

**Salak (*Salacca zalacca* (Gaertner.) Voss.) – The Snakefruit from Indonesia
Preliminary Results of an Ecophysiological Study**

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Abstract

The genus of Salacca, which is known as SALAK or SNAKE FRUIT, is found naturally in Indonesia and other South East Asian countries. In Indonesia, salak is widely cultivated in the lowlands throughout the islands. The objectives of this study are to investigate the effect of water stress on net CO₂ assimilation rate (P_n), stomatal resistance (R_s), growth and leaf water potential (Ψ_l) of salak seedlings at different environmental conditions in the greenhouse and growth chambers. The study has been carried out in Berlin - Dahlem. The water stress treatments applied to the plants were: (1) Control plants (C), sufficient water supply daily; (2) Flooding the plants (F) during the entire measuring period; (3) Intermediate drought (ID), watering only once in a week and (4) Drought (D), watering only in the 2nd week of the study in the greenhouse or without water supply during the period in respectively in the growth chambers. The study showed that salak belongs to a group of drought susceptible and flood-tolerant species. No differences in P_n , R_s and plant growth were found among control, intermediate drought and flooded plants at the end of the study. The stressed plants showed some adaptation abilities to water logging stress, such as a decrease in leaf size and the formation of new roots.

1. INTRODUCTION

The genus of *Salacca* consists of 21 species and 4 varieties (Mogea, 1992) and is found naturally in Indonesia and other South East Asian countries (Harsono and Mogea, 1994). Salak plants have been introduced into New Guinea, Queensland (Australia), Ponape Island (Caroline Archipelago) and the Fiji Islands (Schuiling and Mogea, 1992). SALAK is a spiny palm, which

does not form a trunk but rather sprouts the leaves from the ground level. Fruits are in tight, globose bunches, round, 2.5 - 10 cm x 5 - 8 cm across. The fruit skin is covered with regularly arranged scales, giving the appearance of a reptile skin (snake fruit). The edible part is the aromatic and translucent whitish pulp, resembling in taste a mixture of pineapple and banana. Each fruit contains 1 to 3 dark brown seeds.

In Indonesia, salak is widely cultivated in the lowlands throughout the islands. There are many different SALAK cultivars, each of those has its particular taste and fruit characteristics. An important cultivar for the Indonesian market and very prospective for export is PONDOH. Regardless, the present major problems in the development of SALAK production are quality, quantity and continuity of supply. Currently, there is an increasing interest in investigating SALAK production techniques and postharvest properties in Indonesia. However, as mentioned by Santoso (1990), very limited studies on the ecophysiological aspects have been done so far.

Photosynthesis is the basis for plant growth and production. Beside the plant-related factors, environmental conditions influence the net CO₂ assimilation rate (P_n). Environmental factors include light, water, CO₂ concentration and temperature. So far, the effect of water availability on the metabolism of salak plants has not been determined. The objectives of this study are to investigate the effect of water stress on P_n , R_s , growth and Ψ_1 of salak seedlings at different environmental conditions in the greenhouse (GH) and growth chambers (GC).

2. MATERIALS AND METHODS

Salak seeds cultivar *Pondoh* from Sleman, Indonesia, were germinated in sand flats in a greenhouse at Berlin-Dahlem. After about 1.5 months seedlings with 2 leaves (about 25 cm long) were transferred to single pots (16 x 12 cm), which were filled with compost: sand = 2:1. The water stress treatments applied to the plants were:

- (1) Control plants (C), sufficient water supply daily
- (2) Flooding the plants (F) during the entire measuring period
- (3) Intermediate drought (ID), watering only once in a week and
- (4) Drought (D), watering only in the 2nd week of the study in the greenhouse or without water supply during the period respectively in the growth chambers

2.1. Study in the Greenhouse

During the experiment, 24 plants were grouped into 4 treatments (C, F, ID, D) and placed in a shade area inside the greenhouse. All data readings were carried out in the greenhouse. A 400 W lamp was used to supply additional light during the gas exchange measurements. Before the measurement, plants were kept under the lamp for about 1 hour for adaptation. Data readings

have been conducted several times to 5 different plants at each measurement in between 10.00-13.30 in June 2001. The data of P_n and R_s were measured using a portable photosynthesis system (CI-301PS, CID Inc., USA) and only fully developed leaves were used for the measurement. Environmental conditions during the measurement in the greenhouse are presented at Table 1.

2.2. Study in the growth chambers

40 seedlings in the growth chamber 1 (GC1) and 12 seedlings in the growth chamber 2 (GC2) were grouped into four watering treatments as mentioned before (C, F, ID and D). Conditions of twelve hours photoperiod were arranged to both of growth chambers. Relative humidity was uncontrolled in GC1 and controlled at 70% in GC2. Environmental conditions during the measurement in the chambers are presented at Table 1. Shoot length and leaf area were recorded before and after the experiment with a ruler and leaf area meter (CI – 202, CID Inc., USA). The data of P_n and R_s were measured in 1-week-intervals on 3 plants and 3 replicates per plant in the chambers. Dry weight of shoots and roots was determined only for the experiment at GC1 by drying the samples in an oven at 85°C to constant weight at day 50 of the study. Ψ_1 of 2 –3 fully developed leaves per plant and 2 plants for each stress treatments was measured using the scholander bomb at week 6. Except D treatment plants were measured only at week 2 in GC2 and at week 3 for plants in GC1 namely at wilting conditions.

P_n and growth data were subjected to the standard analysis of variance (ANOVA), with significant difference between means (LSD) determined at $P \leq 0.05$ and then further analysed with Tukey test.

Table 1. Environmental conditions during the measurement in the greenhouse and in the growth chambers

Location	Air Temperature (°C)	Leaf Temperature (°C)	PAR** ($\mu\text{mol m}^{-2}\text{s}^{-1}$)	Relative Humidity (%)	CO ₂ concentration (ppm)
GH	25 – 43	23 - 47	144 - 2058	13 - 70	258 - 383
GC1	24 - 32	24 - 34	43 - 98	28 - 70	260 - 319
GC2	21 - 26	22 - 27	136 - 253	28 - 70	317 - 441

** PAR = Photosynthetic Active Radiation

3. RESULTS AND DISCUSSION

3.1. P_n and R_s of seedlings in the greenhouse and growth chambers

P_n of control treatment plants (C) was relatively low ranging from 1.2 - 2.8, 0.2 - 0.5 and 1.7- 2.6 $\mu\text{mol m}^{-2} \text{s}^{-1}$ in GH, GC1 and GC2 respectively (Fig. 1 and 2.). R_s ranges of C plants were 26.0 - 84.8, 10.3 - 71.1 and 4.0 - 31.5 $\text{mmolm}^{-2} \text{s}^{-1}$ in GH, GC1 and GC2 respectively (Fig. 1 and 2). According to Santoso (1990), salak includes in shade plants (30 – 70% of direct sunlight) and optimal temperature for the species is 20 – 30°C. P_n data presented were gathered from fluctuating temperatures, light intensity and relative humidity in GH and GC (Table 1.). P_n of salak seedlings in GC1 was very low due to the low light intensity in the chamber (Fig. 2). The other environmental factors, i.e. high temperature and low air humidity resulted in a stomatal closure, which caused the decrease of P_n .

No significant differences were found between P_n of control plants (C) and P_n of other stressed plants except F and ID in the middle of study in GC2, D in GC2 and in GH (Fig. 1 and 2.). In some measurements during the experiments, no net CO_2 uptake was recorded for F in GH and also ID and F in GC1 (Fig. 1. and 2.). D plants wilted and died after 3 weeks in GC1 and after 2 weeks in GC2 indicating the high susceptibility of plants to drought. R_s of all plants in GC2 was relatively constant at a low level, i.e. less than 45 $\text{mmol m}^{-2}\text{s}^{-1}$ and it was lower as compared to R_s of plants in GC1 and GH (Fig.1. and 2). Only R_s of D plants was significantly different compared to R_s of the treated plants in GH and GC. R_s of ID and F in the middle of study was also significantly different compared to C in GC1, but no difference was found at the end of the study.

Drought stress reduces P_n due to the restriction of CO_2 diffusion through the closing of stomatal or the inhibition of chloroplast activity. Flooding stress affects many physiological, biochemical and morphological processes (Kozłowski 1984). Soil flooding has been observed to reduce P_n of pecan seedlings (Smith and Ager, 1988), melon (Liao and Lin, 1996), blueberries (Davies 1986, Davies and Flore 1986), citrus trees (Joseph and Yelenosky, 1991) and *Pseudotsuga menziesii* seedlings (Zaerr, 1983) at different levels compared to non-flooded plants depending on the specific plant tolerance.

No difference of P_n and R_s were found amongs C, ID and F of salak plants at the end of all study in GH and GC. Obviously ID plants adapted to increase their stress resistance or acclimated to a certain level of water availability. A mild drought stress renders the photosynthetic apparatus an increased resistance to the particular stress applied (Matthews and Boyer 1984). The flood tolerant species *Fraxinus pennsylvanica* was reported to close the stomata within a day or two after flooding was initiated and then begun to reopen after 15 days of flooding. Stomatal

reopening was closely correlated with emergence and growth of adventitious roots on submerged portions of stems (Kozlowski 1984).

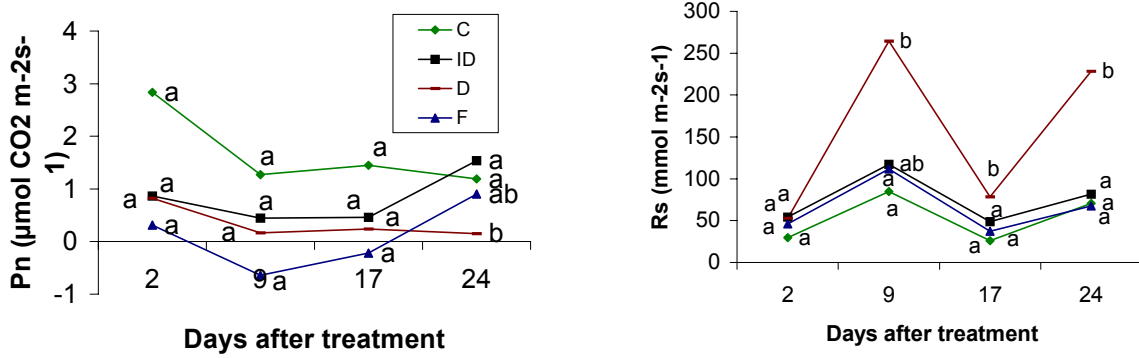


Fig. 1. P_n and R_s of salak seedlings in the greenhouse (GH) under different water stress conditions (C, F, ID and D)

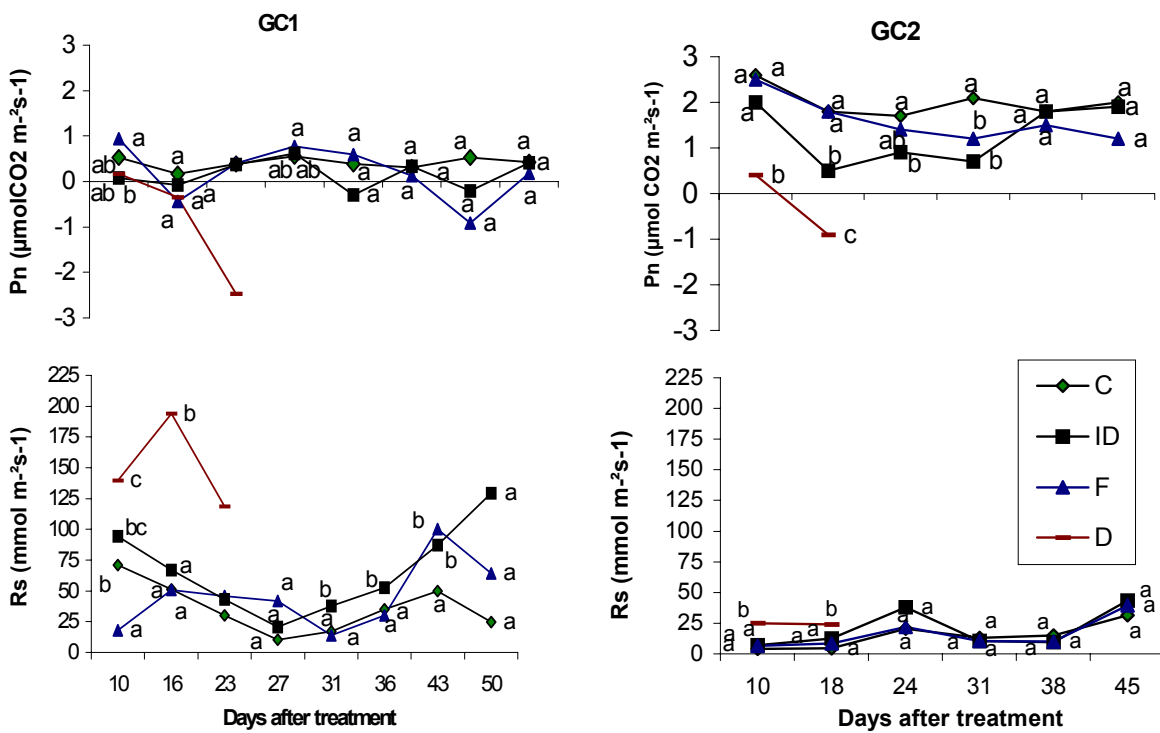


Fig.2. P_n and R_s of salak seedlings at different water stress conditions (C, F, ID and D) in GC1 and GC2

3.2. Plant growth in growth chambers

The shoot dry weight of D significantly differed from the other treatments (C, F and ID), which reduced 50% compared to C. In contrast, there was no significant difference found in root

dry weight among all treatments in GC1 (Table 2.). Even though, there was a reduction of 40% and 30% of root dry weight of F and D respectively. For seedlings growing in GC1, shoot length and leaf area of D were significantly lower compared to other treatments (C, F and ID). No new leaves developed from D during 7 weeks of the study. Leaf growth of F and ID reduced by 40% and only 7% from C respectively. On the other hand, shoot growth of D was 22% of C.

No significant differences were found in leaf growth for all treatments in GC2, and shoot growth of D was significantly different compared to the other treatments (Table 3.). However, leaf growth of F, ID and D reduced by 25%, 68% and 65% of those of C respectively. Shoot length growth of F, ID and D reduced by 20%, 45% and 97% of those of C respectively.

Table 2. Plants dry weight and growth increment of salak plants in GC1 during 7 weeks of the experiment

Location	Treatment	Shoot Dry Weight/Plant (gr)	Root Dry Weight/Plant (gr)	Shoot growth/Plant (cm)	Leaf growth/Plant (cm)
GC1	C	3.10 ± 0.23 a	0.74 ± 0.09 a	30.9 ± 4.02 a	131.24 ± 21.07 a
	F	2.54 ± 0.31 a	0.44 ± 0.08 a	30.8 ± 0.86 ab	79.69 ± 44.22 a
	ID	3.02 ± 0.22 a	0.72 ± 0.10 a	35.8 ± 4.23 a	123.13 ± 14.47 a
	D	1.56 ± 0.13 b	0.52 ± 0.07 a	6.9 ± 3.56 b	0.00 ± 0.00 b

Table 3. Growth increment of salak plants in GC2 during 6 weeks of the experiment

Location	Treatment	Leaf growth/Plant (cm)	Shoot growth/Plant (cm)
GC2	C	195.04 ± 17.26 a	28.93 ± 9.72 a
	F	145.95 ± 11.37 a	23.30 ± 5.24 a
	ID	61.51 ± 30.77 a	16.00 ± 5.52 a
	D	87.28 ± 47.24 a	0.90 ± 0.59 b

There was a significant reduction of growth of water stressed plants in GC1 and GC2 (F, ID and D) compared to C (Table 2 and 3.). In summary, there was no significant difference in growth among all water stressed plants, except D in both of growth chambers. A study on growth of peach trees gave similar results, i.e. shoot length, shoot diameter, shoot number, leaf number and number of vegetative bud did not differ between mild drought, severe drought and control plants (Besset *et al* 2001). In vascular plants, there is a great number of possible responses to tolerate or to avoid anoxia (Hook, 1984). The decrease in stem growth, size of leaf and the development of new roots were the responses to flooding of salak plants.

3.3. Ψ_1 in different plant growth chambers

Ψ_1 data of salak seedlings growing in GC1 and GC2 is presented at Table 4. In GC1 and GC2, Ψ_1 of F was higher compared to Ψ_1 of C at week 6, while Ψ_1 of ID was smaller compared to Ψ_1 of C. A study on flooded starfruit reports on slightly increased Ψ_1 at the first phase until approximately 15 days, then continued by a decline in Ψ_1 (Ismail and Noor, 1996). At the beginning of wilting (D treatment) at week 3 in GC1, Ψ_1 reached -1.15 MPa and those at week 2 in GC2 reached -1.44 MPa. Compared to seedlings growing in GC1 (C, F and ID), which varied from -0.10 MPa and -0.23 MPa, Ψ_1 of plants with same treatment growing in GC2 were much lower and varied between -0.43 MPa and -1.25 MPa. Different conditions of GC1 and GC2 (Table 1) resulted in different responses of Ψ_1 of ID (Table 4). ID of GC2 decreased almost three times lower to C compared to ID in GC1 that decreased only about half times lower to C. It seems that drought tolerance of ID in GC1 was accompanied by high Ψ_1 , while those in GC2 accompanied by low Ψ_1 .

Table. 4. Ψ_1 of salak seedlings under different water stress condition (C, F, ID and D) in GC1 and GC2 at week 6

Treatment	GC1(MPa)	GC2 (MPa)	
C	-0.15	-0.43	Note: * at week 3 ** at week 2
F	-0.10	-0.42	
ID	-0.23	-1.25	
D	-1.15*	-1.44**	

4. CONCLUSIONS

We found out that salak belongs to a group of drought susceptible and flood-tolerant species. The experimental plants wilted within 2-3 weeks of drought, but could stand until 6 weeks of flooding conditions. No differences in P_n , R_s and plant growth were found among control, intermediate drought and flooded plants at the end of the study. The stressed plants showed some adaptation to water logging stress, such as a decrease in leaf size and the development of new roots.

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