Journal of

Plant Sciences

ISSN 1816-4951

Academic
Journals Inc.

www.academicjournals.com

Journal of Plant Sciences 3 (4): 277-286, 2008
ISSN 1816-4951

Soybean Leaf Area, Plant Height and Reproductive Development as Influenced by Zeolite Application and Allophanic Soil

[1]H. Khan, [1]A.Z. Khan, [2] R. Khan,[3]N. Matsue and [3]T. Henmi
[1]Department of Agronomy, NWFP Agricultural University, Peshawar, Pakistan
[2]Department of Plant Breeding and Genetic, Agricultural University, Peshawar, Pakistan
[3]Faculty of Agriculture, Ehime University, 3-5-7 Tarumi, Matsuyama 790-8566, Japan

Abstract: The objective of the present study was to quantify the effects of zeolite application and allophanic soil (KyP and KnP) on leaf area development, plant height and reproductive morphology of 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, 1 and 2 wt.% were used to determine the growth behavior of soybean cultivars grown on two allophanic (KyP and KnP) and a paddy soil. Zeolite application and allophanic soil significantly affected leaf area development, plant height and reproductive morphology of soybean cultivars. Maximum leaf area and plant height were obtained from 2 wt.% zeolite application and allophanic soil (KyP and KnP). Minimum number of days to flowering, pod formation, seed filling duration and physiological maturity were taken by 1 and 2 wt.% zeolite application in both cultivars. The same trend was observed in number of days to reproductive development by KyP and KnP allophanic soil. Enrei took maximum days to all reproductive stages as compared to Harosoy. Zeolite treated plots and allophanic soil (KyP and KnP) attained more plant height than control plots grown on paddy soil without zeolite application. Harosoy produced the tallest plants than Enrei. Present findings supported the results of experiments by demonstrating that zeolite application at planting time promotes leaf area, plant height and encourage the reproductive morphology of soybean cultivars grown on KyP and KnP allophanic soil.

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

INTRODUCTION

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 (Graham and Webb, 1991). To achieve the benefits of balanced use of plant nutrients, it is important to have better agronomic practices with greater emphasis on timeliness and precision in farm operations. Volcanic ash derived soils are among the most productive soils in the world (Shoji *et al*., 1993). These soils support dense populations in areas such as central Java. Volcanic ash-derived soils are mostly associated with mountain slopes (Radcliffe and Gillman, 1985) and they are often used for intensified agricultural production systems such as highland commercial vegetable production in Taiwan, Philippines, Japan, Indonesia and the Costa Rican Andes (Midmore and Poudel, 1996). These intensified agricultural systems are characterized by heavy use of agrochemicals and fertilizers and often associated large soil erosion and down-stream impacts (Shoji *et al*., 1993). Allophane is a clay-size alumino-silicate mineral with short range order, which occur widely in Spodosols and Andisols (Wada, 1989). Allophane has a large propensity of sorbing organic substances.

Corresponding Author: Hamayoon Khan, Department of Agronomy, NWFP Agricultural University, Peshawar, Pakistan

Similarly, allophanic clay stabilizes the microbial biomass and its metabolites (Saggar *et al*., 1996). Andisols are often very fertile and they commonly have physical properties that make them very suitable for agricultural use and most Andisols occurs in climates that are very suitable for agriculture. Zeolites are microporous, crystalline, hydrated aluminosilicates of alkali and alkaline materials that have a high internal surface area (Rollman and Valyocisk, 1981). The unique cation exchange, adsorption, hydration-dehydration and catalytic properties of natural zeolites have prompted slow-release fertilizers and other materials (Pond and Mumpton, 1984). The poor utilization of fertilizers by crops is largely caused by losses of N through denitrification, ammonia volatization, runoff and leaching (Craswell and Vlex, 1979). In view of the high cost of chemical fertilizers, use of natural fertilizer sources for increasing crop production on a sustainable basis has become imperative. Previous results suggest that zeolite are useful in improving certain physical properties of Ultisols by changing soil structure, increasing the amount of plant available water and decreasing the cohesiveness of soil particles. Natural compound such as zeolite minerals have been reported as ameliorants for coarse soils to modify soil Cation Exchange Capacity (CEC) to decrease N leaching and to increase fertilizer recovery (Huang and Petrovic, 1994). Zeolite improves soil structure by coupling high cation exchange capacity (CEC) with a selective affinity for ammonium and potassium (Curkovic *et al*., 1997). Zeolite is very porous with an incredibly large surface area. The retention and timely release of needed nutrients by zeolite improves overall crop yield (Nommik and Vahtras, 1982). It provides a lasting reservoir of nutrients allowing the user to reduce added fertilization while achieving better plant and vegetable performance. Unlike commonly used fertilizers, the plant-growth material dramatically reduces loss of nutrients to groundwater and the environment (Pansini, 1996).

Soybean [*Glycine max* (L.) Merr.] is an important crop of the world and is grown across a wide range of agro-geographical regions from China to Brazil and from Oceania to Canada (Bond *et al*., 1985). Soybean reproductive phenology is fundamental to crop management because of the timing of management practices is based on stages of crop development. An understanding of the developmental processes of a soybean is important in evaluating its yield potential. The use of indeterminate versus determinate maturity groups allows growers to maximize the yield potential within their growing region.

Proper nutrition of soybean is not only important for proper emergence but also important to have the crop in the field when environmental conditions are conducive for proper growth and development. The growth patterns, the anatomy and morphology and particularly the chemical composition (Graham and Webb, 1991). Natural zeolites have been used for a long time in Japan to improve soil quality. Farmers add zeolite to the soil to control soil pH and to improve ammonium retention (Dwyer and Dyer, 1984). In view of the high cost of chemical fertilizers, use of natural fertilizer sources for increasing crop production on a sustainable basis has become imperative.

The optimum rate of zeolite application and its influence on leaf area development, plant height and reproductive morphology is critical because of the economic and industrial importance of soybean and easier availability of zeolite as a source of medium for plant growth. Research on zeolite applications, as fertilizer/soil conditioner on allophanic soil is limited to few studies. Thus, this study was designed to evaluate the response of zeolite application on reproductive morphology, plant height and leaf area development of soybean grown on KyP and KnP allophanic soil.

MATERIALS AND METHODS

To assess the effect of zeolite application on reproductive morphology, plant height and leaf area development of determinate and indeterminate soybean grown on two allophanic (KyP and KnP) and a paddy soil (Table 1), 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 under natural green house environment. Ceramic cylinders pots (h = 20 cm, Ø = 10 cm) were

Table 1: Some physical and chemical properties of the different soil used in the experiment

Soil type	pH (H_2O)	pH (KCl)	CEC	Na	K	Ca	Mg
			------------------------------	(cmol kg^{-1})	------------------------------		
Paddy soil	6.0	5.1	13.8	0.6	0.5	7.0	1.4
Allophanic soil (KyP)	5.7	5.0	17.2	1.8	0.3	0.3	0.2
Allophanic soil (KnP)	6.2	4.8	30.1	1.3	1.9	7.2	2.6

filled with 2 kg of air-dried sieved soil samples. A 3 factor (3×3×2) factorial experiment of three soil and zeolite amendments on two soybean varieties were used. Paddy soil was collected from Ehime University Agriculture Research Farm Hojo and was used as control. KyP having low Si/Al ratio was collected from Kurayoshi, Tottori prefecture, near Mt. Daisen. While for KnP having high Si/Al ratio was collected from Kakino, Kumamoto Prefecture, near Mt. Aso. Three zeolite levels of, 0, 1 and 2 wt.% were applied one day before sowing of the crop. Determinate cultivar (Enrei, [MG] 1V) and indeterminate cultivar, Harosoy [MG] 11) were planted at 30 mm depth. 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 each of P_2O_5 and KCL were applied one day before sowing. 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 growth stages. Irrigation was applied at weekly intervals. 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 growth and development of soybean. The data were recorded on the following parameters of soybean according to standard procedure.

Leaf Area Index (LAI)

Leaf Area Index was calculated was using the following formula.

$$\text{LAI} = \frac{\text{Surface area of sampled leaf}}{\text{Ground area occupied by the sampled plants}}$$

Data regarding plant height was recorded on two plants in each treatment was randomly measured in (cm) from the soil surface to the tip of the plant at the time of maturity. Data on days to various reproductive developmental stages (flowering, pod formation, seed filling duration and physiological maturity) was recorded, when more than 80% of the plants reached to their respective category in each treatment.

Statistical Analysis

The data recorded on different plant parameters were statistically analyzed with the help of MSTAT programme. Main and interaction effects were separated by LSD test at 5% level of probability, if the F-values were significant (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Leaf Area Development

Crop growth depends on adequate formation of leaf area for efficient interception of light (Wilson, 1981). Leaf area per plant increased sharply after emergence reaching peak at pod filling stage and then decreased especially in Enrei (Fig. 1). The reduction of leaf area per plant at later part of growth might be due to senescence of older leaves associated with the remobilization of the stored metabolites from the leaf to the developing pods of soybean seed (Egli, 1990).

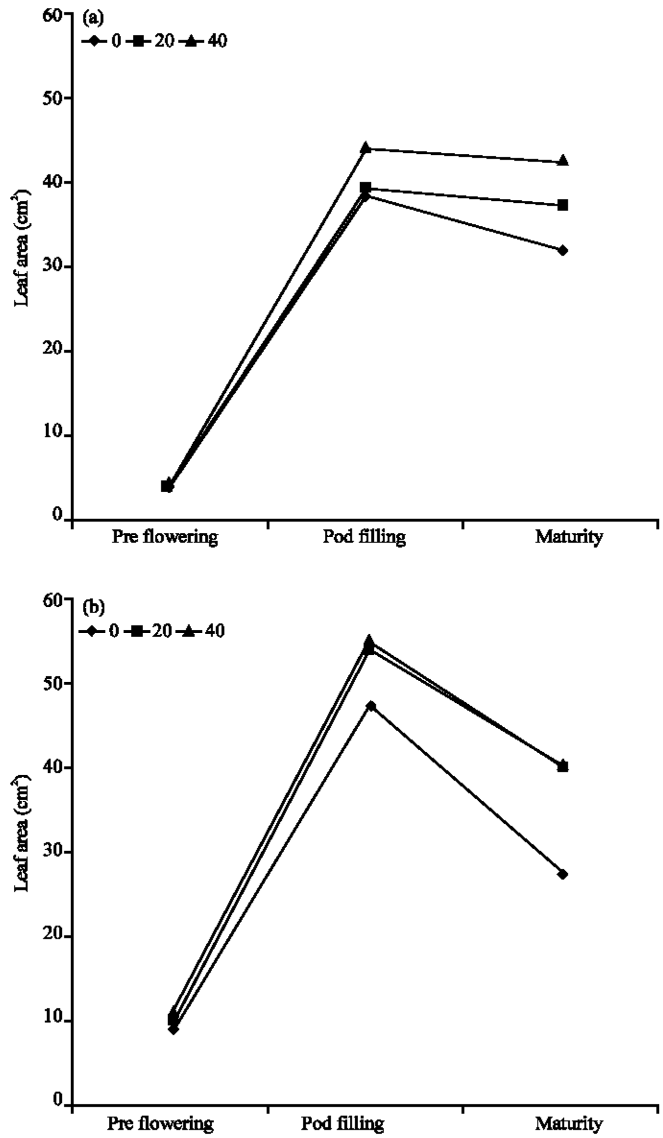

Fig. 1: Leaf area at different reproductive growth stages of (a) Harosoy and (b) Enrei as affected by zeolite application

Similar trends were reported by Matsunaga *et al.* (1989) and Singh *et al.* (1985) in mungbean, Ferdous (2001) in edible oil pea and Misra *et al.* (1994) in ground nut. Among the varieties, Enrei consistently produced more leaf area treatment^{-1} than Harosoy. Zeolite levels significantly influenced leaf area development up to seed filling stage (Fig. 1). Leaf area responded positively up to 1 wt.% zeolite applications and then decreased. Maximum leaf area was obtained at pod filling stage with 2 wt.% zeolite applications and was maintained throughout the crop growth period. Plants grown on paddy soil without zeolite application gave the lowest leaf area. Enhanced leaf area development with high dose of zeolite was also reported for horticultural crops (Munir *et al.*, 2004). Kavoosi (2007) found that increase in zeolite (N) uptake increased nucleic acid, amides and amino acid and hence cell multiplication, which increased leaf area. However, it is evident from (Fig. 1) that despite the magnitude of differences in leaf area due to treatment differences, the trend of leaf area development per treatment remains identical for both the varieties. LAI of both the genotypes peaked at the flowering and pod filling period. Rate of LAI increase at early growth stage was highest in genotype Enrei, with an LAI of 2 at 43 days after sowing while Harosoy cultivar had an LAI of about 1.5. LAI development of both cultivars was greatly affected by zeolite application, but the LAI of both genotype decreased by higher dose of zeolite application at the end of flowering. LAI of both cultivars were about 2.5, much lower than the optimum LAI of 3.5-4 for the tropical conditions (Whigham, 1983).

Plant Height

Plant height is an important morphological component that acts as a potent indicator for availability of growth resources in its vicinity. The height of a plant depends on nutrients especially

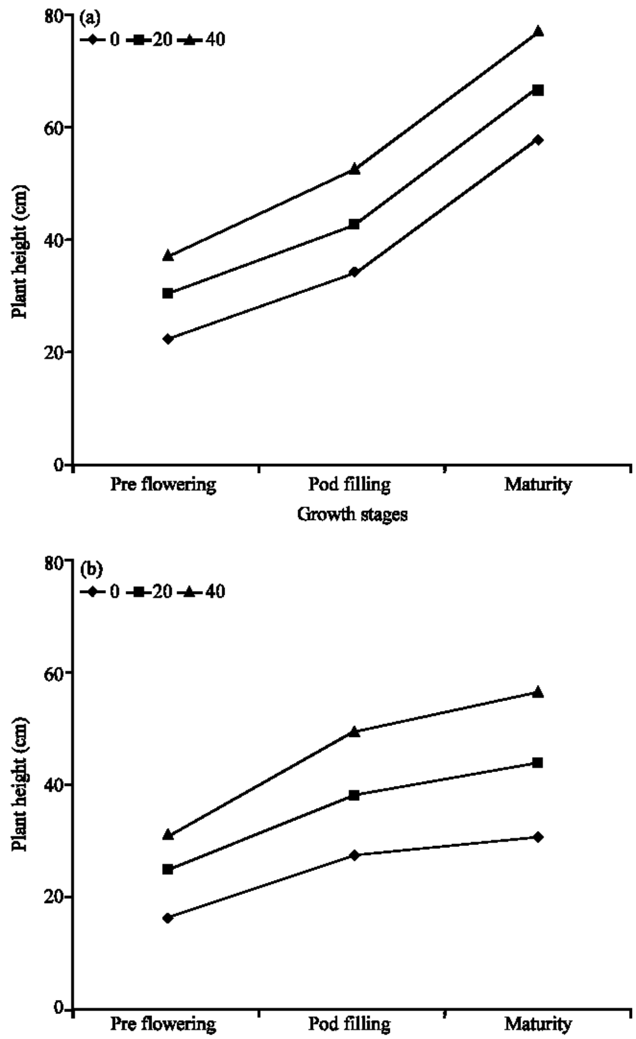

Fig. 2: Plant height at different growth stages of (a) Harosoy and (b) Enrei as affected by zeolite application levels

on nitrogen (Ferdous, 2001). Irrespective of zeolite application, plant height increased over time (Fig. 2). Plant height increased progressively and attaining its maximum height at physiological maturity. The effect of zeolite application on plant height of the two varieties was significant. Maximum plant height of 42.48 and 42.05 cm was recorded with 1 and 2 wt.% zeolite application and the lowest in control treatment grown on paddy soil without zeolite application. Similar trend was reported by Naik (1989) for pea. The rate of increase in plant height of KyP and KnP allophanic soil was more pronounced as compared to paddy soil. KnP and KyP gave 19.77 and 7.11% more taller plants than paddy soil. Maximum plant height from KyP and KnP allophanic soils may be due to less competition among plants for proper space and availability of nutrients for growth and development. Averaged across the allophanic soil, plants in the allophonic soil were 13.44% taller than paddy soil. Kavoosi (2007) observed similar results and found plant height increased significantly in rice crop under proper utilization of zeolite. Significant differences were observed between plant heights of the two cultivars. Harosoy grew taller and attain maximum plant height of 18 cm as compared to Enrei. The difference in plant heights of the two varieties may be due to their growth habit, which is genotypic in nature. Interaction between zeolite×cultivars was significant and both cultivars at 1 and 2 wt.% zeolite application attained maximum plant height and a decreasing trend in plant height was observed without zeolite application. The rate of decrease in plant height of Harosoy was noted about 10.14 cm height reduction with 1 and 2 wt.% zeolite application, where as in Enrei, the reduction in height was about 5.92 cm. This resulted in more difference in plant height at the 2 wt.% zeolite application and less difference at 1 wt.% application.

Soybean Developmental Stages

The developmental stages in soybeans were characterized by the standards established by Fehr and Caviness (1977). The life cycle of the soybean is split into vegetative (V Stage) and reproductive (R Stage) stages. In a determinate genotype, the onset of reproductive development results in the production of flowers on the main axis and conversion of the apical meristem into a reproductive primordia resulting in the termination of the main axis in a floral bud. Determinate types are generally grown in such areas, where the duration of the growing's season is not a limiting factor. Days to different soybean developmental stages increased progressively and took maximum days to physiological maturity by both cultivars. The effect of zeolite application on all reproductive development stages of the two varieties was significant. Minimum days to flowering, pod formation, seed filling duration and physiological maturity were recorded with 1 and 2 wt.% zeolite application as compared to control plots (Table 2). The rate of increase in number of days to various reproductive stages in control plots was faster and linear in both varieties (Fig. 3). Slower trends in number of days to reproductive stages in zeolite treated plots were observed from pod formation to physiological maturity (Fig. 3). Paddy soil took maximum days (120) to various reproductive stages in both cultivars (Fig. 4). A steady decrease in number of days to different reproductive morphology of the two

Table 2: Days to flowering, pod formation, seed filling and physiological maturity of determinate and indeterminate soybean cultivars as affected by zeolite application and different soil types

		Zeolite doses (g)			Soil types		
Treatments	Cultivars	0	20	40	Paddy soil	KyP	KnP
No. of days to	Harosoy	48b	40a	38a	46b	41a	39a
flowering	Enrei	45b	39a	37a	43ab	39a	39a
Pod formation	Harosoy	74b	62a	55a	70b	60a	59a
	Enrei	75b	67a	57a	74ab	65a	62a
Seed filling	Harosoy	99b	83a	78a	97b	81a	78a
	Enrei	101b	86a	75a	102ab	85a	78a
Physiological	Harosoy	118b	106a	97a	119b	104a	96a
maturity	Enrei	120b	110a	101a	125b	105a	99a

Values with different letter (s) are significant at $p \leq 0.05$

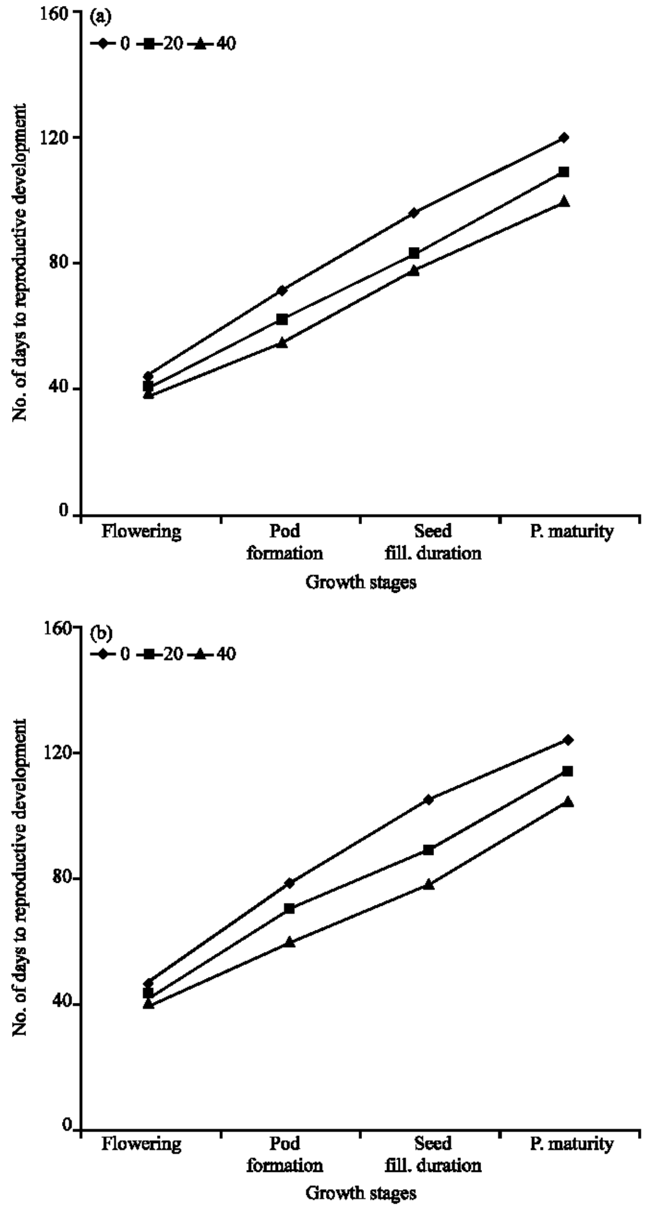

Fig. 3: Number of days to different reproductive stages in (a) Harosoy and (b) Enrei as affected by zeolite application levels

soybean cultivars took place when soybean was planted on KyP and KnP allophanic soil (Fig. 4). Minimum days to various reproductive stages from zeolite treated plots and KyP and KnP allophanic soil is attributed to the high fertility status of these soils plus the nutrients supplement through zeolite application. Therefore, these soils have high potential to provide nutrients for optimum plant growth and development right from the germination to the physiological maturity. In addition to this allophanic soils have high water holding capacity as compared to paddy soil (unpublished data from this laboratory). And continuous moisture supply is a prerequisite for nodulation, because drought

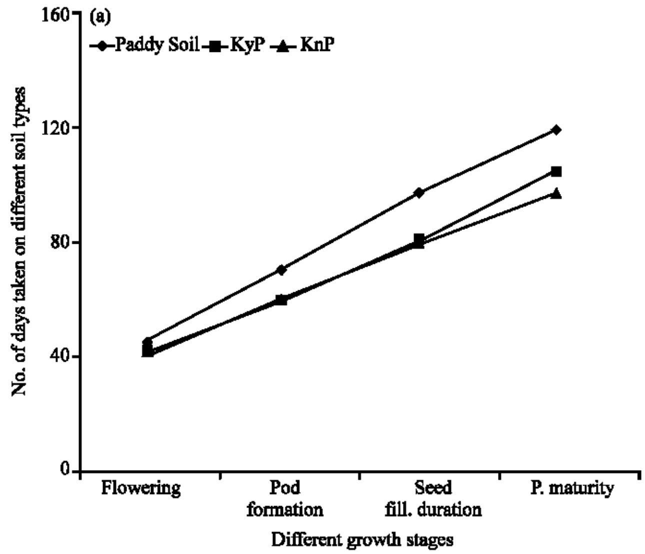

Fig. 4: Number of days to different reproductive stages (a) Harosoy and (b) Enrei as affected by different soil types

reduces the moisture in the soil that protects the bacteria while it lives on the seed surface after planting. A dry seedbed and dry seed will quickly draw moisture from the bacteria on the surface of the seed to dry and die. If enough bacteria die, there will be little nodule formation and insufficient ammonium production for plant support. The length of flowering was slightly shorter in both cultivars and the difference was greater between control and zeolite treated plots in latter reproductive developmental stages. The duration of the reproductive period differed considerably, particularly in Enrei, which is late maturing cultivar. Harosoy cultivar (early maturing) had short reproductive phases while late maturing genotypes had longer reproductive phases. The effects of zeolite applications on the total growth duration were only evident in late maturing genotypes. This resulted improvement in plants towards early maturity and completion of the life cycle (Kavoosi, 2007). Significant differences were observed between reproductive stages of the two cultivars. Harosoy took minimum days to all reproductive development as compared to Enrei. The difference in number of days to reproductive development of the two varieties may be due to their growth habit, which is genotypic in nature. The duration of the life cycle and the individual phases of development within the life cycle are also influenced by air temperature. Rate of development in plants is generally slower under cool environments and faster under warm environments, resulting in either longer or shorter durations of growing phases, respectively.

CONCLUSION AND RECOMMENDATIONS

Results of this experiment indicate that zeolite application and allophanic soil can promote plant growth, enhance leaf area development, plant height and improve the reproductive morphology of determinate and indeterminate soybean cultivars. It is further stated that KnP and KyP allophanic soil show its fertility and high potential for cultivation. Further research is needed on different aspects of zeolite application for ascertaining the beneficial effects in a wider range of environment on different crops.

REFERENCES

Bond, D.A., D.A. Lawes, G.C. Hawtin, M.C. Saxena and J.S. Stephens, 1985. Faba Bean (*Vicia faba* L.). In: Grain Legume Crops, Summerfield, R.J. and E.H. Roberts (Eds.). William Collins Sons Co. Ltd., 8 Grafton Street, London, WIX 3LA, UK., pp: 199-265.

Craswell, E.T. and P.L. Vlex, 1979. Fate of Fertilizer Nitrogen Applied to Wet Land Rice. In: Nitrogen and Rice. Brady, N.C. (Ed.). International Rice Research Institute, Manila, Philippines, pp: 175-192.

Curkovic, L., S. Cerjan-Stefanovic and T. Filipan, 1997. Metal ion exchange by natural and modified zeolites. Water Res., 31: 1379-1382.

Dwyer, J. and A. Dyer, 1984. Zeolites An introduction. Chem. Ind., 2: 237-240.

Egli, D.B., 1990. Seed water relations and the regulation of the duration of seed growth in soybean. J. Exp. Bot., 41: 243-248.

Fehr, W.R. and C.E. Caviness, 1977. Stages of soybean development. Spec. Rep. 80. Iowa State Univ. Coop. Ext. Serv., Ames.

Ferdous, A.K.M., 2001. Effects of nitrogen and phosphorus fertilizers on nutrient uptake and productivity of edible podded pea. M.Sc. Thesis, Department of Agronomy. BSMRAU, Salna, Gazipur, pp: 29-30.

Gomez, K.A. and A.A. Gomez, 1984. Statistical Procedures for Agricultural Research. 2nd Edn. John Wiley and Sons, Inc., New York, ISBN: 0-471-87931-2 pp: 704.

Graham, R.D. and M.J. Webb, 1991. Micronutrients and Disease Resistance and Tolerance in Plants. In: Micronutrients in Agriculture, Mortvedt, J.J., F.R. Cox, L.M. Shuman and R.M. Welch (Eds.). 2nd Edn., Soil Science Society of America, USA, pp: 329-370.

Huang, Z.T. and A.M. Petrovic, 1994. Clinoptilolite Zeolite influence on nitrate leaching and nitrogen use efficiency in simulated and based golf greens. J. Environ. Qual., 23: 1190-1194.

Kavoosi, M., 2007. Effects of zeolite application on rice yield, nitrogen recovery and nitrogen use efficiency. Soil and water department, rice research institute of Iran, Rasht, Iran. Commun. Soil Plant Anal., 38: 69-76.

Matsunaga, R.A., Hamid and A. Hashim, 1989. Dry matter production and yield performance of summer and winter pulses in Bangladesh. J. Fac. Agric. Kyushu Univ., 33: 221-228.

Midmore, D.J. and D.D. Poudel, 1996. Asian vegetable production systems for the future. Agric. Syst., 50: 51-64.

Misra, A.L., A. Isoda, H. Nojima, Y. Takasaki, T. Yoshimera and T. Ishikawa, 1994. Plant type of dry matter production in pea nut cultivars. Varietal differences in dry matter production. Jap. J. Crop Sci., 62: 289-297.

Munir, S., S. Singh, K. Kaur and V. Kapur, 2004. Suppression subtractive hybridization coupled with microarray analysis to examine differential expression of genes in virus infected cells. Biol. Proced., 6: 94-104.

Naik, L.P., 1989. Studies on the effect of plant spacing and graded level of nitrogen, phosphorus and potassium on the yield and yield components of mid season garden pea (*Pisum sativum* L.). Ind. J. Hort., 46: 234-239.

Nommik, H. and K. Vahtras, 1982. Retention and Fixation of Ammonium and Ammonia in Soils. In: Nitrogen in Agricultural Soils. Agronomy Monograph 22. Madison, Wisconsin, Stevenson, F.J. (Ed.), American Society of Agronomy, USA, pp: 123-171.

Pansini, M., 1996. Natural zeolites as cation exchangers for environmental protection. Mineralium Deposita, 31: 563-575.

Pond, W.G. and F.A. Mumpton, 1984. Zeo-Agriculture: Uses of Natural Zeolites in Agriculture and Aquaculture. 1st Edn., West View Press, Boulder, Co, USA. .

Radcliffe, D.J. and G.P. Gillman, 1985. Surface Charge Characteristics of Volcanic Ash Soils from the Southern Highlands of Papua New Guinea. In: Olcanic Soils, Fernandez, C.E. and D.H. Yaalon (Eds.). Desdedt, Germany, pp: 35-46.

Rollman, L.D. and E.W. Valyocik, 1981. Inorganic Syntheses. 1st Edn., John Wily and Sons New York, .

Saggar, S.A., G.P. Parshotam, C.W. Sparling, Feltham and P.B.S. Hart, 1996. 14C-Labelled rye grass turnover and residence times in soils varying in clay content and mineralogy. Soil Biol. Biochem., 28: 1677-1686.

Shoji, S., M. Nanzyo and R. Dahlgren, 1993. Productivity and Utilization of Volcanic Ash In: Volcanic Ash Soils: Genesis, Properties and Utilization. Developments in Soil Science 21, Shoji, S. *et al*. (Eds.). Elsevier, Amsterdam, pp: 209-251.

Singh, B.G., V.J.M. Rao, C.A. Suguna and L.M. Rao, 1985. Varietal differences in growth and yield of mungbean during summer and kharif seasons. J. Plant Physiol., 28: 207-214.

Wada, K., 1989. Allophane and Immogolite. In: Minerals in Soil Environments. Dixon, J.B. and S.B. Wee (Eds.). Soil Science Society of America, Madison, WI, ISBN: 0-89118-787-1, pp: 1051-1088.

Whigham, D.K., 1983. Soybean: Symposium on Potential Productivity of Field Crops Under Different Environments. 1st Edn., International Rice Research Institute, Philippines, ISBN: 971-104-114-6 pp: 205-225.

Wilson, J., 1981. Analysis of light interception by single plant. Ann. Bot., 48: 501-505.