THE EFFECTS OF WATERLOGGING ON GROWTH DEVELOPMENT AND YIELD OF MUNGBEANS

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Abstract

Experiments were conducted to evaluate the effects of waterlogging on the growth and yield of mungbeans and to identify characters to be used for screening for resistance to waterlogging. It was found that waterlogging reduced plant height, plant dry weight, root dry weight, leaf area, number of leaves, seed yield, pods per plant, seeds per plant and seed size. However, it increased the number of days to flower. Within 2-3 days of waterlogging, primary and secondary roots were damaged and replaced through the development of adventitious roots. Selection of mungbeans for resistance to waterlogging was attempted by using different indices developed in this study. It also was found that the response of mungbeans to waterlogging at different stages of growth was not consistent.

Key words: *Mungbean, black gram, waterlogging.*

In certain areas in Thailand, mungbeans are grown as a sequential crop with rice in the paddy field. Therefore, mungbeans are often affected by waterlogging due to excessive rainfall at certain periods in their growing cycle.

Waterlogging adversely affects crops due to the reduction in uptake of oxygen and certain nutrients from the soil (Sheard and Leyshon 1976; Armstrong 1978; Reid 1977). The accumulation of methane, hydrogen sulfide, etc. causing root damage is a common symptom (Hiron and Wright 1973; Sachs et al. 1980). Lack of nitrogen in certain leguminous species due to poor nitrogen fixation is also found (Minchin and Pate 1975; Minchin and Summerfield 1976).

No study has been reported on the investigation of the effects of waterlogging on growth, development and yield of mungbeans. These studies were designed to evaluate the effects of waterlogging on mungbeans and to identify characters to be used for the selection of waterlogging resistant crops.

Materials and Methods

Five experiments were conducted from 1986 to 1990 as follows:

Exp. 1. The effects of waterlogging on the growth and development of mungbeans.

Pot experiments were made using a split-plot design in which mungbean varieties/lines including Kampaeng Saen 1 (KPS 1), PSU 424-61, U-thong 1 and U-thong 2) were used as the main-plots and the periods of waterlogging (0, 1, 2,..and 9 days) were used as the sub-plots. The same amount of soil was used and 2-3 plants were maintained in all pots. The pots were immersed in a water pond 20 days after planting. Characters observed were plant growth (height, dry weight, leaf area, etc.), seed yield and yield components. One set of treatments was observed immediately after the plants were removed from the water, while others were left for harvest.

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Exp. 2. The associations between yield, yield components with other characters of mungbeans affected by waterlogging.

Fifteen varieties/lines of mungbeans were planted in eight pots each. Four pots were immersed in water 20 days after planting and were taken from the water after 10 days. Two pots were used to observe plant dry weight, plant height, amount of adventitious root and two pots were left for harvest to observe yield and yield components. Correlation analyses were made between different characters and yield and also yield components by using respective differential values which were obtained as follows:

Differential value = $(X_1 - X_2) / X_1$

X_1 = characters measured in control pots.

X_2 = characters measured in plants received waterlogging.

Exp. 3. The screening of mungbeans for resistance to waterlogging.

Sixty four mungbeans and blackgram varieties/lines were screened for resistance to waterlogging. Each variety/line was planted in eight pots and four pots were immersed in water 20 days after planting. These pots were taken from the water after 10 days and observed for certain characters to be used as indices for the screening of the variety/line resistant to waterlogging. Two pots for each variety/line were left to observe the response of plants to waterlogging.

Exp. 4. The effects of long durations of waterlogging on mungbean varieties grown in Thailand.

The purpose of this study was to evaluate the response of mungbean varieties to waterlogging over longer periods than previously observed. Four mungbean varieties including U-thong 1, KPS 1, KPS 2 and PSU 1 were used as the main-plots and waterlogging periods of 0, 4, 8, 12 and 16 days were used as the sub-plots in a split-plot experiment with 4 replications. Characters were observed in a similar manner to that used in previous experiments.

Exp. 5. The effects of waterlogging on mungbeans at different growth stages.

The purpose of this study was to evaluate the effect of waterlogging at different stages of plant growth. The experiment was conducted in a split plot design with four replications. Mungbean variety U-thong 1 was used in this study. Growing stage of 10, 20, 30, 40, 50 and 60 days after planting were the main-plots and periods of waterlogging of 0, 3, 6 and 9 days were the sub-plots.

Results and Discussion

Exp. 1. The effects of waterlogging on the growth and development of mungbeans.

Waterlogging adversely affected many characters of mungbeans. Waterlogging decreased root length, plant height, dry matter production, leaf area, number of nodules but increased days to flower and days to maturity (Table 1). The seed yield and all yield components of all varieties/lines were adversely affected just one day after the crop was exposed to waterlogging. Seed yield, pods per plant and seeds per plant decreased continuously from the first day of waterlogging at the rate of about 8-15% per day. However, the effects of waterlogging seemed to change at the 6th day due to the development of adventitious root.

When the crop was exposed to waterlogging, primary roots and secondary roots were damaged and the development of adventitious roots occurred concurrently within 2-3 days. It seemed that the development of adventitious roots is the only mechanism for resistance of the crop to waterlogging.

In this experiment, a variation index was used to measure the rate of resistance to waterlogging (Table 2). By using this method, it was found that U-thong 2 and KPS 1 were more tolerant to waterlogging than others.

Exp. 2. The associations between yield, yield components with other characters of mungbeans affected by waterlogging.

Correlation coefficients between the different characters with seed yield and yield components are shown in Table 3. These correlation coefficients were calculated using differences between characters of the control pots and those affected by waterlogging and were calculated as percent of controls. The associations between seed yield and yield components with plant height, root dry weight, amount of adventitious roots and days to first flower were significant. This experiment confirms our assumption that resistance to waterlogging depends on the development as well as the amount of adventitious roots.

Exp. 3. The screening of mungbeans for resistance to waterlogging.

Table 1. Effects of waterlogging on characters of mungbean exposed to flooding for 0, 1, 2, 3,....., 9 days.[1]

Character	Days of flooding[2]										lsd
	0	1	2	3	4	5	6	7	8	9	(.05)
Adventitious root (g/plant)	-	-	-	0.01	0.02	0.05	0.10	0.16	0.23	0.34	0.01
Days to flower (days)	34	34	36	40	42	44	46	46	47	47	0.69
Plant height (cm)	38	38	32	32	30	30	34	28	26	24	1.80
Plant dry weight (g/plant)	7.8	7.3	5.7	4.2	3.5	3.4	3.8	2.9	2.4	2.4	0.18
Seed yield (g/plant)	8.5	7.5	5.6	4.5	3.2	2.6	3.1	2.8	2.1	1.6	0.18
100-seed weight (g)	6.7	6.6	6.6	6.6	6.6	6.7	6.7	6.7	6.6	5.7	*ns*
Pods/plant	16	13	12	11	8	7	7	7	5	5	0.77
Seeds/plant	128	113	89	75	51	42	48	43	32	25	2.31

[1] *Average of 4 varieties/lines including U-thong 1, U-thong 2, KPS 1 and PSU 424-61.*
[2] *Mungbeans were immersed in the water at 20 days after planting. The water level was about 3 cm above the ground level.*

Table 2. Variation index of seed yield per plant of four mungbean varieties/lines.[1]

Variety/line	Days of flooding									
	0	1	2	3	4	5	6	7	8	9
U-thong 1	1.55	0.95	0.39	0.43	-0.40	-0.43	-0.23	-0.16	0.58	-0.67
U-thong 2	0.48	0.55	0.45	0.62	0.08	-0.22	-0.31	-0.45	-0.51	-0.65
KPS 1	1.36	0.91	0.61	0.42	-0.30	-0.34	0.15	0.00	-0.31	-0.51
PSU 424-61	1.35	1.15	0.21	-0.10	-0.31	-0.40	-0.39	-0.49	-0.49	-0.55

[1] $\text{Variation Index (VI)} = \frac{\text{Yield at ith day - Average yield}}{\text{Average yield}}$

High or positive VI (yield closes to respective means) indicates resistance to waterlogging.

Table 3. Correlation coefficients (r) between two groups of characters of mungbean. [1]

Character	Seeds/ plant	Seed weight/ plant	Pods/ plant	Pod weight/ plant
Plant height	0.54*	0.53*	0.69	0.58
Plant dry weight	0.26	0.23	0.53	0.30
Adventitious root dry weight	-0.54*	0.49*	-0.62**	-0.52*
Adventitious root score	-0.82**	0.75**	-0.77**	-0.83**
No. of leaves	-0.29	-0.16	-0.38	-0.29
Days to flower	-0.56*	0.49*	0.68**	0.62

[1] *Correlations were calculated between differential characters which were obtained as follows:*

$\text{Differential character} = \frac{\text{Control - Waterlogged}}{\text{Control}}$

, indicate significance at 0.05 and 0.01 level of probability, respectively.*

Mungbean lines could be identified for resistance to waterlogging by many procedures (Table 4). Visual selection may be the best procedure for screening varieties/lines but it must be delayed until harvest. The weight of adventitious root of mungbeans may be the best index for selection for resistance to waterlogging.

It was found in this experiment that mungbean variety PSU-1 is less susceptible to waterlogging than others since the variety was selected under this pressure for a number of years.

Exp. 4. The effects of long duration of waterlogging on mungbean varieties grown in Thailand.

As with the above experiments, most of the characters observed were adversely affected by waterlogging. Yield and yield components of all mungbean varieties are shown in Table 5. All characters were not affected during the period of 0-4 days after planting. On the other hand, seed yield and certain yield components of some varieties significantly increased. This may be due to the development of adventitious roots during which primary roots and lateral roots are still functioning. At the later stages of growth, seed yield and yield components of all entries of mungbeans decreased but those of one variety may be faster than another.

The response of mungbeans to waterlogging in terms of seed yield is shown in Table 6. Seed yield per plant decreased as the period of waterlogging increased. Seed yields and pods per plant of mungbeans were less affected by waterlogging in late growth stages.

Exp. 5. The effects of waterlogging on mungbeans at different growth stages.

The Mungbean variety U-thong 1 responded differently to waterlogging at different stages of growth (Table 6). At 10 days after planting the crop was very susceptible to waterlogging. Regrowth was poor after being taken from the water. A low number of leaves (i.e. leaf area per plant), a low dry weight per plant and a low number of adventitious roots were observed. At 20 days, the crop was highly resistant to waterlogging due to the development of adventitious roots. The response of the crop to waterlogging at 30 days was similar to that at 20 days, but pod setting was very poor. However, at 40 days, waterlogging did not seriously affected plant height and plant dry weight but affectes seed yield. At 50-60 days, mungbean was susceptible to leaf senescence and no adventitious roots development was found at these stages. However, seed yield and yield components were not obviously affected since the pod development occurred before this period.

Conclusion

Enough information was accumulated to show that waterlogging affects the growth, development and seed yield of mungbeans. Adventitious root development was the only means that mungbean employs to counteract waterlogging. These roots will become permanent roots after the waterlogging period since all original roots die. Therefore, adventitious root weights or scores can be the best index for resistance to waterlogging. Mungbean yields are usually affected by waterlogging, but waterlogging for 3-6 days (but not longer) may partly improve yields due to the stimulation of adventitious root development.

Table 4. Variety/line of mungbeans selected for resistance to waterlogging.

Index for selection	Variety/line selected
1. Weight of adventitious root	VC 2764B, VC 1178, VC 2754A, VC 3004A VC 2802A, V2984, U-thong 2, CPI 30757 PSU 1.
2. Differential height	VC 2764B, VC 2754A, VC 2771A, V 2984 CPI 40704, CPI 30757, U-thong 2, KPS 1.
3. Differential days to flower	VC 2755A, VC 2754A, VC 2771A, N 63, D2, U-thong 2.
4. Visual selection	CPI 30757, V 2984, U-thong 2.

Table 5. Yield and yield components of mungbeans received different periods of flooding.

Variety/line	Periods of flooding (days)					
	0	**4**	**8**	**12**	**16**	**Mean**
			Yield (g/plant)			
KPS 1	2.61	2.33	1.76	1.36	0.80	1.77
KPS 2	2.19	2.68	2.05	1.38	1.03	1.86
PSU 1	2.92	3.23	2.77	1.57	1.21	2.34
VC 2755A	2.52	3.38	2.08	1.10	0.89	1.99
U-thong 1	2.47	2.39	1.54	1.39	0.75	1.71
Mean	**2.60**	**2.80**	**1.99**	**1.31**	**0.88**	**1.91**
			Seeds/plant			
KPS1	40	40	30	26	15	30
KPS 2	34	44	35	24	19	31
PSU 1	42	46	47	30	23	36
VC 2755A	37	50	36	22	18	32
U-thong 1	42	40	32	24	16	33
Mean	**40**	**44**	**36**	**26**	**18**	**33**
			100-seed weight (g)			
KPS 1	6.40	5.85	5.78	5.19	5.24	5.69
KPS 2	6.43	6.02	5.83	5.57	5.49	5.88
PSU 1	8.10	7.81	5.81	5.14	5.18	6.41
VC 2755A	6.88	6.63	5.75	4.79	4.52	5.72
U-thong 1	5.81	5.96	4.82	5.03	4.31	5.19
Mean	**6.71**	**6.32**	**5.53**	**5.65**	**4.83**	**5.69**
			Pods/plant			
KPS 1	5.67	5.33	3.42	3.75	2.38	4.15
KPS 2	6.63	5.11	4.67	3.42	2.53	4.42
PSU 1	6.67	6.58	6.08	4.33	3.08	5.35
VC 2755A	6.92	7.43	4.33	2.67	2.92	4.85
U-thong 1	5.25	5.10	4.58	4.33	2.92	4.44
Mean	**5.96**	**5.82**	**4.60**	**3.61**	**2.70**	**4.54**

F-test[1]		Varieties/lines	Periods
	Yield	ns	**
	Seeds/plant	ns	**
	100-seed weight	ns	**
	Pods/plant	*	**

[1] *ns = not significant.*

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Table 6. Yield and yield components of mungbean variety U-thong 1 exposed to waterlogging at different stages of growth.

Period of waterlogging	Days after planting						
	10	20	30	40	50	60	Mean
			Seed weight (g/plant)				
0 days	1.64	2.88	2.65	2.13	2.31	2.02	2.27
3 days	0.47	0.75	0.75	0.85	3.00	1.64	1.24
6 days	0.60	0.80	-	0.80	2.00	2.35	1.09
9 days	0.38	0.73	-	0.48	1.41	1.69	0.78
Mean	**0.77**	**1.30**	**-**	**1.06**	**2.18**	**1.92**	
			Pods/plant				
0 days	4.56	5.74	5.44	5.37	5.31	5.18	5.26
3 days	3.08	4.00	2.50	2.91	7.25	5.00	4.12
6 days	1.75	2.87	0.00	2.75	4.43	6.12	2.99
9 days	1.50	2.83	0.00	2.00	4.06	4.31	2.45
Mean	**2.72**	**3.86**	**1.98**	**3.26**	**5.27**	**5.15**	
			100-seed weight (g)				
0 days	5.80	6.33	5.93	6.62	6.16	5.32	6.02
3 days	4.38	4.40	5.27	5.39	5.41	5.14	5.00
6 days	4.31	4.49	-	5.02	5.46	5.36	4.93
9 days	4.96	5.14	-	4.89	5.10	6.11	5.24
Mean	**4.86**	**5.09**	**-**	**5.48**	**5.53**	**5.48**	

F-test	Stages of growth	Periods of waterlogging
Seed weight/plant	**	**
Pods/plant	**	**
100-seed weight	ns	**

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