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Zeolite Application Affects Vegetative Phenology of Determinate and Indeterminate Soybean Grown on Allophanic Soil

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Abstract: The objective of this study was to quantify the effects of Zeolite and Allophane on vegetative phenology of determinate and inderminate soybean. One determinate (Enrei, [MG] 1V) and indeterminate cultivar (Harosoy [MG] 11) were planted in pots on April 20th at the Faculty of Agriculture, Ehime University, Matsuyama Japan during 2007. Zeolite levels of 0, 20 and 40 g were used to determine the growth behavior of soybean cultivars grown on KyP and KnP of allophanic soil. Zeolite and allophanic soil application significantly affected vegetative phenological parameters of soybean cultivars. Minimum number of days to emergence, unifoliate first and second and 6th trifoliate leaf formation were taken by 20 and 40 g Zeolite application in both cultivars. KyP and KnP of allophanic soil took minimum days to all vegetative phonological parameters. Enrei cultivar took minimum days to emergence and in all respective vegetative developmental periods than Harosoy. Zeolite treated plots attained more plant height than control plots. Both KyP and KnP of allophanic soil gave maximum plant height as compared to paddy soil. Harosoy produced the tallest plants than Enrei. Present findings support the results of experiments by demonstrating that Zeolite application at planting time encourages the initiation of vegetative phenology of soybean cultivars grown on KyP and KnP of allophanic Soil.

Key words: Zeolite, allophanic soil, determinate and indeterminate cultivars, morphological, maturity group

INTRODUCTION

Fertilization is crucial to crop productivity sustenance under continuous land-use, but crop response could vary widely in different agro-ecologies. Plant nutrients are essential for producing sufficient and healthy food for the world's expanding population. Plant nutrients are therefore a vital component of any system of sustainable agriculture. Proper use of nutrients control rate and character of plant growth. Moreover, agricultural intensification requires increased flows of plant nutrients to crops and higher uptake of those nutrients by crops. The depletion of nutrient stocks in the soil, which is occurring in many developing countries, is a major but often hidden form of land degradation. On the other hand, excessive applications of nutrients, or inefficient management, can cause environmental problems, especially if large quantities of nutrients are lost from the soil/crop system into water or the air. Balanced use of plant nutrients corrects nutrient deficiency, improves soil fertility, increases nutrient and water use efficiency, enhances crop yields and farmer's income, betters crop and environmental quality. To reap the benefits of balanced use of plant nutrients, it is important to have good quality seed, adequate moisture and better agronomic practices with greater emphasis on

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timeliness and precision in farm operations. Understanding crop phenology is fundamental to crop management, where timing of management practices is increasingly based on stages of crop development. Predicting and understanding crop phenology and canopy development is important for many reasons including improving the efficacy of management practices and accuracy of simulation models and decision support systems. Temperature is the primary factor controlling phenological development rates, with photoperiod and vernalization often being important for some crops as well (McMaster and Smika, 1988; McMaster, 1997). Factors such as water, nutrients, salinity, CO_2, etc. are generally important as secondary factors and often must exceed threshold values before influencing phenology. Length of photoperiod strongly influences the morphology of soybean [*Glycine max* (L.) Merrill] plant by causing changes in the time of flowering, maturity and dry matter production. Soybean cultivars do not have the same critical day length. Therefore the effect of planting date on vegetative and reproductive periods may not be similar for different cultivars (Anderson and Vasilas, 1985). Significant differences in dry matter accumulation and morphological features were found (Beaver and Cooper, 1982) between determinate and indeterminate soybean and between soybean isolines (Wilcox, 1985). Average dry matter yields of 1902 kg ha^{-1} (Hanway and Weber, 1971a), 10220 kg ha^{-1} (Hanway and Weber, 1971b), 8512 kg ha^{-1} (Henderson and Kamprath, 1970) have been reported from different cultivars. Zeyanda *et al*. (1981) stated that May planting decreased dry matter yield. Green *et al*. (1977) reported that yield from indeterminate cultivars was more than semi-determinate and matured 5 days later and have 6 days longer reproductive period. Parvez *et al*. (1989) reported that node and pod numbers, leaf area index, crop growth rate, total biomass and seed yields were significantly increased with increasing plant population density up to a certain population density depending on spatial arrangement. They further stated that seed yield of both determinate and indeterminate soybean in subtropical latitudes is optimized by May seeding, high PPD (40 plants m^{-2}) and use of square planting patterns as approximated by narrow-row culture. This study was undertaken to determine the influence of zeolite nutrition on vegetative phenology of determinate and indeterminate soybean cultivars grown on KyP and KnP of allophanic soil under the agro-ecological environment of Japan.

MATERIALS AND METHODS

To assess the effect of Zeolite levels and Allophanic soil on Vegetative Phenology of Determinate and Indeterminate Soybean, a pot experiment was carried out at the Faculty of Agriculture, Ehime University, Matsuyama Japan, during 2007. The experiment was carried out in completely randomized design in green house under natural environment. Ceramic cylinders pots (h = 20 cm, Ø = 10 cm) were filled with 2 kg of air-dried sieved soil samples. A 3 factor (3×3×2) factorial experiment of three allophanic soil and zeolite amendments with two soybean varieties were used. Normal soil (paddy soil) was collected from Ehime University Agriculture Research Farm Hojo and was used as control. Allophanic soil of KyP having low Si/Al ratio were collected from Kurayoshi Tottori prefecture near Moutain Daisen. Whereas, allophanic soil of KnP having high Si/Al ratio were collected from Kakino Kumamoto Prefecture near Moutain Aso. Three zeolite levels of 0, 20 and 40 g were applied in the ratio of 1:2 one day before sowing of the crop. Determinate cultivar (Enrei, [MG] 1V) and indeterminate cultivar, Harosoy [MG] 11) were planted at 30 mm depth in the above soils. Maximum seed were planted to obtain the required plant population density that should be quite enough to study the required parameters. A basal dose of 5 g N and 10 g of P_2O_5 and KCl were applied one day before starting the experiment. All soils samples were sieved through a 2 mm sieve before application. The 18 combinations were replicated 3 times so there were 18×3 = 54 experimental units. The 54 pots were arranged within 18×3 arrays of rows with 20 cm distance between pots. Normal cultural practices for raising a successful crop were applied uniformly to all the experimental units. The plots were hand weeded at different vegetative stages. Irrigation was applied as and when required. A set of basic plant measurements were recorded during the course of study to evaluate the crop progression toward maturity and also to asses the vegetative/reproductive balance of the crop as described by Fehr and Caviness (1977). Basic plant measurements data were recorded on alternate day to evaluate the development phases of growth and development of soybean. The data on the following vegetative phonological parameters were recorded according to standard procedure.

- Days to emergence.
- Days to unifoliate leaf formation.
- Days to trifoliate leaf formation.
- Days to 6th trifoliate leaf formation.
- Plant height.

Data on days to emergence and other phonological parameters was recorded, when more than 80% of the plants reached to their respective category in each treatment. The data regarding plant height was recorded on two plants averaged at the time of maturity. Data were statistically analyzed using analysis of variance techniques appropriate for completely randomized design with varieties split on allophanic soil. Main and interaction effects were separated by LSD test at 0.05 level of probability, if the F-values were significant.

RESULTS AND DISCUSSION

Days to Emergence

Speed of emergence measured as days to emergence in the field is important for proper crop stand especially under adverse seedbed conditions during spring planting. Days to emergence of the two soybean cultivars grown on allophanic soil and affected by zeolite nutrition indicates that both KyP and KnP of allophanic soil took 6 days to emergence as compared to paddy soil (Table 1). Minimum days to emergence in both KyP and KnP of allophonic soil may be due to its nutritional status and its water holding capacity (Khan *et al.*, 2006). Plots treated with 20 and 40 g of zeolite took 6 day to emergence as compared to control treated plots. Variety Enrei took minimum days to emergence than Harosoy. The difference in days to emergence among varieties may be due to their genetic make up.

Table 1: Days to emergence of determinate and indeterminate soybean cultivars as affected by zealite and different soil types

Soil types	Cultivars	Zeolites doses (g) 0	20	40	Mean*
S×V×Z					
Paddy soil	Harosoy	9	7	7	8
	Enrei	8	6	6	7
KyP	Harosoy	8	6	6	7
	Enrei	8	6	6	7
KnP	Harosoy	8	6	6	7
	Enrei	8	6	6	7
S×Z					
Paddy soil		9	7	7	7b
KyP		8	6	6	6a
KnP		8	6	6	6a
Z×V					
	Harosoy	8	6	6	7b
	Enrei	8	6	6	6a
Mean		8b	6a	6a	

*: Means of the same category followed by different letter(s) are significantly different at 0.05% level of probability using LSD test. LSD Varieties: 0.042, LSD Soil: 0.051, LSD Zeolite: 0.051

Table 2: Days to unifoliate leaf formation of determinate and indeterminate soybean cultivars as affected by zealite nutrition and different soil types

Soil types	Cultivars	Zeolites doses (g) 0	20	40	Mean*
S×V×Z					
Paddy soil	Harosoy	16	13	12	13
	Enrei	14	13	12	13
KyP	Harosoy	13	10	10	11
	Enrei	13	10	10	11
KnP	Harosoy	13	10	10	11
	Enrei	13	10	10	11
S×Z					
Paddy soil		15	13	12	13b
KyP		13	10	10	11a
KnP		13	10	10	11a
Z×V					
	Harosoy	14	11	10	11
	Enrei	13	11	10	11
Mean		13b	11a	10a	

*: Means of the same category followed by different letter(s) are significantly different at 0.05% level of probability using LSD test

Days to Unifoliate Leaf Formation

The statistical analysis of data indicates that zeolite nutrition had significant effect on unifoliate leaf formation of the two soybean cultivars grown on KyP and KnP of allophanic soil, whereas, the effect of cultivar and interactions were non-significant (Table 2). Minimum days (10) to unifoliate leaf formation were taken by 20 and 40 g zeolite treated plots. Minimum days to unifoliate leaf formation in zeolite treated plots may be due to slow-release fertilizers and other materials. Both KyP and KnP of allophanic soil took 11 days to unifoliate leaf formation as compared to paddy soil. Both cultivars took same number of days (11) to unifoliate leaf formation. These results are in line with those of Kavoosi (2007) stated that zeolite application significantly affected the vegetative phenology of rice crop.

Days to Trifoliate Leaf Formation

The statistical analysis of data reveals that zeolite nutrition and allophanic soil had significantly affected the trifoliate leaf formation of the two soybean cultivars (Table 3). Minimum number of days (15) to trifoliate leaf formation was taken by 20 and 40 g Zeolite application as compared to control treated plots. KnP and KyP of allophanic soil took minimum number of days (15) to trifoliate leaf formation. Control treated plots took maximum days to trifoliate leaf formation. Minimum days to trifoliate leaf formation in zeolite treated plots may be due to slow-release fertilizers and its availability at proper time. Both cultivars took same number of days (17) to trifoliate leaf formation. Kavoosi (2007) stated that zeolite nutrition at early growth stages significantly affected the vegetative phenology of rice and other crops.

Days to 6th Trifoliate Leaf Formation

The data recorded on 6th trifoliate leaf formation show that zeolite and allophanic soil had significantly affected the 6th trifoliate leaf formation of the two soybean cultivars (Table 4). Zeolite applied at the rate of 40 g took minimum number of days (26) to 6th trifoliate leaf formation followed by 20 g of zeolite application. Favorable micro-environment for growth and development may be the reason for minimum days to 6th trifoliate leaf formation. A steady increase in number of days to 6th

Table 3: Days to trifoliate leaf formation of determinate and indeterminate soybean cultivars as affected by zeolite nutrition and different soil types

Soil types	Cultivars	Zeolites doses (g) 0	20	40	Mean*
S×V×Z					
Paddy soil	Harosoy	23	18	17	19
	Enrei	23	18	17	19
KyP	Harosoy	18	14	14	15
	Enrei	18	15	14	15
KnP	Harosoy	18	14	14	15
	Enrei	18	14	14	15
S×Z					
Paddy soil		23	18	17	19b
KyP		18	14	14	15a
KnP		18	14	14	15a
Z×V					
	Harosoy	19	15	15	17
	Enrei	19	15	15	17
Mean		19b	15a	15a	

*: Means of the same category followed by different letter(s) are significantly different at 0.05% level of probability using LSD test. (LSD for Soil: 1.690, LSD for Zeolite: 0.276)

Table 4: Days to 6th trifoliate leaf formation of determinate and indeterminate soybean cultivars as affected by zeolite nutrition and different soil types

Soil types	Cultivars	Zeolites doses (g) 0	20	40	Mean*
S×V×Z					
Paddy soil	Harosoy	39	31	29	33
	Enrei	33	30	27	30
KyP	Harosoy	34	28	25	29
	Enrei	30	26	24	26
KnP	Harosoy	33	29	27	30
	Enrei	29	26	22	25
S×Z					
Paddy soil		36	30	28	31b
KyP		32	27	24	27a
KnP		31	27	24	28a
Z×V					
	Harosoy	35e	29c	27b	30b
	Enrei	30d	27b	24a	27a
Mean		33c	28b	26a	

*: Means of the same category followed by different letter(s) are significantly different at 0.05% level of probability using LSD test. LSD Varieties: 0.739, LSD Soil: 0.906 LSD Zeolite: 0.906 LSD interaction (Z×V): 1.279

trifoliate leaf formation occurred in paddy soil. Cultivar Enrei took minimum days (27) to 6th trifoliate leaf formation than Harosoy. The difference in days to 6th trifoliate leaf formation among varieties may be due to their genetic make up.

Plant Height (cm)

Plant height is an important morphological character that acts as a potent indicator for availability of growth resources in its vicinity. The height of a plant depends on the availability of nutrients especially nitrogen (Ferdous, 2001). Irrespective of zeolite application, plant height increased over time (Table 5). Plant height increased progressively over time and attaining the highest at physiological maturity. The rate of increase in both KyP and KnP allophanic soil was significant as compared to paddy soil. The effect of zeolite application on plant height of the two varieties was significant. The highest plant height of 42.48 and 42.05 cm was recorded with 20 and 40 g zeolite application and the lowest in control treatment. This trend was similar with the result reported for pea (Naik, 1989), for

Table 5: Plant height (cm) of determinate and indeterminate soybean cultivars as affected by zeolite nutrition and different soil types

Soil types	Cultivars	Zeolites doses (g) 0	20	40	Mean*
S×V×Z					
Paddy soil	Harosoy	21.77a	29.38bc	47.93e	33.02bc
	Enrei	16.94a	29.03bc	38.37d	28.11a
KyP	Harosoy	65.08g	75.35h	56.85f	65.76e
	Enrei	31.12bc	32.72c	40.96d	31.43bc
KnP	Harosoy	42.93d	55.48f	38.02d	45.48d
	Enrei	26.35b	30.04bc	32.78c	29.84ab
S×Z					
Paddy soil		19.35a	29.21b	43.15d	30.57a
KyP		48.10e	54.03f	48.89e	50.34c
KnP		34.64c	42.94d	35.04c	37.66b
Z×V					
	Harosoy	43.26d	53.40f	47.06e	48.08b
	Enrei	24.79a	30.71b	37.37c	30.95a
Mean		34.02a	42.05b	42.48b	

*: Means of the same category followed by different letter(s) are significantly different at 0.05% level of probability using LSD test. LSD Varieties: 1.654, LSD Soil: 2.026, LSD Zeolite: 2.026, LSD interaction (Z×V): 2.866. LSD interaction (S×V): 2.866. LSD interaction (S×V×Z): 4.964

mung bean (Akhtaruzzaman, 1998) and for edible pea (Ferdous, 2001). Among the two soybean varieties, Harosoy gave maximum plant height as compared to Enrei. Significant differences were observed between plant heights of the two cultivars and Harosoy grew about 18 cm taller than Enrei. The difference in plant heights of the two varieties may be genotypic in nature. Interaction between Zeolite×cultivars was significant and both cultivars at 20 and 40 g zeolite application attained maximum plant height and a decreasing trend in plant height was observed at zero application, the rate of decrease in plant height of Harosoy was noted about 10.14 cm height reduction with 20 and 40 g zeolite application, where as in Enrei, the reduction in height was about 5.92 cm. This resulted in more difference in plant height at 40 g zeolite application and less difference at 20 g application.

CONCLUSIONS AND RECOMMENDATIONS

It is concluded from the present investigation that zeolite application at the rate of 20 and 40 g promote/encourage the Vegetative Phenology of determinate and indeterminate soybean under the agro-climatic environment of Japan. It is further stated that KnP and KyP of Allophanic soil show its fertility and high potential for all kind of Crops.

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