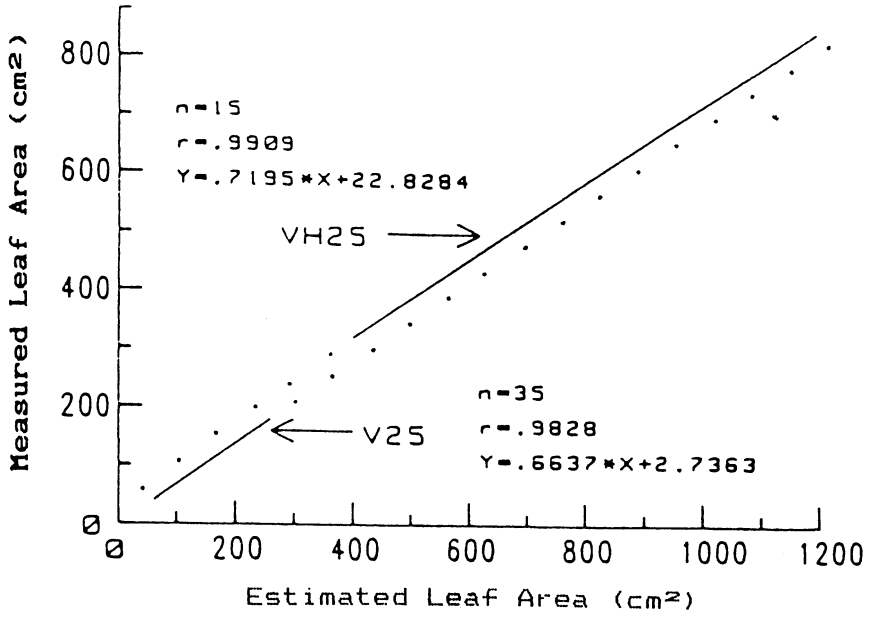


Fig 4. Age affects on the linear regressions of the estimated areas to the measured values of the 25 C-treated plants. Plants of V25 were harvested after treatment, while plants of VH25 were harvested after grown to maturity.

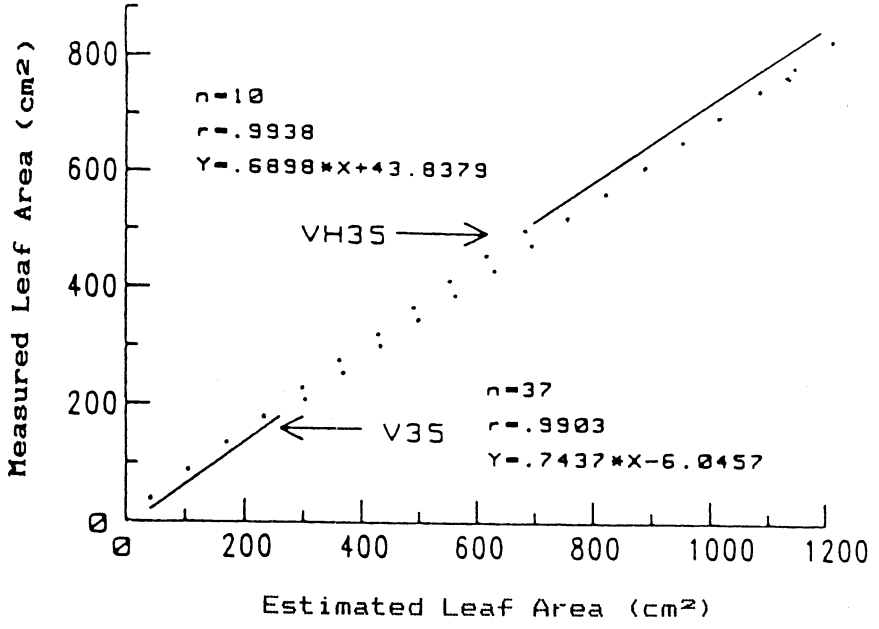


Fig 5. Age affects on the linear regressions of the estimated areas to the measured values of the 35 C-treated plants. Plants of V35 were harvested after treatment, while plants of VH35 were harvested after grown to maturity.

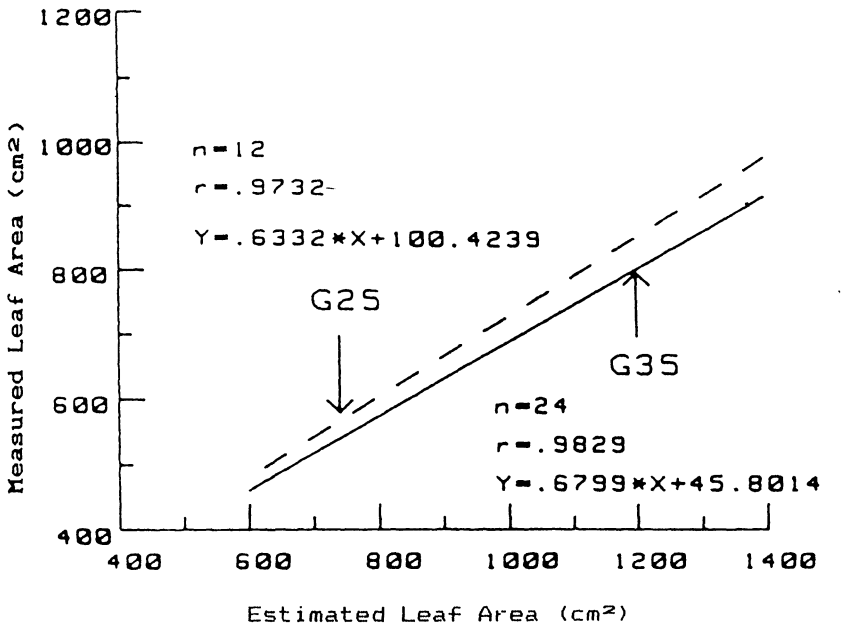


Fig 6. Temperature effects on the linear regressions of the estimated leaf areas to the measured values after treatments in the grain-filling stage. The values of X are the estimated leaf areas and the values of Y are the measured leaf areas. G25 and G35 were the 25 C and 35 C treatments at the R-1 stage (8th to the 15th day from heading), respectively.

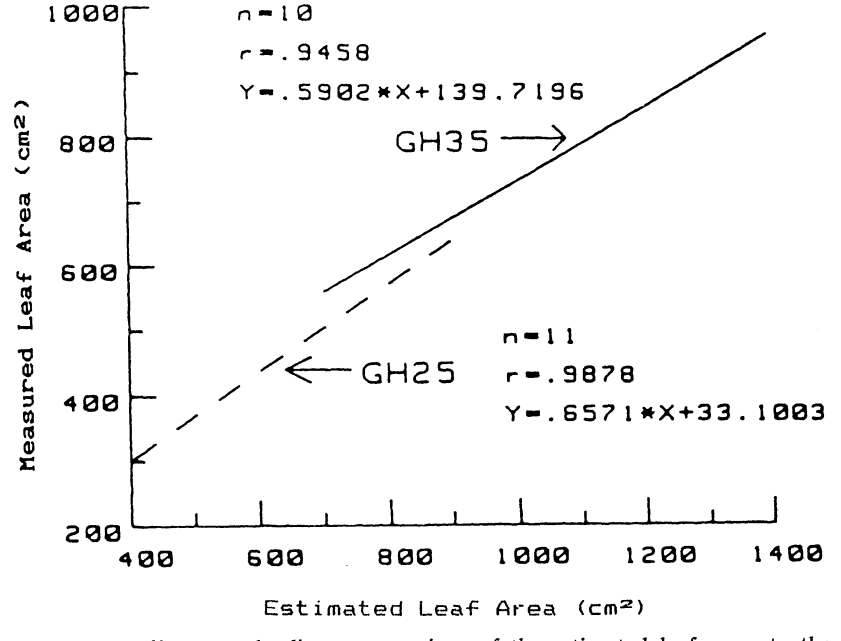


Fig 7. Temperature effects on the linear regressions of the estimated leaf areas to the measured values after treatments in the grain-filling stage. The values of X are the estimated leaf areas and the values of Y are the measured leaf areas. GH25 and GH35 were the 25 C and 35 C treatments at the R-1 stage (8th to the 15th day from heading) and collected at harvest, respectively.

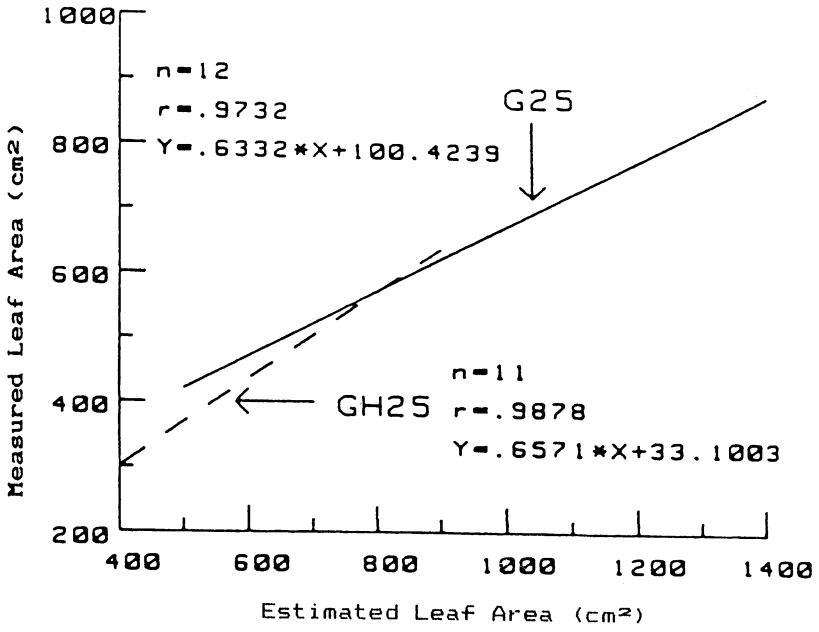


Fig 8. Age affects on the linear regressions of the estimated areas to the measured values of the 25 C-treated plants. Plants of V25 were harvested after treatment, while plants of VH25 were harvested after grown to maturity.

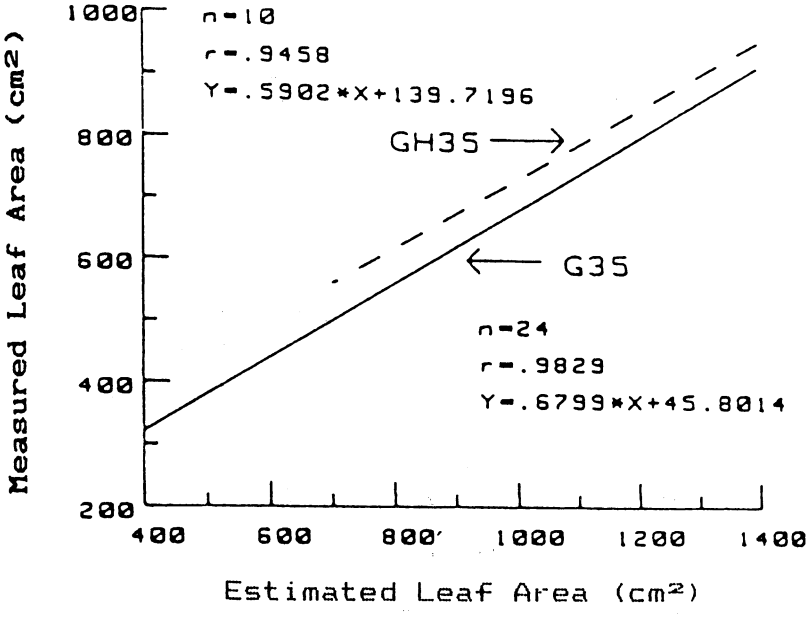


Fig 9. Age affects on the linear regressions of the estimated areas to the measured values of the 35 C-treated plants. Plants of V35 were harvested after treatment, while plants of VH35 were harvested after grown to maturity.

References

1. Beadle, C.L. 1985. Plant growth analysis. p.21. In Techniques in Bioproductivity and Photosynthesis, Coombs, J., D.O. Hall, S.P. Long and J.M. O. Scurlick, eds. Pergamon Press, Oxford.
2. Bollich, C.N., J.G. Atkins, J.E. Scott, and B.D. Webb. 1973. Registration of Labelle rice. Crop Sci. 13 : 773—774.
3. Bollich, C.N., B.D. Webb. M.A. Marchetti, J.E. Scott, and J.W. Stansel. 1984. Lemont characteristics and performance. pp. 2—10. In The Semidwarf-a New Era in Rice Production. The Texas Agri. Exp. Sta., College Station, Texas, USA.
4. Bollich, C.N., B.D. Webb. M.A. Marchetti, and J.E. Scott. 1985. Registration of Lemont rice. Crop Sci. 25 : 883—885.
5. Hunt, R. 1982. Plant Growth Curves : The Functional Approach to Plant Growth Analysis. Univ. Press, Baltimore, USA.
6. Van Bavel, C.H.M., R. Lascano, and D.R. Wilson. 1978. Water relations of fritted clay. Soil Sci. Soc. Amer. J. 42 : 657—659.
7. Watsom, D.J. 1947. Comparative physiological studies on the growth of field crops. I. Variation in net assimilation rate and leaf area between species and varieties and within and detween years. Ann. Bot. N.S. 11 : 41—76.
8. Yoshida, S. 1981. Fundamentals of Rice Crop Science. pp. 11—12. IRRI. Los Banos, Philippines.

株齡與溫度對水稻(*Oryza sativa* L.)葉面積之影響[1]

楊 純 明[2] James L Heilman[3]

摘 要

本試驗在研究水稻之葉面積測定值和估計值間之相關，以及株齡和溫度對此一關係的影響。結果顯示，在控制環境下，葉面積測定值和估計值間有顯著相關。因此，在水稻全生育期內之葉面積，可藉由葉長與葉寬之測量來估算其實際值。但是當經過溫度處理後，則因葉長與葉寬間之比例變更，而改變葉面積測定值和估計值間之關係。所以，當水稻生長期間因溫度發生顯著差異時，應實施測試及迴歸分析，重新確定兩者之關係，才能據以使用估計值估算實際之葉面積。

關鍵詞：葉面積，葉齡，溫度，水稻，*Oryza* sativa L.

1. 臺灣省農業試驗所 研究報告第 1533 號。
2. 臺灣省農業試驗所副研究員，臺中縣霧峰鄉 41301 萬豐村中正路189號。
3. 副教授，美國德州農工大學土壤暨作物系。Dept of Soil & Crop Sic., Texas A & M Univ., College Station, Texas 77843,USA