Water Use Efficiency and Nutrient Uptake of Soybean Grown in P-Deficient Soil under Water Deficit

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INTRODUCTION

Soybeans are an important crop world-wide. In Thailand, soybean production is not sufficient to satisfy the needs for human food and animal feed in the country. Therefore, it is important to increase production of soybean by expanding into areas where it is not normally grown. Growing soybeans after rice is one way to increase production, and soybeans can use residual soil moisture after a rice crop. However, if a non-rice crop is grown after rice during the rainless period in Thailand, the plant normally experiences water deficit at the reproductive stage. Phosphorus is an important element for growth and development of plants. Phosphorus has been shown to contribute to increased root dry weight, resulting in increased water and nutrient uptake. Most paddy fields in rain-fed areas in northeastern Thailand have low soil fertility. Phosphorus application could increase P availability and development of the root system. Therefore, the objective of this study was to investigate the effects of P application on water use efficiency and nutrient uptake of Thai soybean cultivars under water deficit.

MATERIALS AND METHODS

The experiment was done in a greenhouse in Manhattan, Kansas, between 25 Aug. 2009 (planting) and 4 Dec. 2009 (harvest). The soil was a Morrill loam, collected from a field near Manhattan, Kansas. It was naturally low in phosphorus (6.5 ppm). Plants grew in large pots (28 cm tall; 15 cm diameter). Half of the pots had no P fertilizer added to the soil, and half of the pots had P fertilizer added to the soil. Fertilized soil received 40 ppm P. The phosphorus fertilizer was granular triple super phosphate (0-46-0).

Two cultivars of soybean [*Glycine max* (L.) Merr.] were used:

- 'Chiangmai 60' (abbreviated CM60, a traditional Thai cultivar)
- 'KKU74' (an improved cultivar developed by Khon Kaen University in Thailand)

Germinated seedlings were transplanted into pots on 28 Aug. 2009. There were three water levels: 75-80% of pot capacity (W0 or control); 40% of pot capacity at the R1 stage (W1); and 40% of pot capacity at the R3 stage (W2). Pots were weighed to keep them at their appropriate water level and to determine water used. Plant height was measured weekly. Stomatal resistance was measured with a diffusion porometer (Model SC-1, Decagon Devices, Pullman, WA) every 2 days from 43 days after transplanting (DAT) until the end of the experiment. At harvest (99 DAT), roots were extracted and root and shoot dry weights were determined. Water use efficiency for each plant in a pot was calculated at harvest by dividing shoot dry weight by total water used throughout the experiment. Roots and shoots were analyzed for concentration of nutrients by the Soil Testing Laboratory at Kansas State University. Figure 1 shows an overview of the experiment on 15 Sept. 2009. Soybeans need short days to flower. So black plastic was hung on the walls of the greenhouse 41 DAT to block out lights at night from adjoining greenhouses (Fig. 2). The experiment was a factorial, randomized complete block design with 4 replications.

Fig. 1. Overview of the pots on 15 Sept. 2009

Fig. 2. Black plastic to block out night lights

RESULTS

WATER USE EFFICIENCY AND DRY WEIGHTS

Water use efficiency and shoot and root dry weights were increased by P application (Table 1).

Table 1. Water use efficiency, shoot dry weight, and root dry weight of two soybean cultivars grown in P-deficient soil under three watering regimes

Treatment	Water use efficiency (mg/g water)	Shoot dry weight (g/plant)	Root dry weight (g/plant)
<u>Watering regimes</u>			
Well watered	2.31a†	48.41a	6.37a
Water deficit at R1 stage	1.49b	18.98c	2.76c
Water deficit at R3 stage	1.74b	30.32b	5.41b
<u>Phosphorus rates</u>			
No P added	1.35b	22.06b	3.88b
40 mg P/kg added to soil	2.34a	43.09a	5.82b
<u>Soybean cultivars</u>			
KKU74	2.04a	36.50a	5.19b
CM60	1.66a	28.65b	4.51b

†Means followed by the same letter in a column are not significantly different by LSD.

RESULTS (continued)

HEIGHT

KKU74 was taller than CM60, and P application increased height. Well-watered plants were the tallest, and plants with water deficit at the R1 stage were the shortest (Fig. 3).

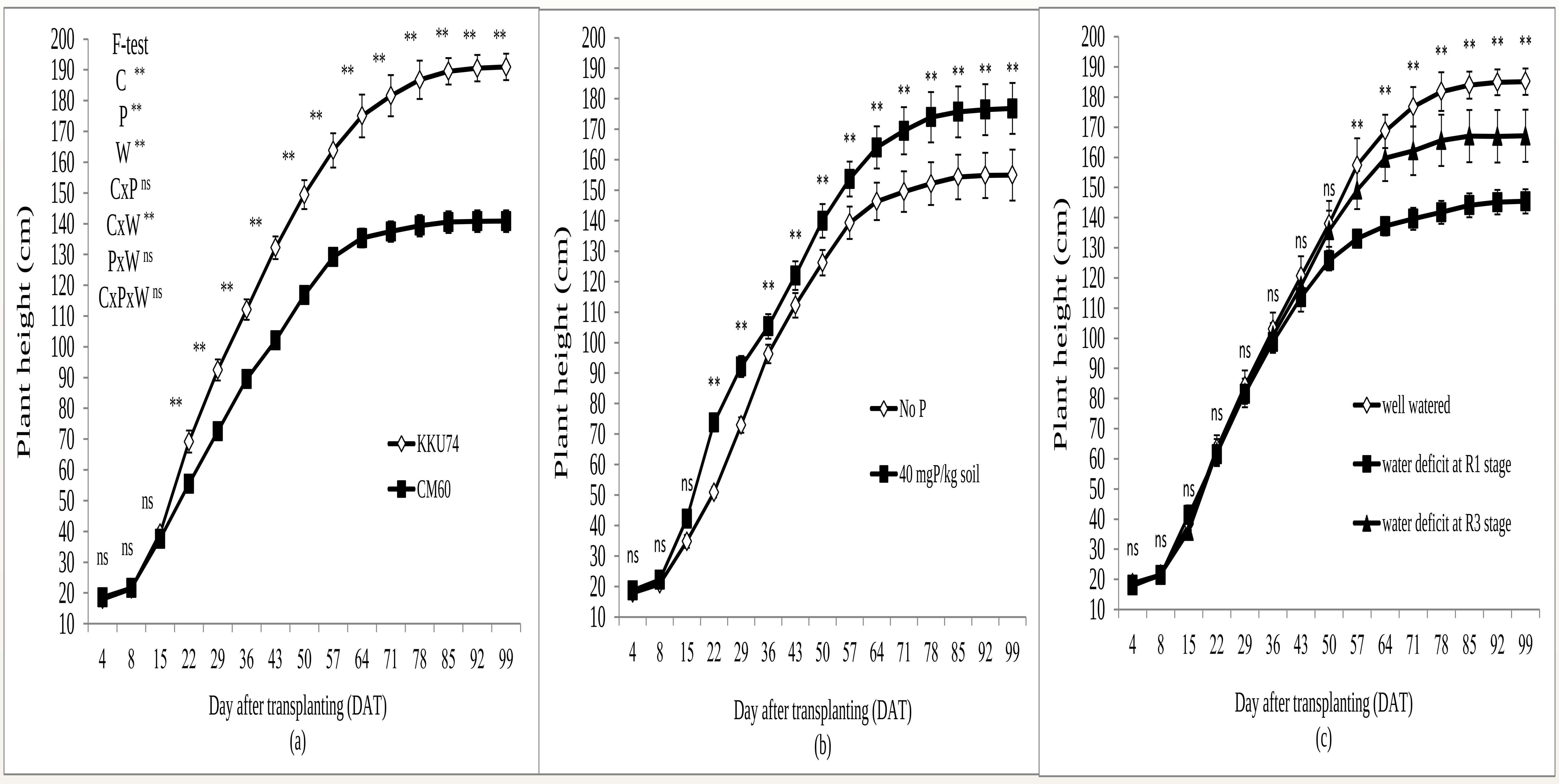

Figure 3. Plant height of two soybean cultivars grown in P-deficient soil under three watering regimes. Left: comparison of cultivars; middle: comparison of P treatments; right: comparison of watering regimes

STOMATAL RESISTANCE

Stomatal resistance was increased by P application (Fig. 4).

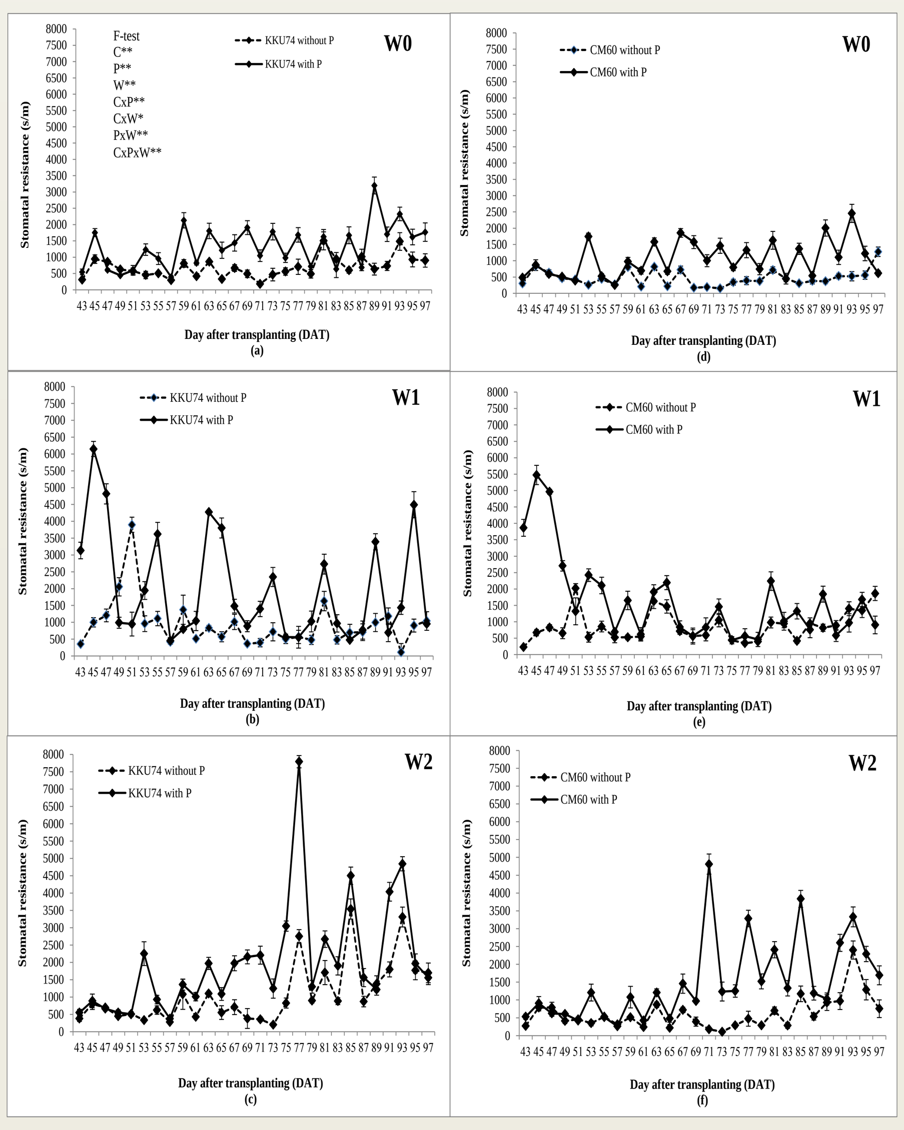

Figure 4. Stomatal resistance of two soybean cultivars grown under two P application rates and three watering regimes. The ordinate shows stomatal resistance in units of s/m. The abscissa shows days after transplanting (DAT).

Top left: KKU74 with and without P, control (W0)
Top right: CM60 with and without P, W0
Middle left: KKU74 with and without P, W1 (drought at the R1 stage)
Middle right: CM60 with and without P, W1
Lower left: KKU74 with and without P, W2 (drought at the R2 stage)
Lower right: CM60 with and without P, W2.

NUTRIENT UPTAKE

<u>Shoots</u>

Soybean cultivars differed in K, Mg, S, and Fe uptake, but did not differ in N, P, Ca, Cu, Mn, Zn, and Cd uptake. KKU74 had a higher K, Mg, S, and Fe uptake than CM60. Phosphorus application increased N, P, K, Ca, Mg, S, Fe, Mn, Zn, and Cd uptake. Copper uptake decreased when soybeans received P fertilizer. Plants grown with water deficit at the R1 stage had lower N, P, K, Ca, Mg, S, Cu, Fe, Mn, Zn, and Cd uptake compared to plants grown under the other treatments.

<u>Roots</u>

Soybean cultivars differed in N and Mg uptake by the roots. KKU74 had a higher N and Mg uptake than CM60. Phosphorus application increased N, P, K, Ca, Mg, S, Fe, Mn, Zn, and Cd uptake. Phosphorus application decreased Cu uptake. Water deficit decreased N, P, K, Ca, Mg, S, Cu, Fe, Mn, Zn, and Cd uptake. Roots grown with water deficit at the R1 stage had the lowest N, P, K, Ca, Mg, S, Cu, Fe, Mn, Zn, and Cd uptake.

CONCLUSION

Phosphorus application increased plant height, stomatal resistance, water use efficiency, nutrient uptake, and shoot and root dry weights of both cultivars. Under drought stress and with P fertilization, KKU74 had a higher plant height, stomatal resistance, water use efficiency, nutrient uptake, and shoot and root dry weights than CM60. These results indicated that KKU74 is better adapted to drought than CM60. Both water deficit treatments reduced plant height, water use efficiency, nutrient uptake, and shoot and root dry weights of both cultivars. Water deficit at the R1 stage resulted in the greatest reduction in plant height, water use efficiency, nutrient uptake, and shoot and root dry weights compared to the well-watered control. Because the cultivars differed in water use efficiency and nutrient uptake, the results indicated that soybeans might be bred for high water use efficiency and nutrient uptake under drought stress.

REFERENCE

Jaidee, R., M.B. Kirkham, K.A. Williams, N.O. Nelson, and A. Polthanee. Water use efficiency and nutrient uptake of soybean grown in P-deficient soil under water deficit. Australian Journal of Crop Science (In review).

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