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Response of New Soybean Accessions to Water Stress During Reproductive Phase

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ABSTRACT

Two cultivars and eight newly developed Kasetsart University soybean accessions were planted at the similar experiments conducted at Chiang Mai and Kamphang Saen in dry season, 1989. The objectives was to study the effect of reproductive water stress on growth and yield of soybeans. Split plot design with three replications was used in this study. The main plots composed of four water stress treatments i.e. control, early, mid, and late reproductive water deficit, while sub-plots composed of ten soybean varieties.

It was found that water deficit lowered the yield and dry matter production of soybeans. Number of pods per plant and seed size were affected by reproductive stress while the number of seeds per pod was not affected. Accessions KUSL 20004, KUSL 20010 and Doi Kham produced the top three highest yields and seemed to be least affected by water deficit treatments.

INTRODUCTION

Water stress during the reproductive growth especially during the seed filling period in soybean has been shown greater impact on seed yield than those at the vegetative stage (Doss, *et. al,* 1974 ; Shaw and Laing, 1966 ; Sionit and Kramer, 1977). One effect of water deficit during late reproductive stage is an acceleration of leaf drop and an early end to seed filling even after a period of apparent recovery (Sionit and Kramer, 1977). The abbreviation of the seed filling period may have a greater impact on yield than the direct effect of stress, such as reduced rate of photosynthesis.

Under field conditions, the yield components, associated with stress-induced reduction of yield, shifts from number of seeds and pods during flowering and early pod-filling stages towards size of seed for a water deficit during late seed filling (Shaw and Laing, 1966). Although, some yield loss results, the abortion of pods and seeds associated with water deficits during flowering and early pod development may minimize the effects of the stress by lowering reproductive demand or critical assimilate reserves. With decreasing ability of the plants to adjust reproductive load through pod and seed abortion, continuing high demand for assimilates may exhaust the reserves of carbon and nitrogen in leaves and stems, irreversibly reducing carbon and nitrogen assimilation capacity and abbreviating the seed-filling period.

Whether soybean are grown in the rainy or dry season in Thailand, they are most probably subjected to water stress. If farmers plant soybeans in the middle of the rainy season, water stress during reproductive stage may occur if rainfall ceased early in October. Likewise, soybeans which were planted in the dry season after rice under irrigation may also be subjected to water stress during the

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seed filling period due to an inadequate irrigation in late March and early April. The yield reduction of soybean in the northern provinces which was reported in 1988 in Thailand occurred due to inadequate amount of irrigation supply at mid pod filling stage.

To minimize the problem of reproductive water deficit, it is important to plant soybean varieties which not only produce high seed yield but also have some degree of water stress resistance or tolerance during the reproductive stage. The response of newly developed soybean accessions to periodic water deficit will give valuable informations on how new soybean varieties should be released. This work should also lead into the development of appropriate agronomic management practices for soybean which minimize yield loss due to water deficits during the reproductive phase.

This study was conducted in order to evaluate the response of Kasetsart University newly developed soybean accessions to periodic water deficit during the reproductive growth with special emphasis on the effect of water stress to yield, yield components and total plant dry matter production.

MATERIALS AND METHODS

Eight soybean accessions developed by Kasetsart University, breeding program and two other cultivars were used in this study. They were planted at Kamphang Saen Campus of Kasetsart University, Nakhon Pathom Province, and Chiang Mai Field Crop Research Center, Chiang Mai Province. The following was the list of varieties used in this study.

Accession	KUSL 20004
Accession	KUSL 20010
Accession	KUSL 20014
Accession	KUSL 20017
Accession	KUSL 20018
Accession	KUSL 20043
Accession	KUSL 20050
Accession	KUSL 20056
Cultivar	DOI KHAM
Cultivar	NAKORNSAWAN 1

The statistical design of the experiment was a split plot with three replications. Main plots were four water deficit regimes and sub plots were the ten soybean genotypes. Experiment were conducted at Chiang Mai and Kamphang Saen on 11 January and 17 January, 1989 respectively. The detail of water stress treatments imposed on soybean was shown in Table 1.

Table 1 Water stress treatments imposed to soybeans at Chiang Mai and Kamphang Saen, dry season 1989.

Treatment	Kamphang Saen*	Chiang Mai*
T_1, Control	irrigation of weekly interval	irrigation at weekly interval
T_2, Early reproductive deficit	no irrigation during 35-56 DAE	no irrigation between 35-56 DAE
T_3, Mid reproductive deficit	no irrigation during 56-77 DAE	no irrigation between 49-70 DAE
T_4, Late reproductive deficit	no irrigation during 77-98 DAE	no irrigation between 63-84 DAE

* DAE = Days after emergence

Each variety of soybean was planted in a four row plot in well prepared seed beds done throughly ploughed and harrowed the land twice for the benefit of controlling weeds. Nitrogen fertilizer at the rate of 20 kg N/rai was given in the form of $(NH_4)_2SO_4$ by broadcasting between ploughing. The land was ridged up to 20 cm high by mechanical ridger and spaced at 50 cm apart. Three to five soybean seeds were planted in the middle of the ridge at the distance between hill of 25 cm. Prior to planting, seeds were inoculated with *Rhizobium japonicum* by mixing seeds with the inoculum throughly. Seedlings were thinned to one plant per hill after emergence.

Soil samples were taken from each of the main plots at 35, 56, 77 and 98 days after emergence (DAE) at Kamphang Saen and 35, 49, 63 and 77 DAE at Chiang Mai. At every sampling date except at 35 DAE, four soil samples were taken at 25, 50, 75 and 100 cm depth from every main plots before and after irrigation. Soil moisture determination were taken on the basis of oven dry weight. At maturity, ten plants of soybean in the second row of each plot were cut at ground level for yield, yield components and total dry weight determination.

RESULTS AND DISCUSSION

1. Soil moisture determination

Tables 2 and 3 showed the percentage of soil moisture (dry weight basis) at Kamphang Saen and Chiang Mai in various moisture stress treatments imposed to ten soybean cultivars planted in dry season of 1989. It should be pointed out that there were slight different in water stress regimes imposed to the experiments at Kamphang Saen and Chiang Mai. The period of stress between T_2 and T_3 and T_4 at Chiang Mai overlapped each other for one week. At Kamphang Saen T_2, T_3 and T_4 treatments were sequentially subjected to soybean. However, moisture content of soil during the stress period was particularly lower than the control in both Chiang Mai and Kamphang Sean. Stress at late reproductive stage (T_4) for both Kamphang Saen and Chiang Mai did not affected soybean cultivar Nakhon Sawan 1 since it already reached maturity.

2. Yield of soybean

Grain yield of soybean genstypes planted at Chiang Mai and Kamphang Saen under four water deficit regimes were shown in Table 4. The average yield of soybean varieties across locations across water stress treatments showed that accession KUSL 20010, KUSL 20004 and cultivar Doi Kham ranked first to third respectively. Cultivar Doi Kham gave the highest yield in all water stress treatments (T_2 - T_4) at Chiang Mai ($P < 0.01$), while accession KUSL 20056 gave the highest yield in T_2 at Kamphang Saen ($P < 0.01$). Accession KUSL 20010 gave the highest yield in both T_2 and T_4 treatments at Kamphang Saen as well. In the control, accession KUSL 20004 gave the highest yield of 410.3 kg/rai at Kamphang Saen while KUSL 20010 gave the highest yield of 397.1 kg/rai at Chiang Mai ($P < 0.01$).

The average yield of ten soybean genotypes planted under normal irrigation regime was much higher than the stress treatments at both locations ($P < 0.01$). Among ten genotypes tested, accessions KUSL 20004, KUSL 20010 and Doi Kham gave considerably high yield under different water deficit regimes.

Table 2 Percentage of soil moisture (dry weight basis) at Kamphang Saen Campus, Kasetsart University in various moisture deficit treatments imposed on ten soybean cultivars planted in the dry season of 1989.

Soil depth (cm) \ Days of sampling (DAP*)	35	56		77		98	
	Control (T_1)	Control (T_1)	Stress between 35-56 days (T_2)	Control (T_1)	Stress between 56-77 days (T_3)	Control (T_1)	Stress between 77-98 days (T_4)
0 - 25	14.82	14.01	9.88	16.97	13.62	15.31	12.29
26 - 50	12.48	12.54	10.64	20.69	19.97	18.19	17.56
51 - 75	13.67	13.95	12.55	24.64	25.18	24.30	23.90
76 - 100	19.71	18.73	12.30	29.70	25.15	28.27	24.94
0 - 50	13.65	13.28	10.27	18.83	16.80	16.75	14.92
0 - 100	15.17	14.81	11.34	23.00	20.98	21.52	19.67

* DAP = Days after planting

Table 3 Percentage of soil moisture (dry weight basis) at Chiang Mai Field Crop Research Center from various moisture deficit treatments imposed on ten soybean cultivars planted in the dry season of 1989.

Soil depth (cm) \ Days of sampling (DAP*)	35	49		63		77	
	Control (T_1)	Control (T_1)	Stress between 35-56 days (T_2)	Control (T_1)	Stress between 49-70 days (T_3)	Control (T_1)	Stress between 63-84 days (T_4)
0 - 25	15.72	14.60	11.00	12.19	8.07	12.19	11.50
26 - 50	14.51	14.54	13.43	13.93	10.08	13.93	11.92
51 - 75	15.02	15.46	14.83	12.54	12.35	12.54	12.53
76 - 100	13.89	16.44	15.44	13.02	11.94	13.02	14.97
0 - 50	15.11	14.57	13.71	13.06	10.42	13.06	11.71
0 - 100	14.78	15.34	14.42	12.92	11.28	12.92	12.73

* DAP = Days after planting

Table 4 Grain yield (kg/rai) of ten genotypes of soybeans planted under different reproductive water deficit at Chiang Mai and Kamphang Saen in dry season, 1989.

Treatments / Cultivars and accessions	Treatment 1		Treatment 2		Treatment 3		Treatment 4		Variety
	CM	KPS	CM	KPS	CM	KPS	CM	KPS	Mean
KUSL 20004	336.4	410.3	250.7	372.7	243.9	276.0	271.5	272.4	304.3
KUSL 20010	397.1	353.1	276.0	344.5	284.5	293.1	299.5	329.2	322.2
KUSL 20014	299.3	393.7	276.2	288.3	302.2	273.1	299.3	279.5	301.5
KUSL 20017	253.6	369.5	198.2	359.1	242.7	150.7	232.4	230.7	254.7
KUSL 20018	309.6	322.1	216.7	302.0	252.6	212.1	276.2	256.0	268.4
KUSL 20043	286.8	368.6	191.5	344.6	242.1	106.7	221.1	281.3	255.4
KUSL 20050	315.7	333.6	217.0	348.8	241.2	240.9	255.7	287.1	280.0
KUSL 20056	391.5	379.3	233.4	376.7	237.5	280.2	258.0	253.4	301.3
Doi Kham	377.9	348.5	283.6	332.4	313.5	223.5	328.5	238.5	305.8
Nakornsawan 1	147.3	147.9	99.8	138.1	117.8	120.6	149.6	147.1	133.5
Mean for treatment within location	311.5	342.7	224.3	320.7	247.8	217.7	259.1	257.5	272.7
Mean for treatment across location	327.1		272.5		232.8		258.4		

$L.S.D._{0.05}$ KPS water stress 53.10 cultivar 39.62 C.V.(%) 16.94
$L.S.D._{0.05}$ CM water stress 30.96 cultivar 32.68 C.V.(%) 15.40

3. Yield components

Table 5, 6 and 7 showed the effect of water deficit at different period on pod production, number of seeds per pod and seed size of ten soybean varieties planted at Chiang-Mai and Kamphang Saen. It was found that the mean number of pods per plant in the control treatment was higher than those subjected to different water stress regimes at Chiang Mai ($P < 0.01$) but not at Kamphang Saen. Most of the cultivars and accessions which gave higher yield under stress condition were also produced more pods per plant. In addition, accession KUSL 20050 produced considerably high number of pod per plant in the early reproductive water deficit (T_2). Similarly, KUSL 20043 also produced more pods per plant in the T_2 and T_3 treatments.

The number of seeds per pod of ten soybean genotypes did not evidently affected by water stress (Table 6). It was observed that soybeans planted at Chiang Mai produced slightly lower number of seeds per pod than those planted at Kamphang Saen. The water stress treatments were not as critical as those imposed on soybean by Cure *et al* (1983) due to shallow ground water level at Chiang Mai. In addition, occurrance of 1 - 2 days of rainfall in March at Kamphang Saen would confound the stress conditions ; therefore, the water deficit treatment used may not be severe enough to affect the number of seeds per pod as found by Cure *et al* (1983).

Table 5 Number of pod per plant of ten varieties of soybeans planted under different reproductive water deficit at Chiang Mai and Kamphang Saen in dry season, 1989.

Treatments / Cultivars and accessions	Treatment 1		Treatment 2		Treatment 3		Treatment 4		Variety
	CM	KPS	CM	KPS	CM	KPS	CM	KPS	Mean
KUSL 20004	65.4	81.7	49.8	83.6	52.4	63.8	58.1	60.7	64.5
KUSL 20010	77.7	70.7	58.9	76.3	54.1	64.7	60.1	71.5	66.8
KUSL 20014	65.1	71.9	57.5	58.3	51.4	57.3	51.8	57.3	58.9
KUSL 20017	61.7	84.2	58.9	77.3	50.8	39.2	58.1	64.8	61.9
KUSL 20018	73.0	59.9	48.3	61.6	50.8	47.7	58.2	57.8	57.2
KUSL 20043	72.8	72.1	55.9	87.5	50.9	42.6	59.2	83.3	65.6
KUSL 40050	76.9	73.5	62.4	79.3	52.2	63.3	65.2	66.6	67.5
KUSL 20056	75.8	71	52.6	83.7	46.7	67.5	56.9	55.3	63.7
Doi Kham	79.1	82.4	66.8	72.7	76.8	79.7	76.4	61.1	74.4
Nakornsawan 1	26.5	26.2	19.1	26.1	24.4	24.7	28.2	33	26.1
Mean for treatment within location	67.4	69.4	53	70.7	51.1	55.1	57.2	61.1	60.7
Mean for treatment across location	68.4		61.9		53.1		59.2		

$L.S.D._{0.05}$ KPS water stress not significant cultivar 7.66 C.V.(%) = 14.71

$L.S.D._{0.05}$ CM water stress 3.82 cultivar 5.31 C.V.(%) = 11.41

Table 6 Number of seeds per pod of ten varieties of soybeans planted under different reproductive water deficit at Chiang Mai and Kamphang Saen in dry season, 1989.

Treatments / Cultivars and accessions	Treatment 1		Treatment 2		Treatment 3		Treatment 4		Variety
	CM	KPS	CM	KPS	CM	KPS	CM	KPS	Mean
KUSL 20004	2.29	2.5	2.42	2.3	2.52	2.6	2.13	2.6	2.42
KUSL 20010	2.07	2.2	2.06	2.7	2.15	2.4	2.16	2.5	2.28
KUSL 20014	2.02	2.1	2.23	2.5	2.1	2.7	2.22	2.6	2.31
KUSL 20017	1.96	2.5	2.05	2.6	2.29	2.3	2.12	2.4	2.28
KUSL 20018	1.83	3.0	2.03	2.6	2.08	2.4	1.99	2.4	2.29
KUSL 20043	1.95	2.3	1.85	2.5	2.27	2.4	1.93	2.3	2.19
KUSL 20050	2.04	2.4	1.96	2.4	2.27	2.4	1.98	2.5	2.24
KUSL 20056	2.27	2.7	2.07	2.3	2.29	2.3	2.14	2.6	2.33
Doi Kham	2.18	2.5	2.00	2.4	1.83	2.5	1.87	2.2	2.19
Nakornsawan 1	1.87	2.2	2.02	2.2	1.81	2.2	1.96	2.1	2.05
Mean for treatment within location	2.05	2.44	2.07	2.4	2.16	2.4	2.05	2.4	2.26
Mean for treatment across location	2.24		2.23		2.28		2.22		

$L.S.D._{0.05}$ KPS water stress not significant cultivar 2.14 C.V.(%) 10.82
$L.S.D._{0.05}$ CM water stress not significant cultivar 1.96 C.V.(%) 11.60

Table 7 Seed size (g/100 seeds) of ten varieties of soybeans planted under different reproductive water deficit at Chiang Mai and Kamphang Saen in dry season, 1989.

Treatments / Cultivars and accessions	Treatment 1		Treatment 2		Treatment 3		Treatment 4		Variety
	CM	KPS	CM	KPS	CM	KPS	CM	KPS	Mean
KUSL 20004	14.07	16.4	13.07	18.0	12.36	16.1	13.72	14.9	14.83
KUSL 20010	15.42	17.0	14.30	16.8	15.49	15.5	14.54	15.6	15.58
KUSL 20014	14.2	16.5	13.44	17.3	17.38	16.0	16.69	15.5	15.88
KUSL 20017	13.14	16.31	10.44	16.6	13.02	11.2	11.94	13.8	13.31
KUSL 20018	14.60	16.2	13.87	17.8	14.91	15.3	14.96	14.7	15.30
KUSL 20043	12.62	16.6	11.41	16.4	13.10	11.0	12.14	14.9	13.52
KUSL 20050	12.45	15.1	10.97	16.5	12.71	13.6	12.38	15.5	13.65
KUSL 20056	14.34	16.8	13.55	17.3	13.99	14.9	13.25	14.7	14.86
Doi Kham	13.79	16.5	13.46	15.9	13.99	14.8	14.52	13.1	14.51
Nakornsawan 1	18.53	19.9	16.29	19.0	16.47	19.7	16.9	20.5	18.42
Mean for treatment within location	14.32	16.7	13.08	17.2	14.34	14.8	14.10	15.3	14.98
Mean for treatment across location	15.52		15.12		14.58		14.71		

$L.S.D._{0.05}$ KPS water stress 1.44 cultivar 0.82 C.V.(%) 6.29

$L.S.D._{0.05}$ CM water stress 0.72 cultivar 1.45 C.V.(%) 12.76

Table 8 Total plant weight (g/plant) of ten varieties of soybeans planted under different reproductive water deficit at Chiang Mai and Kamphang Saen in dry season, 1989.

Treatments / Cultivars and accessions	Treatment 1		Treatment 2		Treatment 3		Treatment 4		Variety
	CM	KPS	CM	KPS	CM	KPS	CM	KPS	Mean
KUSL 20004	37.84	41.4	28.60	44.1	30.31	33.2	30.33	30.2	34.50
KUSL 20010	44.19	38.6	34.37	38.1	33.91	33.7	33.34	37.0	36.65
KUSL 20014	34.11	42.2	31.52	32.5	31.48	30.9	33.71	31.7	33.52
KUSL 20017	31.18	43.3	29.88	38.7	31.51	18.5	33.00	29.1	31.90
KUSL 20018	42.75	32.0	33.13	31.6	29.62	24.5	33.43	27.5	31.82
KUSL 20043	36.62	41.0	25.59	43.6	30.53	17.6	29.44	36.3	32.59
KUSL 20050	38.30	36.3	24.46	37.9	28.84	29.9	31.96	32.6	32.53
KUSL 20056	44.35	41.8	27.86	36.3	26.74	32.6	30.54	28.2	33.55
Doi Kham	44.41	40.7	34.03	35.6	38.30	31.7	39.58	27.9	36.53
Nakornsawan 1	17.95	16.0	12.40	14.5	14.26	13.8	17.73	18.1	15.60
Mean for treatment within location	37.17	37.3	28.18	35.3	29.55	26.6	31.31	29.8	31.92
Mean for treatment across location	37.23		31.74		28.07		30.55		

$L.S.D._{0.05}$ KPS water stress 6.46 cultivar 3.83 C.V.(%) 14.57

$L.S.D._{0.05}$ CM water stress 2.45 cultivar 3.32 C.V.(%) 12.47

Seed size of soybean planted at Kamphang Saen was reduced by water stress particularly in T_3 and T_4 treatments than those planted at Chiang Mai (Table 7). This may due to the shallow ground water at Chiang Mai. Although the plot at Kamphang Saen received unexpected rainfall for 1 - 2 days (0.7 mm) in early March, however, climate was extremely dry and hot in mid March and April. With the exception of cultivar Nakhon Sawan 1, other soybean genotypes did not showed great variation in seed size. Soybean planted at Chiang Mai produced smaller seed size in comparision to those planted at Kamphang Saen particularly in the control (T_1) and early reproductive deficit (T_2).

4. Total plant weight

Total plant weight of soybean varieties planted at Chiang Mai and Kamphang Sean in the four water deficit regimes was shown in Table 8. Total plant weight of soybean were similar to grain yield in term of varietal response to water deficit during the reproductive growth. Accessions KUSL 20004, 20010 and cultivar Doi Kham were the three highest dry matter production. Soybeans planted in the plots receiving water deficit treatments produced lower total plant weight than the control in both locations. The average total dry matter yield of ten soybean genotypes planted at Chiang Mai and Kamphang Saen were comparable.

CONCLUSION

The result of this experiment can be summarized as followed : (1) water deficits imposed on soybean during the reproductive phase would significantly lower the yield and total dry weight of soybean plants. (2) among the yield components, the number of pods per plant and seed size were affected by water deficit while the number of seed per pod was not significantly affected in this study. (3) cultivar Doi Kham, accessions KUSL 20004 and KUSL 20010 gave considerable high seed yield and total dry matter among genotype tested in most of the water deficit treatments and seemed to be less affected by water deficit than other soybean lines.

Although, the level of water deficit imposed in this study may not be as critical as previously reported (Cure *et al* 1983 ; Doss, *et al,* 1974), and not all yield components of soybean were affected by water deficits as those reported previously. However, the field conditions in which these experiments were conducted represented the soybean growing areas in dry season in Thailand. Since water stress is one of the important limiting factors for soybean, therefore the need to minimize water deficit through introduction of drought resistant cultivars coupling with better crop management would be essential to achieve successful soybean production.

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