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Effects of Excess Moisture in the Soil at Different Stages of Development on the Growth and Seed Yield of Soybean

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Abstract: At the stages of flower bud differentiation and ripening, soybean plants grown in pots were treated with two levels of excess moisture in the soil; waterlogging (water table of 5 to 7 cm below the soil surface) and flooding (water is about 2 to 3 cm above the soil surface) for various days. Growth, seed yield and yield components were investigated. At the flower bud differentiation stage, seed yield and vegetative growth were markedly depressed by both waterlogging and flooding treatments. The longer the duration of the treatment, the severer the effects on seed yield. In this case, the numbers of branches and nodes per plant were decreased, whilst the shedding of buds, flowers and pods were increased. The resultant decrease in the number of pods per plant was the major reason for the decrease in seed yield. At the ripening stage, soybean was more tolerant to excess moisture in the soil. Vegetative growth was not affected by either treatment of the water table. Further, seed yield was not decreased significantly from control within 20 day's waterlogging and 4 day's flooding; however, it decreased when the term of the treatment was longer than that. The major reason for the decrease in seed yield was due to the decrease in the 100 seed weight.

Key words: Developmental stages, excessive soil moisture, seed yield, soybean, yield components

Introduction

Too little or too much water in soil is an acute agricultural problem, because each of these factors is somewhat difficult and often impossible to regulate. Although the effects of water stress on crops have been widely reported, the plant's responses to excess moisture in the soil have received relatively little attention. Excess rainfall (Fisher, 1925; Van der Paauw, 1962, 1972) and poor drainage (Baker, 1963) have long been associated with lighter crop yields.

Soybean is an important summer upland crop. Recently in Japan soybean has been cultivated also in drained paddy fields. Soybean yield in a drained paddy field is higher than in ari upland field because of the available water and mineral supplies. However, soybean is apt to be injured by excessive soil moisture in a drained paddy field. The earlier the growing period was, the greater effects of excessive soil moisture on dry matter production and seed yield (Sugimoto *et al*., 1988a). During the flower bud differentiation and the flowering stage, vegetative growth was markedly depressed and seed yield was decreased due to the decrease in the number of pods per plant. At the ripening stage, vegetative growth was not affected by excess moisture in the soil (Fukui, 1965) however, a decrease in 100 seed weight brought about a decrease in seed yield (Fukui, 1965; Sugimoto *et al*., 1988a). Bele is known about seed yield of various duration of excess moisture in the soil at different developmental stages. In this study, the effects of the duration of excessive soil moisture treatments at different developmental stages on the growth, seed yield, and yield components of soybean were examined.

Materials and Methods

Soybean plants *Glycine max* (L.) Merr. cv. Tamahornare were grown in pots (20 cm in diameter and 20 cm deep) containing clay loam soil. Fertilizer was applied at the rate of 0.3, 1.0 and 1.0 g per pot of N, P_2O_5 and K_2O, respectively. Five seeds per pot were sown on 28 June 1989. Following emergence, plants were thinned to one plant per pot. The plants were periodically sprayed with insecticide.

At the stages of flower bud differentiation and ripening, soybean plants were treated with two levels of soil moisture condition, waterlogging (water is about 5 to 7 cm below the soil surface) for 3, 6, 10, 20, 30 days and until maturity and flooding (water is about 2 to 3 cm above the sail surface) for 2, 4, 6, 8, 10 and 15 days. Control plants were watered to field capacity assuring minimal water stress. Six pots were used for each treatment. At the maturation stage seed yield, yield components and some characters of the stem were investigated.

Results

Effects of waterlogging: Seed yield of the waterlogged plants at the flower bud differentiation stage was not decreased significantly by 3 days' treatment. However it was decreased by 13, 15, 33, 44 and 53% due to the treatments for 6, 10, 20, 30 days and until maturity, respectively (Fig. 1). A decrease in seed yield was brought about by a decrease in the number of pods per plant. At the ripening stage, seed yield was not significantly decreased by 20 day's treatment however, it was decreased by 19 and 27% when plants wore treated for 30 days and until maturity, respectively. At this stage, a decrease in 100 seed weight resulted in a decrease in seed yield. The number of seeds per pod in waterlogged plants ranged from 1.68 to 1.73 and there was no significant difference from the control plants.

Stem characteristics in the waterlogged plants are shown in Table 1. At the flower bud differentiation stage, vegetative growth was inhibited, having shorter and lighter stems, as well as fewer branches and nodes when the duration of the treatment was prolonged. The number of pods per node was reduced significantly when plants were treated for more than 30 days. At the ripening period, these factors were not affected by the water logging treatments.

Effects of flooding: At the flower bud differentiation stage, 2, 4, 6, 6 and 10 days of flooding decreased seed yield by 11, 37, 35, 47 and 75%, respectively, and more than 15 days of

Table 1: Effects of watenogging on the stem characteristics

Growing period	Duration (Days)	Sem length (cm)	Stem weight (g)	Blanches per plant	Nodes per plant	Pods per node
Control	0	56.0	12.10	9.50	53.67	2.01
Flower bud	3	53.9	10.06**	9.60	55.20	1.97
drtrerentation	8	54.6	10.55*	7.83	53.50	1.82
	10	53.8	8.93**	8.33	51.00	1.91
	20	53.4	8.13**	7.33*	41.20**	1.86
	30	53.3	8.50**	6.50*	43.50**	1.48**
	M	52.5*	8.23**	7.17*	42.50*	1.39**
Repening	3	54.7	11.45	9.50	55.83	1.89
	6	56.4	11.96	10.20	52.44	1.98
	10	55.3	11.60	10.60	54.60	1.89
	20	57_3	1138	10.40	56.20	1.67
	30	55.4	11.50	9.20	52.60	1.89
	M	54.2	11.43	9.17	53.00	1.89

*,**: Significant different from the control at $p<0.05$ and $p<0.01$ (Fisher LSD), respectively
M: Treatment until maturity

Table 2: Effects of waterlogging on the stem characteristics

Growing period	Duration (Days)	Sem length (cm)	Stem weight (g)	Blanches per plant	Nodes per plant	Pods per node
Control	0	56,0	12.10	9.50	53.67	2.01
Flower hod	2	54.7	10.03*	9,00	54,57	1.77
ditterentation	4	55.3	7.03**	7,33**	43.33**	169**
	6	57.0	8.10**	7.00**	47.00*	1.62**
	8	51.5*	5.60**	6.50**	41.25**	1.57**
	10	44.0**	3.66**	4.80**	34.80**	1.16**
	15	Died				
Repening	2	55.5	12.46	9.80	53.00	2.02
	4	55.2	12.65	9.67	52.83	1.97
	6	57.2	12.64	9.20	53.80	1.91
	10	56.9	12.38	9.60	55.20	1.73*
	20	55.3	13.28	9.50	51.83	1,72*
	M	55.3	12.30	9.40	52,60	1.73*

*,**: Significant different from the control at $p<0.05$ and $p<0.01$ (Fisher LSD), respectively
M: Treatment until maturity

flooding resulted in the death of all plants (Fig. 2). A decrease in seed yield was brought about by a decrease in the number of pods per plant, and when the treatments were prolonged for more than 8 days, 100 seed weight decreased significantly. At the ripening stage, seed yield of the flooded plants was not significantly decreased within 4 day's treatments; however, it was decreased by 11, 34, 52 and 54% due to the treatments for 6, 10, 20 days and until maturity, respectively. A decrease in seed yield of the flooded plants was brought about by the decrease in the number of pods per plant and 100 seed weight. The number of seeds per pod in the flooded plants ranged from 1.64 to 1.75 and there was no significant difference from the control plants.

Stem characteristics of the flooded plants are shown in Table 2. At the flower bud differentiation stage, vegetative growth of flooded plants generally was inhibited more severely than that of the waterlogged plants. However, at the ripening stage vegetative growth was normal in comparison to the control. The number of pods per node was reduced when a plant was treated more than 4 days at the flower bud differentiation stage and more than 10 days at the ripening stage, respectively.

Discussion

At the flower bud differentiation stage, seed yield and vegetative growth, such as stem length, stem weight and the numbers of blanches and nodes per plant, were depressed

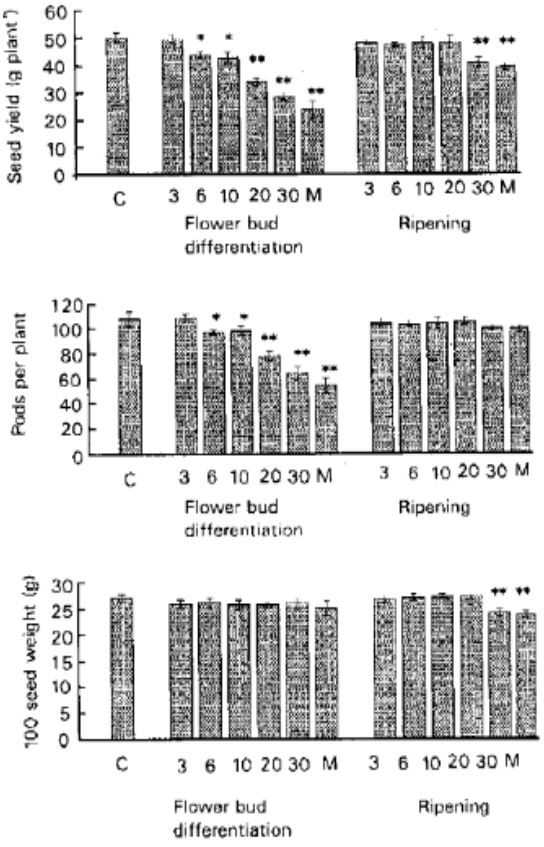

Fig. 1: Effects of waterlogging 'water table of 5 to 7cm below the soil surface) at the stages of flower bud differentiation and ripening on seed yield, pods per plant, and 100 seed weight. C: Control, M: Treatment until maturity. *, **: Significant different from control at $p<0.05$ and $p<0.01$ (Fisher LSD test), respectively

markedly by both waterlogging and flooding. The longer the duration of the treatment the severer the effects on vegetative growth and seed yield. The maior reason for the decrease in seed yield was due to the decrease in the number of pods per plant. In this case, the number of pods per node decreased because of longer duration of the treatment. One of the reasons for the reduction in the number of pods per node might be the shedding of buds, flowers and pods. The decrease in the number of branches and nodes per plant and increments in the shedding of buds, flowers and pods seemed to have caused a decrease in the number of pods per plant and hence the decrease in seed yield at this stage. The earlier the growth stage was, the greater were the effects of excessive soil moisture on bleeding, stomatal aperture, mineral absorption, and photosynthesis (Konno *et al.*, 1964; Sugimoto *et al.*, 1988b, 1991; Urano *et al.*, 1958). These physiological depressions caused by excess moisture in the soil seemed to have resulted in significant suppression of vegetative growth and increments in the shedding of buds, flowers, and pods in younger plants.

At the ripening stage, soybean was more tolerant to excess moisture in the soil compare to the flower bud differentiation

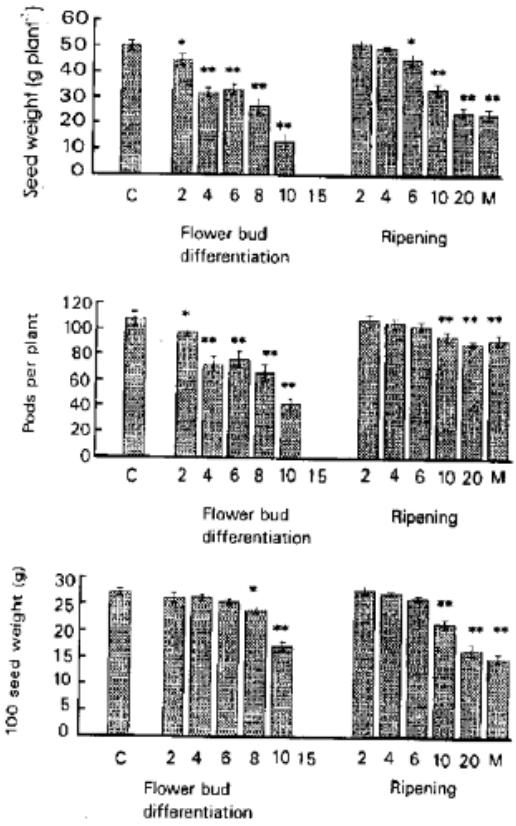

Fig. 2: Effects of flooding (water table of 2 to 3 cm above the soil surface) at the stages of flower bud differentiation and ripening on seed yield, pods per plant and 100 seed weight. C: Control, M: Treatment until maturity, *,**: Significant different from control at $p<0.05$ and $p<0.01$ (Fisher LSD test), respectively

stage. Vegetative growth in the treated plants was not affected significantly by either water condition in the soil. Seed yield was not decreased significantly from control by 20 days waterlogging and 4 days flooding however, it decreased when the duration of the treatments was prolonged to more than 30 day's waterlogging and 6 day's flooding. The major reason for the decrease in seed yield was due to the decrease in 100 seed weight. Sugimoto *et al*. (1988a) indicated that dry matter production was decreased due to the acceleration of leaf yellowing and defoliation. The resultant decrease in 100 seed weight brought about the decrease in seed yield.

There is considerable evidence that increasing the supplemental nitrate (Cannell, 1977; Cannell *et al*., 1980; Sugimoto and Satou 1993) and foliar application of urea (Garcia and Hanway, 1976; Hong *et al*., 1977; Ikeda *et al*., 1957; Sugimoto *et al*., 1989) can at least offset the effects of excess moisture in the soil. When soybean plants were injured by excess moisture in the soil, supplemental nitrate or foliar application of urea would be recommended for recovering from the injury.

Soybeans require more water compared to other cereal plants (Jodo, 1986; Teare *et al*., 1973). Recently in Japan, soybeans have been cultivated in a drained paddy field. Soybeans grown in a drained paddy field seem to be able to produce more yields compared to non-irrigated upland grown-soybeans. Shimada *et al*. (1992) indicated that a sufficient water supply proportionate to leaf area maintains higher leaf water potential and photosynthesis and eases the reduction of chlorophyll content at ripening stage, resulting in higher yield and vigorous growth. The results of this experiment recommend supplying sufficient irrigation at the ripening stage, because soybeans performed tolerantly to excess moisture in the soil at this stage.

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