# Response of Leaf Water Potential and Growth Characteristics to Irrigation Treatment in Soybean

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**ABSTRACT : oybeans [*Glycine max* (L.) Merr.] are frequently exposed to unfavorable environments during growing seasons and water is the most important factor limiting for the production system. The purpose of this study was to determine the leaf water potential changes by irrigation, and to evaluate the relationships of leaf water potential, growth and yield in soybeans. Three soybean cultivars, Hwangkeumkong, Shinpaldalkong 2, and Pungsannamulkong, were planted in growth chamber and field with irrigated treatments. Leaf water potential of three soybean cultivars was positively correlated with leaf water content during vegetative and reproductive growth stages in growth chamber and field experiments. Leaf water potentials measured for three soybean cultivars under growth chamber were higher than those of under field conditions. Higher leaf water potential with irrigated plots under field was observed compared to conventional plots during reproductive growth stages. Leaf water potentials of three soybean cultivars were continually decreased during reproductive growth stages under field and there was no significant difference among them. Number of leaves, leaf water content, pod dry weight, number of seeds and seed dry weight with irrigated plots were higher than those of conventional plots. The results of this study suggested that leaf water potential could be used as an important growth indicator during the growing season of soybean plants.**

***Keywords*** : soybean, growth stage, leaf water potential, leaf water content, irrigation, pod dry weight, seed number, seed weight.

Soybeans [*Glycine max* (L.) Merr.] are grown in areas characterized by variable crop season precipitation and temperature conditions. Under agricultural conditions, soybean plants are exposed to unfavorable environments that lead to some degree of stress. Soil water deficits, suboptimal temperatures, and poor soil fertilities may cause some growth restrictions during the growing season, so that the yield of soybean at the end of the season expresses only a small fraction of their genetic potential. Of all the resources that soybean plants need to grow and function, water is the most important factor and at the same time limiting for the productivity. Water deficit can reduce plant growth by modifying physiological processes.

Leaf water potential has been used as a common variable to describe plant responses to water deficits. Plants grown in growth chambers show rapid reduction in leaf expansion, starting at a leaf water potential of -0.20 to -0.40 MPa, while field data show rapid leaf expansion at -0.80 to -1.00 MPa (McCree & Davis, 1974). Jung & Scott(1980) reported that the maximum and minimum seasonal leaf water potentials of soybean plants found under field conditions were 0.34 and -1.71 MPa, respectively. The average seasonal predawn and midday leaf water potential were -0.42 and -1.16 MPa for the irrigated soybeans and -0.52 and -1.29 MPa for the nonirrigated soybeans, respectively. Therefore, the nonirrigated soybeans were stressed approximately -0.10 MPa more than the irrigated soybeans.

Change in leaf water potential in response to water stress is one of the major physiological processes responsible for drought tolerance. Genotypic variability for leaf water potential had been demonstrated in soybean plants (Sloane *et al.*, 1990), suggesting that leaf water potential might be one of the criteria for selecting drought-tolerant soybean genotypes. Ideally, the plant water potential should be used to determine the time of irrigation, and soil water potential should be indicated the amount of irrigation water.

Doss et al. (1974) reported soybean yields increased from 24 to 55% when irrigated at 50% of the available soil moisture during the entire season. Previous investigations of soybean seed yield response to water supply during specific developmental stages indicated that reproductive growth stage is more sensitive to water deficits than vegetative growth stage. Especially, insufficient water during the pod filling period can be a major barrier for higher soybean yields and is an important management concern (Pendleton & Hartwig, 1973). Most other researches have supported this conclusion (Brady *et al.*, 1974; Doss *et al.*, 1974; Dusek *et al.*, 1971; Hill *et al.*, 1979; Momen *et al.*, 1979; Sionit & Kramer, 1977). It is well known that water stress reduces soybean yield (Doss *et al.*, 1974; Ashley & Ethridge, 1978) and that the effects of water stress on yield components are

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influenced by the timing and severity of the stress (Sionit & Kramer, 1977).

The purpose of this study was to evaluate the relationships of the leaf water potentials between growth chamber and field condition during early vegetative growth stages, and the yield components and leaf water potentials to irrigation treatment conducted at various developmental growth stages of soybean cultivars.

The results will be applied to set up the appropriate watering strategy in soybean cultivation under drought environment.

## MATERIALS AND METHODS

### Growth chamber experiment

This experiment was conducted to determine leaf water potential and growth of soybean during vegetative growth stages (V1-V3) at the College of Life and Environmental Science, Korea University, Seoul, Korea. Three soybean cultivars [*Glycine max* (L.) Merr.], "Hwangkeumkong" (25.0), "Shinpaldalkong 2" (19.5) and "Pungsannamulkong" (10.7 g/100 seeds), were used. The seeds were planted on 18 March, 5, 14 April and 5 May 2001 in 3.8 L plastic pots containing sandy loam soil in a growth chamber illuminated with a fluorescent light (14 h light, 210 $\mu$ol $m^{-2}s^{-1}$) and maintained at 25°C/20°C (day/night). The relative humidity was fixed to 60%. Each experiment was arranged in a completely randomized design: of three soybean cultivars and three sampling dates (V1-V3) with four replications. Pots were adequately watered with tap water to avoid water stress. Positions of the pots were randomly changed daily to minimize positional effects in the growth chamber. One plant was collected from each pot every time to determine leaf water potential and water content. Leaf water potentials were measured six times a day at 09:00, 10:00, 11:00, 14:00, 15:00, and 16:00 using dewpoint microvoltmeter and used the mean value of morning and afternoon. Leaf samples used for the determination of leaf water potential were weighed and dried at 80 for 48 h to measure water content.

### Field experiment

Field experiment was conducted to determine leaf water potential and growth of soybean from vegetative growth (V1-V3) to reproductive growth (R1-R8) stages at the field in Korea University. The cultivars used for field experiment were same as those for the growth chamber experiment. Seeds were hand-planted in silty clay loam soil on 13 May 2001. Planting density was 60×15 cm with two seeds. The experimental design was split plot design with subplots of three soybean cultivars, main plots of conventional and irrigated treatments, and four replications. The irrigated treatment was commenced on 22 August and continued until on 8 October 2001. Sprinkler irrigation was accompanied about 20 mm weekly bases. The conventional plot in which artificial irrigation was not conducted was subjected to the natural rainfall during all stages of growth. The field site was tilled and fertilized with a broadcast application of 4.5, 7.0, and 6.0 kg per 10a of N, P, and K, respectively, prior to planting. Physiological growth stages were described as V1, V2, V3, R1-R8 according to Fehr and Caviness (1977). Rainfall during the growing season was poorly distributed (data not shown).

### Measurement of leaf water potential and water content

Leaf water potential was measured on fully expanded, central leaflets using a dewpoint microvoltmeter (HR 33T, C-52, Wescor). Leaf water potentials were determined by comparing the microvoltmeter output with calibration curves for diurnal times and leaf positions of soybean plants. Soybean leaf discs punched from near the center of fully expanded leaflets were placed into dewpoint microvoltmeter fitted with sample chamber. At the end of the measurements, the leaf samples were collected and measured dry weight after oven-drying at 80°C for 48 h. The time required between leaflet excision and sealing in the sample chamber was less than 5 sec, which minimized the amount of water loss from the tissues.

Water content was determined as :

$$WC(\%) = [(\text{Fresh wt.} - \text{Dry wt.})/\text{Fresh wt.}] \times 100$$

### Growth measurement

Soybean yield components were observed to classify the effect of irrigated treatment on individual components, such as number of plants, number of pods, number of seeds and seed weight. Five soybean plants were sampled at the growth stages of V1, V2, V3, and R1-R8. The samples were separated into stems, leaves, pods and seeds, and weighed after oven-drying at 80°C for 48 h. Abnormal seeds such as wrinkled, diseased, etched, discolored, and misshapen seeds were separated from each treatment batch, and weighed. Only normal seeds were used for determining the number and weight of seeds.

### Data collection and statistical analysis

The collected data were statistically analyzed using the Statistical Analysis System (SAS Institute Inc., Cary, NC) package and analysis of variance was conducted on the data using PROC ANOVA procedures. The significance of difference among treatments was tested using the least significant difference (LSD). Correlation analyses were performed using PROC CORR procedures.

## RESULT AND DISCUSSION

### Growth chamber experiment

Leaf water potential of three soybean cultivars during vegetative growth stages (V1-V3) was presented in Table 1. There was not significantly different among cultivars and vegetative growth stages. Leaf water potentials among three soybean cultivars measured at V1 growth stage were observed similar values -0.71, -0.74 and -0.72 MPa, respectively. Although no significant difference was found for leaf water potential among cultivars at each growth stage, the magnitude of cultivar difference was much greater at V3 than V1 or V2 growth stage. The leaf water potential at V3 growth stage was shown highest in Hwangkeumkong and lowest in Shinpaldalkong 2. The difference of leaf water potential was nearly -0.18 MPa. The leaf water potential of morning was highly positive correlated with the leaf water potential of afternoon (r=0.5634***).

The dry weight and water content of leaf and total plant during vegetative growth stages (V1-V3) of three soybean cultivars were presented in Table 2. Leaf dry weight increased at V1-V2 growth stages. Total dry weight continually increased during V1-V3 growth stages. No significant

**Table 1.** Changes in leaf water potential measured during morning and afternoon in three soybean cultivars under the growth chamber.

| Cultivar | Leaf water potential (a.m.) | | | | Leaf water potential (p.m.) | | | |
|---|---|---|---|---|---|---|---|---|
| | Growth stage | | | $LSD_{0.05}$ | Growth stage | | | $LSD_{0.05}$ |
| | V1 | V2 | V3 | | V1 | V2 | V3 | |
| | MPa | | | | | | | |
| Hwangkeumkong | -0.74 | -0.87 | -0.79 | NS | -0.68 | -0.65 | -0.77 | NS |
| Shinpaldalkong 2 | -0.70 | -0.80 | -0.98 | NS | -0.78 | -0.90 | -0.93 | NS |
| Pungsannamulkong | -0.78 | -0.83 | -0.93 | NS | -0.66 | -0.88 | -0.88 | NS |
| $LSD_{0.05}$ | NS | NS | NS | | NS | NS | NS | |

NS: Not significant.

**Table 2.** Dry weight and water content of leaf and whole plant in vegetative growth stage under the growth chamber.

| Cultivar | Leaf dry weight | | | | Leaf water content | | | |
|---|---|---|---|---|---|---|---|---|
| | Growth stage | | | $LSD_{0.05}$ | Growth stage | | | $LSD_{0.05}$ |
| | V1 | V2 | V3 | | V1 | V2 | V3 | |
| | | g/leaf | | | | % | | |
| Hwangkeumkong | 0.03 | 0.05 | 0.05 | 0.02 | 82.3 | 81.9 | 81.1 | NS |
| Shinpaldalkong 2 | 0.03 | 0.07 | 0.06 | 0.02 | 79.8 | 79.7 | 79.7 | NS |
| Pungsannamulkong | 0.02 | 0.04 | 0.04 | 0.02 | 81.0 | 78.6 | 79.4 | NS |
| $LSD_{0.05}$ | NS | NS | NS | | NS | NS | NS | |

| Cultivar | Total dry weight | | | | Total water content | | | |
|---|---|---|---|---|---|---|---|---|
| | Growth stage | | | $LSD_{0.05}$ | Growth stage | | | $LSD_{0.05}$ |
| | V1 | V2 | V3 | | V1 | V2 | V3 | |
| | | g/leaf | | | | % | | |
| Hwangkeumkong | 0.08 | 0.13 | 0.33 | 0.10 | 84.7 | 84.9 | 85.3 | NS |
| Shinpaldalkong 2 | 0.08 | 0.22 | 0.39 | 0.14 | 84.1 | 83.2 | 78.6 | NS |
| Pungsannamulkong | 0.06 | 0.13 | 0.20 | 0.06 | 81.8 | 82.6 | 83.6 | NS |
| $LSD_{0.05}$ | NS | NS | NS | | NS | NS | NS | |

NS: Not significant.

**Table 3.** Changes in leaf water potential measured during morning and afternoon in three soybean cultivars under the field conditions.

| Cultivar | Leaf water potential (a.m.) | | | | Leaf water potential (p.m.) | | | |
|---|---|---|---|---|---|---|---|---|
| | Growth stage | | | $LSD_{0.05}$ | Growth stage | | | $LSD_{0.05}$ |
| | V1 | V2 | V3 | | V1 | V2 | V3 | |
| | MPa | | | | | | | |
| Hwangkeumkong | -0.75 | -1.08 | -1.13 | NS | -0.99 | -0.93 | -1.36 | NS |
| Shinpaldalkong 2 | -0.73 | -0.68 | -0.78 | NS | -1.10 | -0.84 | -1.15 | NS |
| Pungsannamulkong | -0.79 | -1.04 | -1.07 | NS | -1.01 | -1.36 | -1.17 | NS |
| $LSD_{0.05}$ | NS | NS | NS | | NS | NS | NS | |

NS: Not significant.

**Table 4.** Dry weight and water content of leaf and whole plant in vegetative growth stage under the growth chamber.

| Cultivar | Leaf dry weight | | | | Leaf water content | | | |
|---|---|---|---|---|---|---|---|---|
| | Growth stage | | | $LSD_{0.05}$ | Growth stage | | | $LSD_{0.05}$ |
| | V1 | V2 | V3 | | V1 | V2 | V3 | |
| | g/leaf | | | | % | | | |
| Hwangkeumkong | 0.04 | 0.07 | 0.10 | 0.01 | 77.6 | 78.8 | 77.4 | NS |
| Shinpaldalkong 2 | 0.04 | 0.08 | 0.11 | 0.01 | 78.5 | 77.6 | 74.5 | Ns |
| Pungsannamulkong | 0.03 | 0.08 | 0.09 | 0.02 | 76.5 | 74.1 | 76.0 | NS |
| $LSD_{0.05}$ | NS | NS | NS | | NS | NS | NS | |
| Cultivar | Total dry weight | | | | Total water content | | | |
| | Growth stage | | | $LSD_{0.05}$ | Growth stage | | | $LSD_{0.05}$ |
| | V1 | V2 | V3 | | V1 | V2 | V3 | |
| | g/leaf | | | | % | | | |
| Hwangkeumkong | 0.12 | 0.22 | 0.48 | 0.07 | 79.4 | 79.7 | 80.1 | NS |
| Shinpaldalkong 2 | 0.12 | 0.24 | 0.48 | 0.11 | 80.0 | 80.2 | 80.7 | NS |
| Pungsannamulkong | 0.09 | 0.24 | 0.42 | 0.03 | 79.6 | 77.0 | 77.7 | NS |
| $LSD_{0.05}$ | NS | NS | NS | | NS | NS | NS | |

NS: Not significant.

differences for water content were found between cultivars and growth stages.

### Field experiment for vegetative growth stages (V1-V3)

Leaf water potentials of three soybean cultivars during vegetative growth stages were presented in Table 3. Leaf water potential changes between cultivars and vegetative growth stages were not significant difference. Leaf water potentials among three soybean cultivars measured at V1 growth stage were observed similar values shown as -0.87, -0.92 and -0.90 MPa, respectively. But the leaf water potential differences among three soybean cultivars were appeared at V2 growth stage. The leaf water potential difference between Hwangkeumkong and Pungsannamulkong

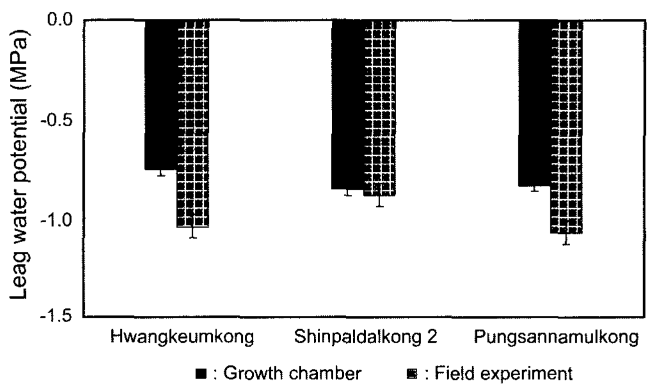


**Fig. 1.** Leaf water potential of three soybean cultivars during vegetative growth stages under the growth chamber and the field conditions.

was 0.44 MPa. When the leaf water potential was compared between growth chamber and field experiments, leaf water potentials measured under growth chamber were generally higher than those of field for all cultivars due to adequate watering as shown in Fig. 1.

The dry weight and water content of leaf and total plant during vegetative growth stages (V1-V3) were shown in Table 4. Significant differences for leaf dry weight and total dry weight were found among growth stages and continually increased as stage progressed. Leaf water content tended to be decreased until V3 growth stage. But total water content somewhat decreased at V2 growth stage and then tended to increased at V3 growth stage probably due to weather conditions.

### Field experiment during reproductive growth stages

The daily and seasonal measurements of water status of soybean plants were conducted in order to characterize leaf water potential response to soil water deficits. Leaf water potentials were measured to conventional and irrigated plots for three soybean cultivars. The seasonal trends in leaf water potential between two treatments were shown in Fig. 2. Values of leaf water potential for conventional plot were continually decreased, but increased those for irrigated plot measured during from 22 August to 8 October. The average differences of leaf water potential between conventional and irrigated plots were ranged from -0.38 to -0.48 MPa. Consequently, these data implied that soybean plants of conventional plots were stressed more than those of irrigated plots. Jung and Scott (1980) showed that as water deficits were progressed, differences in leaf water potentials between the conventional and irrigated soybeans were increased (Carlson *et al.*, 1979). The leaf water potential of three soybean cultivars on conventional plots was decreased to about -2.29 MPa, whereas that on irrigated plots was to near -1.85 MPa during the late reproductive growth stages. In addition, there was significantly different between treatments and this result was in agreement with Jung & Scott (1980) suggested that irrigation had a great effect on leaf water potential during a day, and leaf water potential below 1.10 MPa inhibited photosynthesis in soybeans (Ghorashy *et al.*, 1971; Boyer, 1970; Huang *et al.*, 1975).

The seasonal trends of the leaf water potential in three soybean cultivars from 4 July to 8 October were illustrated in Fig. 3. There was no significantly difference among three cultivars. The reason for this behavior was not clear in this experiment, but could relate to leaf anatomy or stomatal distribution differences among three cultivars. Leaf osmotic potential level could also be different among three cultivars, and this would influence cell turgor pressure. Further study is needed to clarify this cultivar differences.

The diurnal trends in the leaf water potential both morning and afternoon during from 4 July to 8 October were presented in Fig. 4. Leaf water potential difference of three soy-

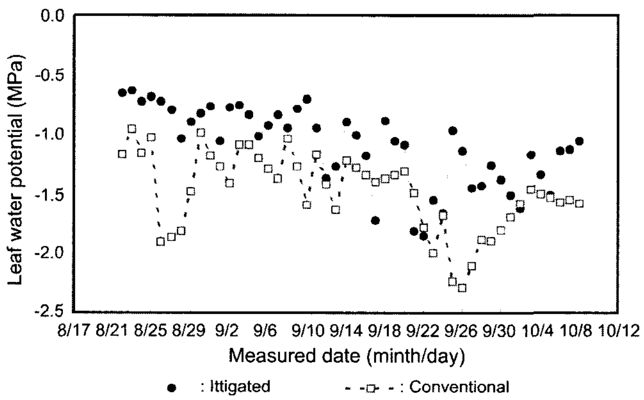


**Fig. 2.** Leaf water potential of three soybean cultivars by conventional and irrigated treatments from 22 August to 8 October under the field conditions.

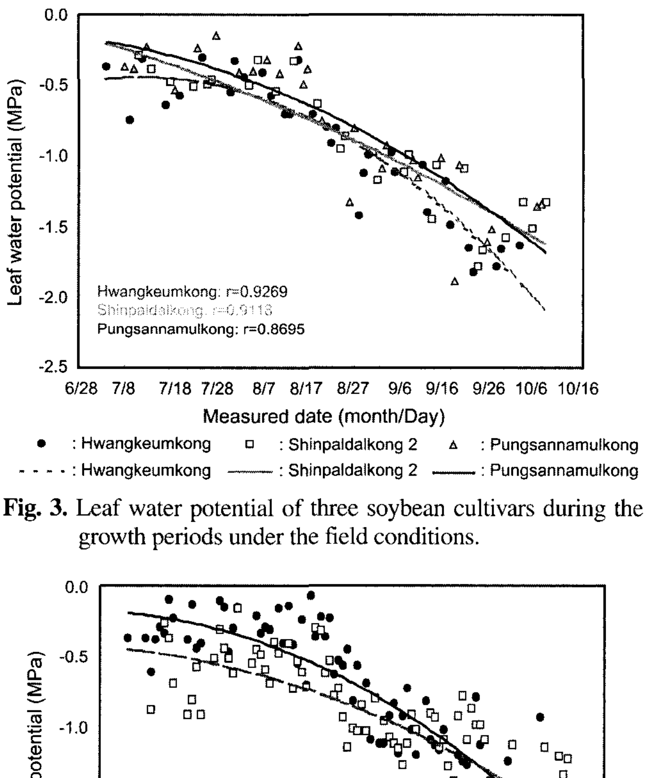


**Fig. 3.** Leaf water potential of three soybean cultivars during the growth periods under the field conditions.

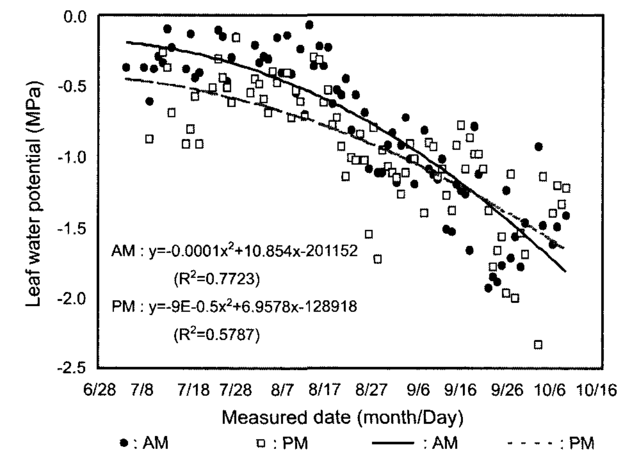


**Fig. 4.** Leaf water potential of three soybean cultivars measured during morning and afternoon under the field conditions.

bean cultivars measured morning and afternoon was about -0.14 MPa, but no significant difference was found between them. As one might expect, therefore, individual diurnal shifts did greatly not affect on leaf water potential. During the morning, leaf water potential remains at a somewhat higher level than that of afternoon. During the afternoon, when atmospheric demand exceeds the ability of the root system to provide water to the leaves, leaf water potential decreases, and the stomata close, reducing the leaf water potential to low levels (Hsiao & Xu, 2000). Some mechanism was operating within the leaves that allow these plants to have differing levels of leaf water potential. It may be that leaf osmotic potential by balancing the measured leaf water potential as noted by Turner & Begg(1973) in maize (*Zea mays* L.). This relationship is expressed by

$$\psi_L = P + \pi$$

Where $\Psi_L$ is the measured leaf water potential, and P and are leaf turgor pressure and leaf osmotic potential, respectively. There is other evidence for this type of osmoregulation in plants (Ackerson *et al.,* 1977; Hellebust, 1976). Unfortunately, leaf osmotic potential and turgor pressure

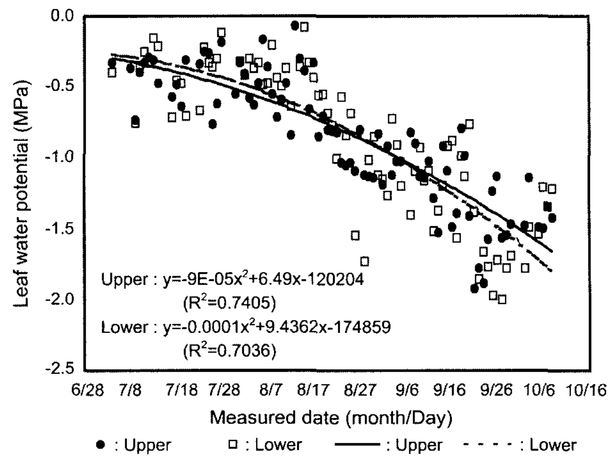


**Fig. 5.** Leaf water potential according to different leaf positions of three soybean cultivars under the field conditions.

**Table 5.** Correlation coefficidng of water potential, dry weight and water content of leaf in treatments, leaf positions and diurnal times.

| | | CLDW (n=137) | CLWC (n=137) | ILWP (n=137) | ILDW (n=137) | ILWC (n=137) |
|---|---|---|---|---|---|---|
| Treatments | CLWP | -0.00584 | 0.45545*** | -0.15937 | 0.01201 | -0.06287 |
| | CLDW | | -0.29989*** | 0.06521 | -0.06647 | 0.00278 |
| | CLWC | | | -0.11542 | 0.04906 | -0.00492 |
| | ILWP | | | | -0.13703 | 0.46775*** |
| | ILDW | | | | | -0.47390 |
| | | LLDW (n=149) | LLWC (n=149) | ULWP (n=148) | ULDW (n=148) | ULWC (n=148) |
| Leaf positions | LLWP | 0.10983 | 0.44438*** | 0.60174*** | -0.16662* | 0.29386*** |
| | LLDW | | -0.31053*** | 0.10710 | 0.24367*** | 0.03661 |
| | LLWC | | | 0.32331*** | -0.15395 | 0.28302*** |
| | ULWP | | | | -0.19651* | 0.49794*** |
| | ULDW | | | | | -0.4314*** |
| | | MLDW (n=149) | MLWC (n=149) | ALWP (n=148) | ALDW (n=148) | ALWC (n=148) |
| Diurnal times | MLWP | -0.11140 | 0.41726*** | 0.44854*** | 0.0864 | 0.24499*** |
| | MLDW | | -0.38610 | -0.03502 | -0.00499 | 0.02830 |
| | MLWC | | | 0.20908* | 0.01047 | 0.18157* |
| | ALWP | | | | -0.01178 | 0.49128*** |
| | ALDW | | | | | -0.37036*** |

*,**,***: significant at the 0.05, 0.01 and 0.001 probability levels, respectively.
CLWP: Leaf water potential in conventional treatment. CLDW: Leaf dry weight in conventional treatment.
CLWC: Leaf water content in conventional treatment. ILWP: Leaf water potential in irrigated treatment.
ILDW: Leaf dry weight in irrigated treatment. ILWC: Leaf water content in irrigated treatment.
LLWP: Water potential in lower leaf. LLDW : Leaf dry weight in lower leaf. LLWC: Leaf water content in lower leaf.
ULWP: Leaf water potential in upper leaf. ULDW: Leaf dry weight in upper leaf. ULWC: Leaf water content in upper leaf.
MLWP: Leaf water potential measured during morning. LDW : Leaf dry weight. LWC : Leaf water content.
ALWP: Leaf water potential measured during afternoon. LDW : Leaf dry weight. LWC : Leaf water content.

were not collected in this experiment which requiring more detailed studies in the future. Under extreme demand during midday, the apparent osmotic adjustment was unable to be fully effective so turgor loss and stomatal closure were evident. Stevenson & Shaw (1971) reported that diurnal measurement of water potential in leaves at the top of a soybean cultivars (Wayne) canopy showed that the lowest water potentials were obtained between 12:00 and 14:00. Since these measurements were made with leaves fully illuminated and perpendicular to incoming light, they should represent the driest leaves in the canopy.

The seasonal trends in the leaf water potential between upper and lower leaves from 4 July to 8 October were presented in Fig. 5. Regression analyses between upper and lower leaves showed a better fit quadratic regression. Coefficients of determination ($R^2$) between upper and lower leaves were 0.7405 and 0.7036, respectively. There was no significant difference of leaf water potential between upper and lower leaves. Hsiao & Xu (2000) demonstrated that near noon on a sunny day leaves at the top of the canopy of both

**Table 6.** Growth charateristics of three soybean cultivars in irrigated treatment measured on Augst 28 and September 13, 2001.

| Investigated date | Treatment | Cultivar | No. of Leaves | Leaf dry wt. (g/plant) | Leaf water content (%) | Plant leight (cm) | No. of nodes on main stem | No. of branches/ plant | Stem dry wt. (g/plant) | Stem water content (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| Aug. 28 | Conventional | 1 | 146.0 | 10.9 | 67.3 | 66.7 | 13.7 | 5.4 | 17.0 | 67.9 |
| | | 2 | 92.7 | 8.6 | 64.8 | 59.5 | 12.7 | 2.3 | 15.2 | 66.9 |
| | | 3 | 279.3 | 16.0 | 67.8 | 53.0 | 14.7 | 10.6 | 20.5 | 71.3 |
| | | Mean | 172.7 | 11.8 | 66.6 | 59.7 | 13.7 | 6.1 | 17.6 | 68.7 |
| | Irrigated | 1 | 170.3 | 14.9 | 69.1 | 58.8 | 13.3 | 6.1 | 18.3 | 69.4 |
| | | 2 | 97.3 | 13.1 | 65.3 | 56.3 | 13.7 | 6.5 | 17.9 | 69.1 |
| | | 3 | 206.3 | 12.9 | 71.0 | 59.0 | 14.0 | 8.7 | 16.5 | 73.5 |
| | | Mean | 158.0 | 13.6 | 68.5 | 58.0 | 13.7 | 7.1 | 17.5 | 70.7 |
| Sep. 13 | Conventional | 1 | 127.9 | 10.1 | 49.5 | 57.3 | 13.7 | 6.8 | 17.7 | 70.0 |
| | | 2 | 126.7 | 9.5 | 43.6 | 57.5 | 13.8 | 7.6 | 17.3 | 70.9 |
| | | 3 | 187.8 | 13.2 | 68.8 | 57.9 | 13.8 | 7.6 | 17.2 | 71.5 |
| | | Mean | 147.5 | 10.9 | 54.0 | 57.6 | 13.8 | 7.2 | 17.4 | 70.8 |
| | Irrigated | 1 | 181.7 | 13.4 | 68.1 | 57.6 | 13.8 | 7.3 | 17.4 | 70.8 |
| | | 2 | 185.8 | 13.5 | 68.3 | 57.7 | 13.8 | 7.4 | 17.3 | 71.1 |
| | | 3 | 185.1 | 13.4 | 68.4 | 57.7 | 13.8 | 7.4 | 17.3 | 71.1 |
| | | Mean | 184.2 | 13.4 | 68.3 | 57.7 | 13.8 | 7.4 | 17.3 | 71.0 |
| $LSD_{0.05}$ | Aug | CT | 27.3 | 2.7 | 4.5 | 6.2 | 0.7 | 1.1 | 4.2 | 3.1 |
| | | TRT | NS | NS | NS | NS | NS | 0.9 | NS | NS |
| | Sep | CT | 30.6 | 3.3 | 12.4 | 5.2 | 1.0 | 1.1 | 3.7 | 8.3 |
| | | TRT | 25.0 | NS | 10.1 | NS | NS | NS | NS | NS |

1: Hwangkeumkong. 2: Shinpaldalkong 2. 3: Pungsannamulkong.
CT: Cultivar. TRT: Treatment.

**Table 7.** Yield components of three soybean cultivars under conventional and irrigated treatments.

| Treatment | Cultivar | No. of pods per plant | Pod dry wt. (g/plant) | No. of seeds per plant | Seed dry wt. (g/plant) |
|---|---|---|---|---|---|
| Conventinal | 1 | 44.9 | 7.2 | 49.9 | 6.2 |
| | 2 | 44.0 | 5.1 | 68.7 | 6.4 |
| | 3 | 112.7 | 6.7 | 84.3 | 1.3 |
| | Mean | 67.2 | 6.3 | 67.6 | 4.6 |
| Irrigated | 1 | 50.0 | 8.5 | 74.8 | 15.0 |
| | 2 | 51.3 | 5.3 | 84.2 | 10.1 |
| | 3 | 155.2 | 9.8 | 253.4 | 7.6 |
| | Mean | 85.5 | 7.9 | 137.5 | 10.9 |
| $LSD_{0.05}$ | CT | 23.2 | 1.7 | 20.1 | 2.8 |
| | TRT | NS | 1.4 | 16.4 | 2.3 |

1: Hwangkeumkong. 2: Shinpaldalkong 2. 3: Pungsannamulkong.
CT: Cultivar. TRT: Treatment.

maize and sorghum [*Sorghum bicolor* (L.) Moench] were about -1.00 MPa lower in water potential than leaves at the low part of the canopy. Stevenson & Shaw (1971) reported that although the part of the canopy was the top, the cultivar difference in leaf water potential also was apparent in other leaves when those leaves were fully illuminated and perpendicular to incoming light.

Correlation between leaf water status and dry weights for three soybean cultivars, two treatments, diurnal times and leaf positions was shown in Table 5. Leaf water potential was highly positive correlated with leaf water content for three cultivars, and leaf water potential of conventional and irrigated treatments was highly positive correlated with leaf water content. According to leaf position, upper and lower leaf water potentials were highly correlated with leaf water content and leaf water potential of morning and afternoon was also highly positive correlated with leaf water content.

Growth characteristics of three soybean cultivars in irrigated plots were generally higher than those of conventional plots (Table 6). More growth advantages obtained from adequate water on entire season in irrigated plots during growth periods. In conventional plots, the reduced values of growth characteristics compared to irrigated plots was depended on the time and duration of the water deficit period and amount of rainfall during pod filling period of soybean plants.

The number and dry weight of pods and seeds in three soybean cultivars were significantly greater in irrigated than in conventional plots (Table 7). Irrigated plots had significant effect on growth characteristics and these data consisted with the results of other research (Yang *et al.,* 2000). Significant differences among cultivars and between treatments were observed in pod dry weight, number of seeds and seed dry weight. The results of this study could be concluded that in the absence of water stress during reproductive development, the soybean plants could develop a maximal number of pods and seeds, and that leaf water potential could be used as an important growth indicator during the growing season of soybean plants.

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