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Variety and Cultivation-practice Influences on the Growth Characteristics and Yield of Maize (*Zea mays* L.) under Drought Stress at Flowering

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Abstract

In northeast Thailand, maize (*Zea mays* L.) is mainly grown under rainfed conditions. In this region, frequent dry spells are often the cause of periodic drought-stress that leads to decreased yields, especially during the critical growth stages. The objective of the study was to identify and assess variety and cultivation-practice effects on the growth and yield of maize under temporary drought stress induced during the flowering stage. Under controlled soil-moisture conditions, three varieties (*Suwan5* - open-pollinating; *Big717* and *Big949* - single-cross hybrids) and five cultivation practices (conventional (CT); mungbean (*Vigna radiata* (L.) Wilzek) residue (Mn); spineless mimosa (*Mimosa invisa*) live mulch (Mi); manure (Ma); and plastic mulch (Pl) were studied for two cropping seasons.

There were significant variety differences, apparently independent of the cultivation practices. The two hybrid varieties produced significantly higher grain yields than the open-pollinating variety, i.e., *Big717* > *Big949* > *Suwan5*. The effects of cultivation practices were less prominent, with the exception of *Suwan5*, for which Mn, Mi, and Ma significantly reduced grain yields compared to CT and Pl. *Big717* showed no significant differences between the treatments; *Big949* showed significant treatment response only for the second crop, particularly for the Ma treatment. Overall, the highest average yields were produced by Pl; the lowest by Ma. However, there were no significant differences for the total aboveground biomass between cultivation practices, but between varieties -i.e., *Suwan5* and the two hybrids. The two hybrids had clearly higher harvest indexes (HI) than the open pollinating variety. For *Suwan5* and *Big949* HI was consistently lowest with the Ma treatment. The general trend of the tasseling-silking interval (TSI) was *Big949* > *Suwan5* > *Big717*. For *Big717*, TSI was not affected by any cultivation practices. For the other two varieties, Ma showed longest TSI. *Suwan5* grew more vigorously than the other varieties at the early vegetative stage. Within the varieties, the tallest plants were observed with Ma.

The effects of cultivation practices on the grain yield were less prominent than the variety effects; in some cases the practices, particularly Ma, even had a negative effect on the yield. Therefore, variety selection is still a potential management tool that can effectively control the effects of drought stress on the plants. It is however highly recommended

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that further studies should investigate plant responses for drought-stress periods during other growth stages and with different degrees of drought stress. On-farm trials under uncontrolled drought-stress conditions should be also carried out.

Keywords: cultivation practice, drought stress, maize, Thailand, Zea mays L.

1 Introduction

In the rainfed areas of northeast Thailand, maize is an important -often dominating-crop (Manupeerapan and Grudloyma, 2001). Erratic rainfall is common in this part of the country and dry spells often lead to periodic drought stress. These drought-stress periods frequently cause a significant decrease in the yields, particularly if they occur during the critical flowering stage (Doorenbos and Kassam, 1979; Musick and Dusek, 1980; NeSmith and Ritchie, 1992; Çakir, 2004). In the region, maize is usually grown continuously -sometimes twice a year-, but often also in rotation with mungbean (*Vigna radiata* (L.) Wilzek). Most of the varieties grown are commercial hybrids; few farmers use open-pollinating varieties. The dominating cultivation and crop-husbandry practices are conventional, with disk-ploughing, the application of pre-emergence herbicides, two mineral fertilizer applications and harvesting by hand (Cho, 2003). Crop residue is commonly burnt before the following cultivation cycle, particularly before the second growing season. Recently, some farmers began to apply cattle manure. Spineless mimosa (*Mimosa invisa*) has been introduced as live mulch for nitrogen fixation (Chotechaungmanirat, 1997). Generally, the maize-production system is well established and accepted by the farmers. However, yield losses due to unpredictable dry spells during the growing period remain a crucial problem that has not been addressed successfully in the area. As there are no significant irrigation resources in the region, solutions need to be based on variety selection, and soil and crop-management practices. The objective of the study was to identify and assess variety and cultivation-practice effects on the growth and yield of maize under temporary drought stress induced during the flowering stage.

2 Materials and Methods

The study was conducted in 2003 (first crop) and 2004 (second crop) at the Agricultural Systems Experimental Farm of the Asian Institute of Technology (AIT), about 30 km north of Bangkok.

The maize plants were grown in cylindrical plastic containers (55 cm diameter; 85 cm high) filled with soil to a depth of 75 cm (about 178 liters). The soil used for the experiment was a clay loam (27% sand, 29% silt, 44% clay) with pH 6.6 and with 2.03% organic matter. In each container, 2 plants were grown. For the monitoring of soil moisture, gypsum resistance blocks were buried at depths of 15, 30 and 60 cm. Since the soil moisture was controlled in this experiment, the containers were housed in a translucent rain shelter to prevent the plants from receiving natural rainfall. The initial soil-water holding capacity was 40% at field capacity and 10% at wilting point. Initially, all treatments were watered regularly and kept at soil-moisture contents between field capacity and 60% of the available soil moisture. Drought stress was introduced at the flowering stage. For this, water supply was suspended for 15 days until the soil moisture content reached very closely to the wilting point. After that, the plants were watered as usual.

The varieties tested were *Suwan5*, an open-pollinating variety, and two single-cross hybrids, *Big717* and *Big949*. Fertilizer was applied at super-optimum rates to eliminate the influence of nutrient limitation to crop development. Five cultivation practices were evaluated, i.e., (i) conventional practices - no residues incorporated (CT); (ii) mungbean (*Vigna radiata* (L.) Wilzek) residue incorporated as practiced in a mungbean - maize rotation at the rate of 4.50 t ha^{-1} (Mn); (iii) spineless mimosa (*Mimosa invisa*) live mulch intercropped and incorporated at the rate of 6.25 t ha^{-1} (Mi); (iv) cattle manure incorporated at a rate of 20 t ha^{-1} (Ma); and (v) mulching with commercial plastic sheeting as a control treatment for the best soil-moisture conservation (Pl).

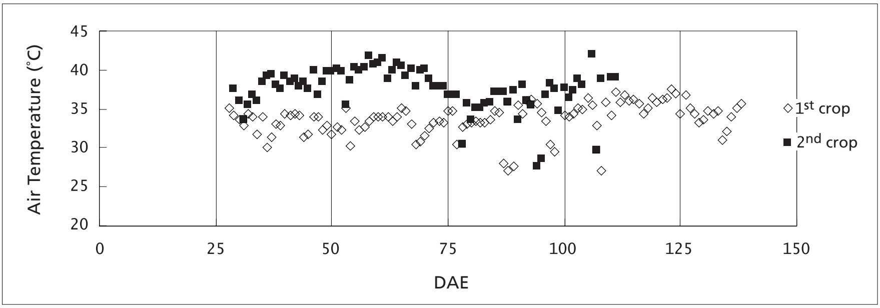
Soil moisture was monitored daily at three depths (15, 30 and 60 cm). Plant growth and development stages of each plant were recorded. At harvest, aboveground biomass of all plant components was measured. Basic climatic data i.e. air temperature and relative humidity was recorded daily. Plant height was measured at 30, 45 and 70 days after emergence (DAE).

The experiments were arranged as a randomized complete block design (RCBD), with five replications. One-way statistical analysis of variance was performed to identify the effects of treatments on biomass, grain yield, plant height and tasseling-silking interval (TSI). The least significant difference test (LSD) at $P < 0.05$ was used to indicate the differences between the treatments.

3 Results and Discussion

Overall, grain and biomass yields of the second crop were significantly lower than the fist crop, most likely due to the high air temperatures during the second growing season (Figure 1). During the second growing season, the maximum air temperatures under the rain shelter were over 40 °C – which is the general high threshold temperature for plants – for a period of 15 days.

Figure 1: Maximum air temperatures under the rain shelter for both crops.



Wickens (1998) depicted that above 40 °C many of the molecules involved in the intermediary pathways (e.g. adenosine triphosphate, ATP), are unstable. This has negative effect on plant development and grain formation. However, the general observed trends and differences between varieties and treatments are similar for both cropping periods.

3.1 Plant Growth and Development

Suwan5 grew more vigorously at the early vegetative stage (measured 30 DAE) than the other varieties (Tables 1 and 2). There were no significant differences between the treatments at the fully-grown stage (measured 70 DAE). Within the varieties, the tallest plants were observed with the Ma treatment.

This could be due to the high mobility of organic phosphorous in the manure which may have led to better phosphorus availability to the plants at the early growth stages. Based on results reported in the literatures and their own studies, Parham *et al.* (2002) hypothesized that the high mobility of manure-P can be attributed to increased microbiological activities induced by manure.

3.1.1 Tasseling and Silking

Tasseling of *Suwan5* (47 DAE) was significantly later than *Big717* and *Big949* (45 DAE). For *Suwan5*, the treatments had no effects on the tasseling date. For both hybrid varieties, early tasseling was only found in the Ma treatment in the first crop.

Due to the high temperatures during the second cropping season -compared to the first crop-, silking was delayed by 3 days for *Suwan5*, 2 days for *Big949*, and 1 day for *Big717*.

3.1.2 Tasseling - Silking Interval (TSI)

Under normal environmental conditions, pollen shedding begins about 2 to 3 days before silking. Drought stress just before or during the flowering period causes a delay in silking that can be measured as an increase in the length of the tasseling silking interval (TSI) (Ribaut *et al.*, 1995). In this study, with water stress introduced at the flowering stage, tassels were produced about 3 to 11 days before silking, depending on the treatments. The general trend of the resulting TSI for both crops was *Big949* > *Suwan5* > *Big717* (Table 3). *Big717* was not affected by any treatment. For the other two varieties and both crops, the Ma treatment had the longest TSI.

3.2 Grain Yield

3.2.1 Variety Response

There were marked variety differences, apparently independent of the cultivation practices (Table 4). For all treatments and both cropping seasons, the two hybrid varieties produced significantly higher yields than the open-pollinating variety, i.e., *Big717* > *Big949* > *Suwan5*. The differences between *Big717* and *Suwan5* were 76% for the first crop and 47% for the second crop.

3.2.2 Cultivation-practice Response

The effects of cultivation practices were less prominent, with the exception of *Suwan5* (Table 4). For *Suwan5*, the Mn, Mi, and Ma treatments significantly reduced grain yields compared to the CT and PI treatments for both crops, with differences of up to 90% (second crop). *Big717* showed no significant differences between the treatments;

Table 1: Plant-height development measured on 30, 45, and 70 DAE for the first crop.

Cultivation practice *	*Height (cm)*									*Practice mean* ‡		
	30 DAE †			*45 DAE* †			*70 DAE* †			*30 DAE*	*45 DAE*	*70 DAE*
	Suwan5	*Big717*	*Big949*	*Suwan5*	*Big717*	*Big949*	*Suwan5*	*Big717*	*Big949*			
CT	125.3 ^{b}	115.4	119.7	187.3	193.5	188.3	222.2	200.7	230.5	120.1 ^{bc}	189.7	217.8
Mn	122.7 ^{b}	110.0	116.4	178.2	183.8	195.0	204.8	203.5	230.0	116.4 ^{bc}	185.7	212.8
Mi	133.1 ^{ab}	124.7	121.5	190.7	197.0	199.3	238.8	211.5	232.0	126.4 ^{ab}	195.7	226.3
Ma	152.5 ^{a}	122.8	139.1	207.2	191.6	202.6	239.0	203.0	240.5	138.1 ^{a}	200.5	227.5
Pl	113.8 ^{b}	112.6	116.8	178.6	184.2	193.8	220.5	197.1	227.5	114.4 ^{c}	185.5	215.0
Variety mean §	129.5 ^{A}	117.1 ^{B}	122.7 ^{AB}	188.4	190.02	195.8	224.4 ^{A}	203.2 ^{B}	232.1 ^{A}			
Statistical analysis ¶												
Practice	0.030	NS	NS	NS	NS	NS	NS	NS	NS	0.001	NS	NS
Variety	-	-	-	-	-	-	-	-	-	0.030	NS	0.000
Block	NS	NS	NS	NS	NS	NS	0.012	NS	NS	NS	NS	0.028
Pract. × Variety	-	-	-	-	-	-	-	-	-	NS	NS	NS

* CT: conventional cultivation practice (removed residues); Mn: mungbean residue incorporated; Mi: spineless mimosa (*Mimosa invisa*) live mulch, intercropped; Ma: cattle manure incorporated; Pl: mulching with commercial plastic sheeting.
Values in †,‡,§ followed by the same letters or with no letters are not significantly different according to LSD test at $P \leq 0.05$; † Mean comparison within varieties in each column, ‡ Mean comparison between practices; § Mean comparison between varieties; ¶ Values show significant levels. NS: non-significant at $P > 0.05$

Table 2: Plant-height development measured on 30, 45, and 70 DAE for the second crop.

Cultivation practice *	*Height (cm)*									*Practice mean* ‡		
	30 DAE †			*45 DAE* †			*70 DAE* †			*30 DAE*	*45 DAE*	*70 DAE*
	Suwan5	*Big717*	*Big949*	*Suwan5*	*Big717*	*Big949*	*Suwan5*	*Big717*	*Big949*			
CT	103.4	94.6	89.7 ^{b}	162.8	161.1	161.5	177.3	157.4	177.9	95.9 ^{ab}	161.8	169.7
Mn	104.5	93.8	88.8 ^{b}	161.4	160.6	163.6	173.6	162.5	183.8	95.7 ^{b}	161.9	173.3
Mi	103.9	101.2	97.5 ^{a}	166.3	165.4	163.5	166.1	167.7	182.4	100.9 ^{a}	165.1	172.1
Ma	107.2	99.7	95.8 ^{ab}	171.3	165.4	163.1	170.4	164.8	173.4	100.9 ^{a}	166.6	169.5
Pl	96.3	90.1	83.4 ^{c}	158.8	155.2	155.0	173.1	152.6	175.4	89.9 ^{c}	156.3	167.0
Variety mean §	103.1 ^{A}	95.9 ^{B}	91.0 ^{C}	164.1	161.5	161.3	171.4 ^{A}	161.0 ^{B}	178.6 ^{A}			
Statistical analysis ¶												
Practice	NS	NS	0.008	NS	NS	NS	NS	NS	NS	0.000	NS	NS
Variety	-	-	-	-	-	-	-	-	-	0.000	NS	0.002
Block	NS	NS	NS	NS	NS	NS	NS	0.035	NS	NS	NS	0.010
Practice × Variety	-	-	-	-	-	-	-	-	-	NS	NS	NS

* CT: conventional cultivation practice (removed residues); Mn: mungbean residue incorporated; Mi: spineless mimosa (*Mimosa invisa*) live mulch, intercropped; Ma: cattle manure incorporated; Pl: mulching with commercial plastic sheeting.
Values in †,‡,§ followed by the same letters or with no letters are not significantly different according to LSD test at $P \leq 0.05$; † Mean comparison within varieties in each column, ‡ Mean comparison between practices; § Mean comparison between varieties; ¶ Values show significant levels. NS: non-significant at $P > 0.05$

Table 3: Tasseling - silking intervals (TSI) of the tested varieties in relation to cultivation practices.

Cultivation practice *	*First crop*				*Second crop* ‡			
	TSI (days) †			*Practice mean* ‡	*TSI (days)* †			*Practice mean* ‡
	Suwan5	*Big717*	*Big949*		*Suwan5*	*Big717*	*Big949*	
CT	4.1 ^{b}	3.8 ^{b}	6.3 ^{bc}	4.7 ^{c}	5.5	5.1	9.8 ^{ab}	6.8 ^{ab}
Mn	5.7 ^{b}	4.7 ^{ab}	6.1 ^{c}	5.5 ^{bc}	8.9	5.1	7.3 ^{bc}	7.1 ^{ab}
Mi	4.3 ^{b}	5.3 ^{a}	7.7 ^{ab}	5.8 ^{b}	9.6	6.4	8.5 ^{abc}	8.2 ^{ab}
Ma	9.7 ^{a}	4.5 ^{ab}	8.8 ^{a}	7.7 ^{a}	9.2	6.1	11.4 ^{a}	8.9 ^{a}
Pl	5.4 ^{b}	3.3 ^{b}	6.3 ^{bc}	5.0 ^{bc}	7.4	6.0	6.5 ^{c}	6.7 ^{b}
Variety mean §	5.8 ^{B}	4.3 ^{C}	7.0 ^{A}		8.1 ^{A}	5.8 ^{B}	8.8 ^{A}	
Statistical analysis ¶								
Practice	0.001	NS	0.004	0.000	NS	NS	0.037	NS
Variety	-	-	-	0.000	-	-	-	0.000
Block	0.033	NS	0.027	NS	NS	NS	NS	NS
Practice × Variety	-	-	-	0.001	-	-	-	NS

* CT: conventional cultivation practice (removed residues); Mn: mungbean residue incorporated; Mi: spineless mimosa (*Mimosa invisa*) live mulch, intercropped; Ma: cattle manure incorporated; Pl: mulching with commercial plastic sheeting.
Values in †,‡,§ followed by the same letters or with no letters are not significantly different according to LSD test at $P \leq 0.05$; † Mean comparison within varieties in each column, ‡ Mean comparison between practices; § Mean comparison between varieties; ¶ Values show significant levels. NS: non-significant at $P > 0.05$

Big949 showed significant treatment response only in the second crop, particularly for the Ma treatment which produced only 10% of PI and 20% of CT. Overall, the highest average yields were produced by PI; the lowest by Ma.

Manure application (i.e., the Ma treatment) is a soil-quality improvement practice recommended by the extension service. Manure has been reported to improve soil properties (SOMMERFELDT and CHANG, 1985) and crop yield (GINTING *et al.*, 1998; PARHAM *et al.*, 2002; SUTTON *et al.*, 1986) especially when combined with fertilizer applications (CHIVENGE *et al.*, 2004). However, Ma showed the overall lowest grain yield, with the exception of *Big717* in the first crop. Ma-treatment plants showed a generally more vigorous growth at the vegetative stage than the others when water was not limited (Tables 1 and 2). Later on, during the induced water-stress period (flowering stage), these more sturdy plants consumed more water than the smaller plants in the other treatments. This may have led to the Ma plants being subjected to more severe water shortage (i.e., drought tress) than the plants in the other treatments and hence producing considerably lower yield.

It can be concluded here that well-grown plants that require larger quantities of water to keep the biomass alive will react more sensitively to drought stress during the flowering stage than plants with smaller biomass at that stage, leading to reduced grain yields.

3.3 Total Aboveground Biomass

For the total aboveground biomass, there were no significant differences between cultivation practices, but between *Suwan5* and the two hybrids (Table 5). Within the varieties, plants tended to produce the same amount. The open pollinating variety, *Suwan5*, gave the lowest total aboveground biomass for all treatments.

3.4 Harvest Index (HI)

The harvest index (HI) – the ratio of grain yield to total aboveground biomass – reflects the efficiency of a plant to translocate assimilated carbohydrates from the vegetative parts to the grains. The two hybrids were clearly more efficient than the open pollinating variety (Table 6), with *Big717* > *Big949* > *Suwan5*. Within-variety differences were only observed with *Suwan5* and *Big949*. For both varieties, HI was consistently lowest with the Ma treatment (manure application). This supports the observations and conclusions made for grain yield (see Table 3). HI was highly correlated with the grain yield in all treatments.

4 Conclusions

The open-pollinating variety *Suwan5* gave the lowest grain yield and the lowest total aboveground biomass. The single hybrid *Big717* produced the overall highest grain yields and the lowest vegetative aboveground biomass. The variety *Big949* produced high biomass, but under drought stress at the flowering stage the high moisture requirements of the plants could not be met and grain filling was reduced leading to low yields.

Within the varieties, the same effect was observed for the Ma treatment. Plants grew faster and produced higher biomass at the flowering stage when moisture stress was

Table 4: Grain yields of the tested varieties in relation to cultivation practices.

Cultivation practice *	First crop				Second crop ‡			
	Grain weight (g/plant) †			Practice mean ‡	Grain weight (g/plant) †			Practice mean ‡
	Suwan5	Big717	Big949		Suwan5	Big717	Big949	
CT	77.1 ^{a}	96.9	99.8 ^{a}	91.3 ^{ab}	21.1 ^{a}	57.1	25.7 ^{b}	34.3 ^{ab}
Mn	62.9 ^{ab}	102.1	90.3 ^{ab}	85.1 ^{bc}	2.9 ^{b}	58.7	35.7 ^{ab}	32.4 ^{ab}
Mi	69.8 ^{a}	107.8	92.7 ^{ab}	89.6 ^{ab}	1.4 ^{b}	57.6	28.2 ^{b}	28.0 ^{b}
Ma	45.1 ^{b}	110.1	83.9 ^{b}	79.7 ^{c}	1.2 ^{b}	39.2	5.2 ^{c}	16.0 ^{c}
Pl	74.3 ^{a}	109.4	97.7 ^{a}	93.8 ^{a}	30.9 ^{a}	50.3	49.0 ^{a}	42.7 ^{a}
Variety mean §	65.5 ^{C}	105.2 ^{A}	92.9 ^{B}		12.2 ^{C}	52.2 ^{A}	27.6 ^{B}	
Statistical analysis ¶								
Practice	0.023	NS	NS	0.012	0.000	NS	0.001	0.002
Variety	-	-	-	0.000	-	-	-	0.000
Block	NS	NS	NS	NS	NS	NS	NS	NS
Practice × Variety	-	-	-	0.015	-	-	-	NS

* CT: conventional cultivation practice (removed residues); Mn: mungbean residue incorporated; Mi: spineless mimosa (*Mimosa invisa*) live mulch, intercropped; Ma: cattle manure incorporated; Pl: mulching with commercial plastic sheeting.
Values in †,‡,§ followed by the same letters or with no letters are not significantly different according to LSD test at $P \leq 0.05$; † Mean comparison within varieties in each column, ‡ Mean comparison between practices; § Mean comparison between varieties; ¶ Values show significant levels. NS: non-significant at $P > 0.05$

Table 5: Total aboveground biomass of the tested varieties in relation to cultivation practices.

Cultivation practice *	First crop				Second crop ‡			
	Total aboveground biomass (g/plant) †			*Practice mean* ‡	*Total aboveground biomass (g/plant)* †			*Practice mean* ‡
	Suwan5	*Big717*	*Big949*		*Suwan5*	*Big717*	*Big949*	
CT	216.9	244.0	238.1	233.0	178.9 ^{a}	189.7	191.5	187.5
Mn	209.3	236.0	247.0	230.7	182.2 ^{a}	203.3	189.4	191.1
Mi	217.4	254.2	235.2	233.6	134.4 ^{c}	191.2	201.7	174.8
Ma	211.3	255.5	254.9	240.6	140.3 ^{bc}	211.9	196.0	183.5
Pl	205.2	253.0	243.9	234.0	170.2 ^{ab}	193.2	204.3	189.2
Variety mean §	210.8 ^{B}	248.5 ^{A}	243.8 ^{A}		161.9 ^{B}	197.8 ^{A}	195.9 ^{A}	
Statistical analysis ¶								
Practice	NS	NS	NS	NS	0.015	NS	NS	NS
Variety	-	-	-	0.000	-	-	-	0.000
Block	NS	NS	NS	NS	NS	NS	NS	NS
Practice × Variety	-	-	-	NS	-	-	-	0.018

* CT: conventional cultivation practice (removed residues); Mn: mungbean residue incorporated; Mi: spineless mimosa (*Mimosa invisa*) live mulch, intercropped; Ma: cattle manure incorporated; Pl: mulching with commercial plastic sheeting.
Values in †,‡,§ followed by the same letters or with no letters are not significantly different according to LSD test at $P \leq 0.05$; † Mean comparison within varieties in each column, ‡ Mean comparison between practices; § Mean comparison between varieties; ¶ Values show significant levels. NS: non-significant at $P > 0.05$

Table 6: Harvest index of the tested varieties in relation to cultivation practices.

Cultivation practice *	First crop				Second crop ‡			
	Harvest index (HI) †			Practice mean ‡	Harvest index (HI) †			Practice mean ‡
	Suwan5	*Big717*	*Big949*		*Suwan5*	*Big717*	*Big949*	
CT	0.32 ^{a}	0.40	0.43 ^{a}	0.38 ^{a}	0.12 ^{b}	0.30	0.13 ^{b}	0.18 ^{ab}
Mn	0.26 ^{ab}	0.44	0.39 ^{a}	0.36 ^{a}	0.02 ^{c}	0.28	0.19 ^{ab}	0.16 ^{b}
Mi	0.31 ^{a}	0.43	0.40 ^{a}	0.38 ^{a}	0.01 ^{c}	0.30	0.14 ^{b}	0.15 ^{b}
Ma	0.20 ^{b}	0.44	0.33 ^{b}	0.32 ^{b}	0.01 ^{c}	0.19	0.03 ^{c}	0.08 ^{c}
Pl	0.36 ^{a}	0.44	0.40 ^{a}	0.40 ^{a}	0.18 ^{a}	0.26	0.24 ^{a}	0.22 ^{a}
Variety mean §	0.29 ^{C}	0.43 ^{A}	0.39 ^{B}		0.07 ^{C}	0.26 ^{A}	0.14 ^{B}	
Statistical analysis ¶								
Practice	0.028	NS	0.025	0.002	0.000	NS	0.000	0.000
Variety	-	-	-	0.000	-	-	-	0.000
Block	NS	NS	NS	NS	NS	NS	NS	NS
Practice × variety	-	-	-	0.024	-	-	-	0.053

* CT: conventional cultivation practice (removed residues); Mn: mungbean residue incorporated; Mi: spineless mimosa (*Mimosa invisa*) live mulch, intercropped; Ma: cattle manure incorporated; Pl: mulching with commercial plastic sheeting.
Values in †,‡,§ followed by the same letters or with no letters are not significantly different according to LSD test at $P \leq 0.05$; † Mean comparison within varieties in each column, ‡ Mean comparison between practices; § Mean comparison between varieties; ¶ Values show significant levels. NS: non-significant at $P > 0.05$

introduced; this led to lower yields due to the higher water requirement, especially with *Suwan5* (both crops) and *Big949* (second crop). Those well-grown plants displayed a significant delay in silking thus increasing the tasseling-silking interval (TSI). These plants therefore had a higher incidence of abortion during the reproductive stage, and hence produced lower grain yields.

The study showed that the effects of cultivation practices on grain yield were less prominent than the variety effects. Moreover, some of the practices, particularly Ma, even had a negative effect on the yield. Therefore, variety selection is still a potential management tool that can effectively control the effects of drought stress on the plants. However, this is the results from the treatments over water stress occurring only during flowering stage and the degree of water stress was high (wilting point). Further studies are therefore highly recommended for the investigation of plant responses to drought-stress periods during other growth stages and with different degrees of drought stress. On-farm trials under uncontrolled drought-stress conditions should be also carried out to confirm the results of the on-station experiment.

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