EFFECT OF SIMULATED ACID RAIN ON THE MORPHOLOGY, DRY WEIGHT FRACTION AND NET PRIMARY PRODUCTIVITY OF *SOLANUM MELONGENA*.

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Abstract: Proper growth of plants is essential for high productivity of food grains and vegetation which may be affected by pollutants in environment. As a part of study of the effect of acid rain on plants, its impact on the morphology, dry weight and net primary productivity was studied. Results of study are being discussed in present publication.

Keywords : *Solanum melongena*, acid rain, Dry weight fraction, net primary productivity

INTRODUCTION

Plant productivity, excellent yield of Crop with proper balance of chemical contents & healthy products of plants are of utmost importance from the point of view of people's health as well as economy of country. Myraids of factories and industrial units are pouring poisonous gases like sulphur dioxide, oxides of nitrogen in the environment which get accumulated in atmosphere and are subsequently converted into acid rain. Acid rain effects adversely to plants, hence, a number of studies have been done and are being carried out on the effect of acid rain on plants. As a part of studies on the effect of acid rain on plants effect of simulated acid rain of pH 3.0, 4.0 and 5.0 was studied on morphology, dry weight fraction and net primary productivity of *Solanum melongena*.

MATERIAL AND METHOD

The seedling of *Solanum melongena* (pusa purple cluster) were sown in each polythene bag filled with equal amounts of garden soil and campus compost. When seedlings were one week old, they were thinned to one plant in each polythene bag. Four sets of plants were prepared with 60 plants in each set.

Acid water solutions of pH 3.0, 4.0 and 5.0 were prepared with the help of pH-meter by adding mixture of H_2SO_4 and HNO_3 of the ratio of 7:3 in the distilled water.

Out of the four sets one was used as control and this was subjected to distilled water simulated acid rain (pH=7.0). The other three sets were subjected to acid rain of pH 3.0, 4.0 and 5.0. A plastic hood was placed around the base of each plant to cover the soil and only foliage was exposed to simulated acid rain. Plants were exposed to simulated acid rains. Plants were exposed to simulated acid rain twice a week till the harvest. 10 ml of acid solution of water was used for each plant each time. Regular harvest of 10 plants each were made at 15 days intervals till the harvest of crop and effect of acid rain of pH 3.0, 4.0 and 5.0 were studied on morphology, dry weight fraction and net primary productivity of the plants.

RESULTS AND DISCUSSION

Plant height : Plant height decreased as a result of simulated acid rain. The decrease in plant height was proportionate to the total accumulation of acid rain. The percentage reduction was highest in 65 days old plants. The reduction is height was 20.72% and 18.13% in plants subjected to different pH concentrations of acid-rain (pH 4.0 and 5.0). However, the effect of acid rain of pH 3.0 was greater than that of pH 5.0 and 4.0. [Table - 1]

Shoot Length : Acid rain has retarded the shoot length. The maximum decrease was recorded in 65 days old plants. The reduction was 18.40% in pH 5.0; 23.94% in pH 4.0 and 26.40% in pH 3.0 simulated acid-rain. [Table - 1]

Root Length : A decrease in average root length was recorded. However, percentage reduction in root length was much lower than in shoot length. [Table - 1]

Number of lateral branches : In the initial stages of growth there was not any marked effect of simulated acid rain on the number of lateral branches, but subsequently gradual decrease was recorded. [Table - 1]

Number of Leaves : Significant reduction in the number of leaves was observed in all treatments. The percentage reduction in the number of leaves increased with the age of plant. Maximum reduction of 30.80% was observed in 80 days old plants subjected to pH 3.0 simulated acid rain. These figures were 20.70% for pH 4.0 and 23.60 for pH 5.0 simulated acid rain respectively. [Table - 1]

Number of floral buds : Significant reduction was observed in the total number of floral buds on the plants exposed to simulated acid-rain. Maximum reduction was in 50 days old plants and subsequently there was slight recovery. The effect of pH 3.0 simulated acid rain was highest in comparison to other treatments. [Table - 1 & 2]

Number of flowers : Flowering was delayed in plants exposed to simulated acid rain in all concentrations. There was also a decrease in the number of flowers in the plants exposed to simulated acid rain. [Table - 1]

Number of buds : The average number of buds per plant also recorded a decrease as a result of simulated acid rain. The maximum reduction was in pH 3.0 simulated acid rain and the minimum in pH 5.0. At the time of harvest there was reduction in the number of buds in treated plants as compared to control. In plants subjected to pH 5.0, 4.0 and 3.0 simulated acid rain reductions were 10.70%, 15.40% and 20.10%, respectively. [Table - 2]

Seed Yield : There was decrease in total seed yield due to simulated acid rain [Table - 2]. Yield was reduced by 17.49%, 21.60% & 29.09% in pH 5.0, 4.0 and 3.0 simulated acid rain, respectively. Though the average number of seeds per plant was not affected, the weight of 100 seeds was reduced by 6.53%, 6.10% and 7.22% in pH 5.0, 4.0 and 3.0, respectively. [Table - 2]

DRY WEIGHT FRACTIONS AND NET PRIMARY PRODUCTIVITY

Data on dry matter accumulation and net primary productivity [Table - 3] show that simulated acid rain caused reduction in dry weight fractions in all treatments. These values were 0.188, 0.182 and 0.176 gm per plant in plants exposed to simulated acid rain of pH 5.0, 4.0 and 3.0 respectively as against 0.209 gm/ plant in control at the age of 20 days, 1.842, 1.816 and 1.738 gm/ plant as against 1.992 gm/ plant in control in 35 days old plants : 4.602, 4.556 and 4.411 gm/ plant as against 5.240 gm/ plant in control in 50 days old plants; 8.012, 7.868 and 7.568 gm/ plant as against 9.917 gm/ plant in control in 65 days old plants and 9.275, 9.010 and 8.709 gm/ plant as against 11.635 gm/ plant in control in 80 days old plant respectively.

Visible injury symptoms : Periodal observations of the plants subjected to simulated acid rain revealed that there were no visible injury symptoms on leaves upto the age of 35 days, but after that some injury symptoms were observed in the form of brownish spots in the marginal and interveinal areas. In general leaves that were expending rapidly or recently expanded were found to be most sensitive to the simulated acid rain. Very small, immature leaves and older leaves were found to be less sensitive.

Simulated acid rain caused visible foliar injury in *Solanum melongena* Var. "Pusa purple cluster" in the form of interveinal and marginal chlorolysis on the adaxial surface. Evans et al (1977) also observed interveinal chlorosis in the leaves of *Phaseolus Vulgaris* and *Helinathus annus* as a result of acid rain. The lessions frequency was correlated with the degree of leaf expansion. The site of initial injury is the leaf surface in which pollutant entry is facilitated through stomata [Evans et al, 1977]. Lessions, which develop due to acid rain are, localized and injury to adjacent cells occur only in localized fashion. Once a lession is formed it serves as a depression for collection of subsequent rain. Injury also developed in the marginal area, where droplets are retained after a rain event. Keever and Jacobson (1983) observed marginal Chlorosis in the leaves of *Zinnia elegans* subjected to acid rain.

Decrease in the production of photosynthate as a result of acid-rain also occurs which may be attributed to reduced leaf area and increase in the rate of respiration due to metabolic perturbation in the leaves as a result of injury. This results in decrease in chlorophyll contents [Sharma & Sharma, 2011] of *Solanum melogena.*

Reduction in plant growth due to acid rain was accompanied by reduction in dry matter accumulation and net primary productivity. These reductions can be attributed to reduction in chlorophyll contents, reduced leaf area and increased rate of respiration resulting from foliar injury. Reduced carbohydrate production may account for decrease in dry weight fractions [Feerenhaugh, 1976].

Reduction is root growth may be due to decrease in translocation of photosynthates to roots from the shoots as has been reported by Wardlaw (1968) in case of SO_2 exposures.

Reduction in the number of leaves on the plants subjected to simulated acid rain was due to inhibition of initiation and premature abscission of leaves. Ferrenbaugh (1976) also observed premature abscission of leaves in *Phaseolus Vulgaris* as a result of acid rain.

There was significant reduction in the seed yield of the plants exposed to a simulated acid rain. Decrease in the seed yield may be attributed chiefly to the decrease in the number of buds and to some extent due to decrease in seed weight. Evans et al (1981) also observed decrease in seed yield in Soyabean exposed to simulated acid rain due to decrease in the number of buds since mass per seed and number of seeds did not vary among treatments. Hindwai et. al (1980) reported reduction in seed and pod growth in *Phaseolus Vulgaris* as a result of acid rain. Irving and Miller (1981) also indicated that acid precipitation apparently caused reduction in seed weight. Lee et al (1981) have demonstrated reduction in marketable yield in five crops (radish, beet, carrot, mustard green and brocolli) on exposure to simulated acid rain.

Greater effect of pH 3.0 simulated acid rain than 4.0 and 5.0 simulated rain on plant growth and yield has been observed. In *Solanum melongena* var. Pusa purple cluster growth and yield was more adversely affected by pH 3.0 than 4.0 and 5.0 simulated acid rain. Higher adverse effect of pH 3.0 acid rain is more pronounced in leaf surface exchange reactions than pH 4.0 and 5.0 acid rains.

Reduction in seed yield was slightly less is pH 4.0 simulated acid rain than pH 5.0 simulated acid rain. This may be due to compensation in reduction by apparent increase in the nutrients (nitrogen compounds) of buds and seeds. Hindwai et al reported reduction is seed and pod growth in *Phaseolus Vulgaris* as a result of acid rain. Reduction is seed weight due to acid rains is also reported by Irving & Miller (1981).

Table 1 : Effect of simulated acid rain of pH 5.0, 4.0 and 3.0 on the morphological parameters of *solanum melogena.*

Morphological Parameters and Control/ pH	No. of Days				
	20	**35**	**50**	**65**	**80**
(1) Plant Height (cm)					
(a) Control	20.50 ±3.51	43.20 ±4.38	77.80 ±3.76	111.40 ±6.27	118.70 ±5.37
(b) pH=5.0	19.70 ±2.85	37.30 ±3.74	65.10 ±3.19	97.20 ±4.38	87.10 ±5.25
(c) pH=4.0	19.30 ±2.94	37.50 ±3.95	67.20 ±2.82	90.90 ±3.86	93.50 ±6.58
(d) pH=3.0	19.60 ±3.18	36.20 ±2.97	61.00 ±4.10	83.25 ±5.08	84.90 ±4.87
(2) Shoot length (cm)					
(a) Control	12.30 (±2.82)	22.90 ±3.31	64.70 ±4.48	94.80 ±5.46	95.90 ±4.02
(b) pH=5.0	11.80 ±3.57	22.90 ±3.81	53.70 ±3.85	72.10 ±3.95	74.00 ±4.58
(c) pH=4.0	11.50 ±2.95	27.70 ±2.86	54.80 ±3.64	75.60 ±4.89	77.10 ±5.01
(d) pH=3.0	11.60 ±3.15	26.90 ±2.54	52.20 ±2.86	68.20 ±4.62	69.90 ±3.83
(3) Root Length (cm)					
(a) Control	8.20 ±1.86	10.30 ±2.12	13.10 ±2.22	16.60 ±2.62	16.80 ±2.35
(b) pH=5.0	7.90 ±2.08	9.80 ±2.06	12.40 ±1.80	15.10 ±1.67	15.10 ±2.16
(c) pH=4.0	7.80 ±2.17	9.90 ±1.89	12.60 ±2.07	15.30 ±2.05	15.40 ±1.62
(d) pH=3.0	8.00 ±1.34	9.00 ±1.94	11.80 ±1.85	14.60 ±2.26	15.00 ±2.74
(4) No. of Branches (per plant)					
(a) Control	3.50 ±0.21	3.75 ±0.22	4.00 ±0.32	5.25 ±0.56	5.50 ±0.12
(b) pH=5.0	3.30 ±0.28	3.50 ±0.19	3.65 ±0.21	4.75 ±0.19	4.75 ±0.19
(c) pH=4.0	3.15 ±0.30	3.25 ±0.28	3.35 ±0.29	4.25 ±0.28	4.25 ±0.20
(d) pH=3.0	2.00 ±0.19	2.90 ±0.26	2.90 ±0.30	3.25 ±0.24	3.25 ±0.19
(5) No. of leaves per plant					
(a) Control	6.00 ±0.56	13.50 ±1.42	17.20 ±0.87	20.20 ±1.87	8.60 ±1.25
(b) pH=5.0	5.60 ±0.98	11.30 ±0.86	15.00 ±1.14	15.40 ±0.92	6.20 ±0.95
(c) pH=4.0	5.60 ±1.18	12.00 ±1.45	15.10 ±1.62	18.90 ±1.22	6.12 ±1.02
(d) pH=3.0	5.80 ±0.73	10.90 1.12	14.10 ±1.68	14.50 ±1.06	5.90 ±1.03
(6) No. of buds per plant					
(a) Control	-	6.50 +10.45	8.50 ±0.62	22.50 ±0.92	28.00 ±0.28

Morphological Parameters and Control/ pH	No. of Days				
	20	35	50	65	80
(b) pH=5.0	-	4.00 +0.12	6.50 ±0.42	18.50 ±0.32	24.25 ±0.16
(c) pH=4.0	-	1.00 +10.00	3.50 ±0.31	11.00 ±0.86	17.25 ±0.18
(d) pH=3.0	-	-	1.75 ±0.18	5.75 ±1.23	13.00 ±0.20
(7) No. of flowers/ Plant					
(a) Control	-	-	4.50 ±0.09	10.50 ±1.21	19.75 ±1.23
(b) pH=5.0	-	-	3.00 ±0.12	7.50 ±0.86	14.50 ±0.48
(c) pH=4.0	-	-	1.50 ±0.16	4.50 ±0.12	10.00 ±0.61
(d) pH=3.0	-	-	0.25 ±0.20	2.75 ±0.95	9.00 ±0.76

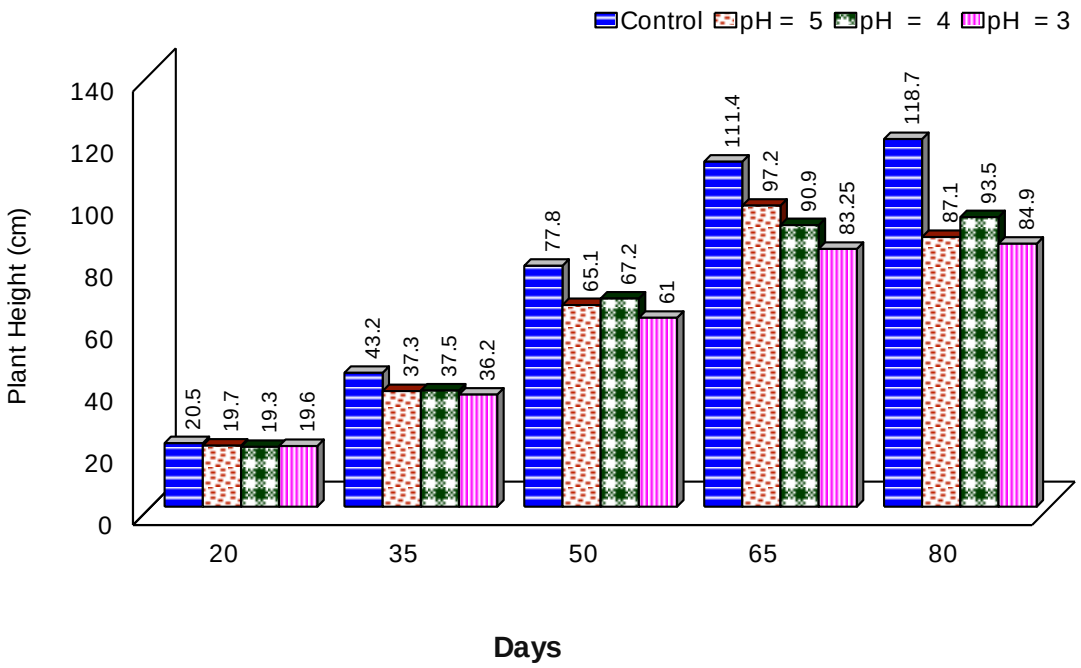
Table 2 : Effect of Simulated acid rain on the yield of *Solanum melogena* var. Pusa Puple Cluster.

	Parameter			% Decrease		
	No. of Buds	Wt of 100 seeds (gm)	Seed yield per plant	In No. of buds	In Wt of 100 seeds	Seed yield per plant
(a) Control	23.07	0.292	4.292			
(b) pH=5.0	20.1	0.276	3.451	12.69	7.53	19.59
(c) pH=4.0	19.05	0.270	3.117	17.44	6.16	22.71
(d) pH=3.0	17.1	0.268	2.922	26.21	8.22	31.91

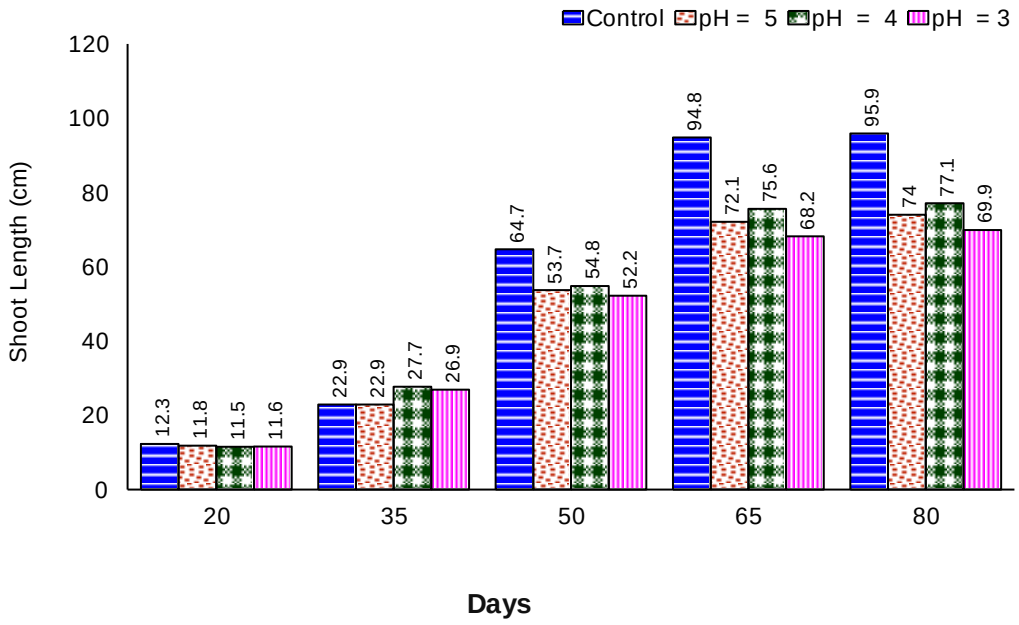
Table 3 : "Effect of simulated acid rain on dry weight fractions and Net primary productivity of *solanum melognea*"

Dry Weight Fractions gm/ pt	Plant Age														
	20 days			35 days			50 days			65 days			80 days		
	Shoot	Root	Total	Shoot	Root	Total	Shoot	Root	Total	Shoot	Root	Total	Shoot	Root	Total
(a) Control	0.188	0.021	0.209	1.656	0.336	1.992	4.628	0.612	5.240	8.992	0.925	9.917	10.513	1.122	11.635
(b) pH=5.0	0.168	0.020	0.188	1.521	0.321	1.842	4.001	0.601	4.602	7.121	0.891	8.012	8.253	1.022	9.275
(c) pH=4.0	0.165	0.017	0.182	1.498	0.318	1.816	3.998	0.558	4.556	6.981	0.887	7.868	8.012	0.998	9.010
(d) pH=3.0	0.160	0.016	0.176	1.423	0.315	1.738	3.892	0.519	4.411	6.692	0.876	7.568	7.121	0.958	8.079
Net Primary Productivity															
(a) Control	0.010			0.056			0.104			0.152			0.145		
(b) pH=5.0	0.00940			0.052			0.082			0.213			0.115		
(c) pH=4.0	0.00935			0.0519			0.082			0.121			0.112		
(d) pH=3.0	0.00900			0.049			0.090			0.116			0.107		

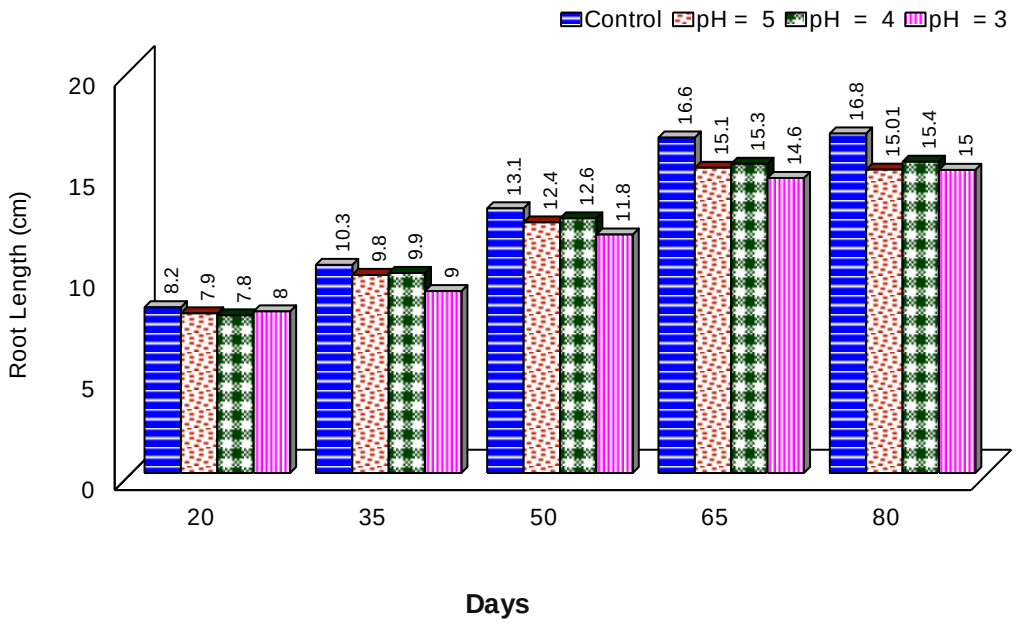
Effect of Simulated acid rain of various pH at Plant height of *Solanum melogena*



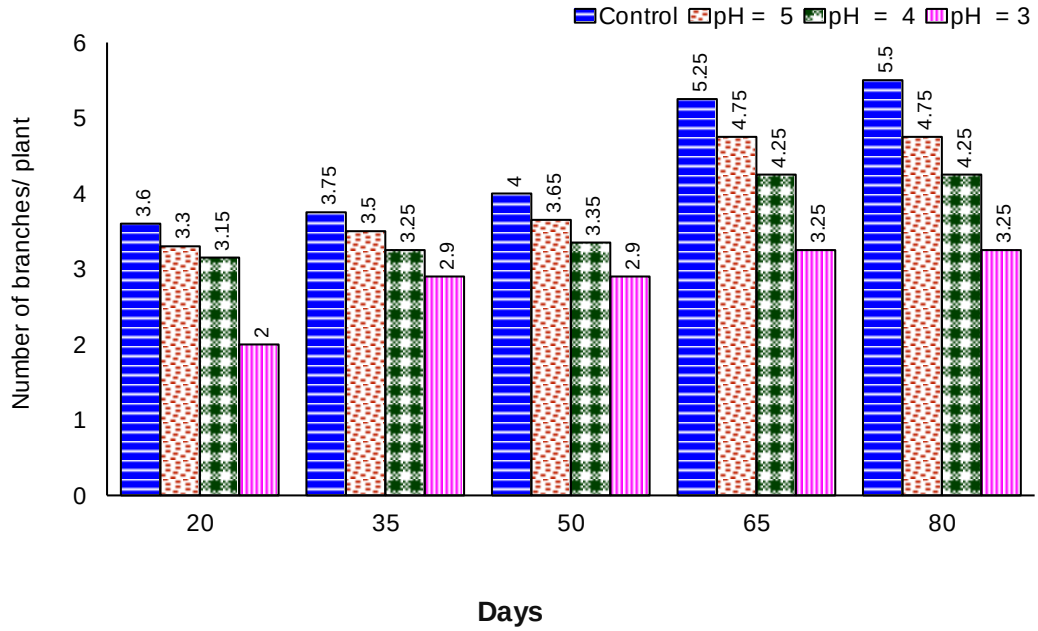
Effect of Simulated acid rain of various pH at shoot length parameters of *Solanum melogena*



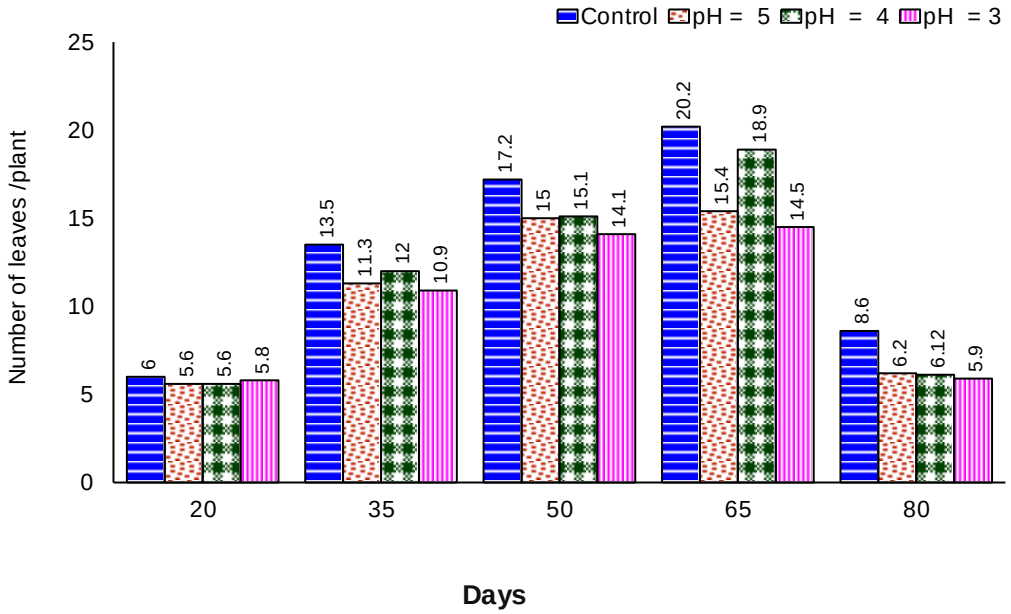
Effect of Simulated acid rain of various pH at Root length parameter of *Solanum melogena*



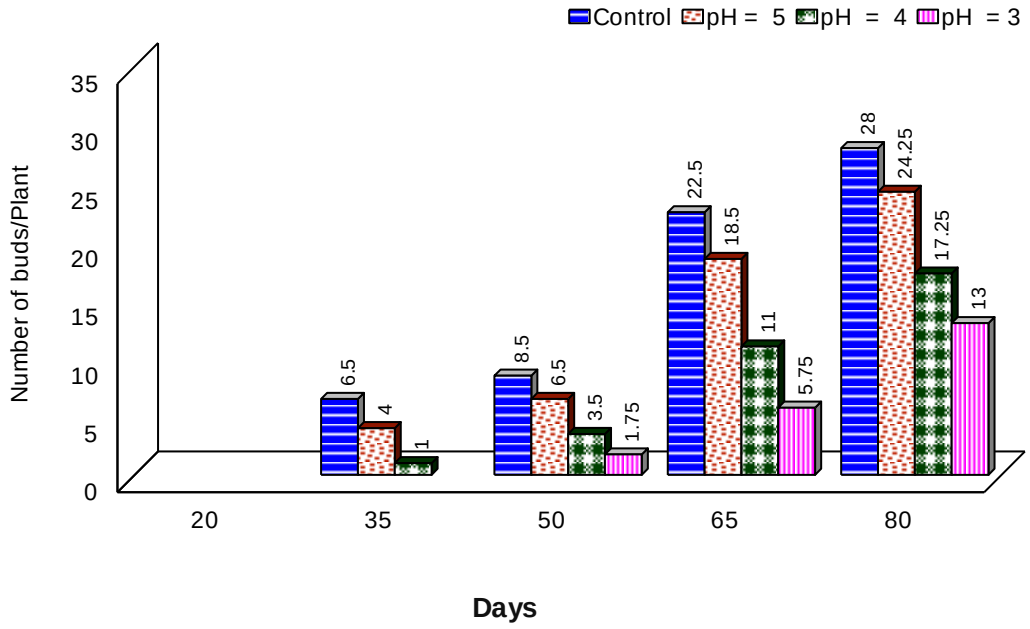
Effect of Simulated acid rain of various pH at Number of branches of *Solanum melogena*

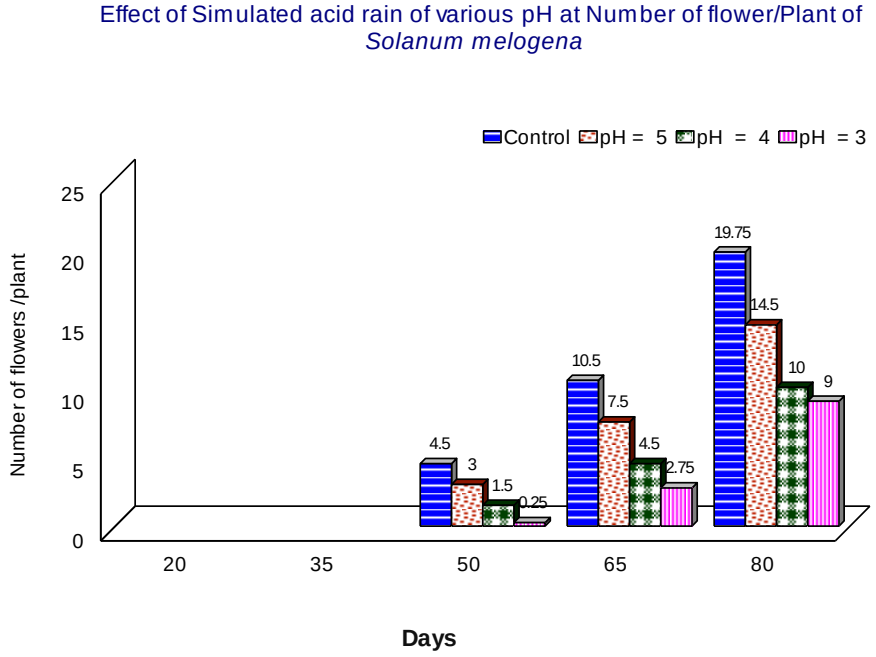


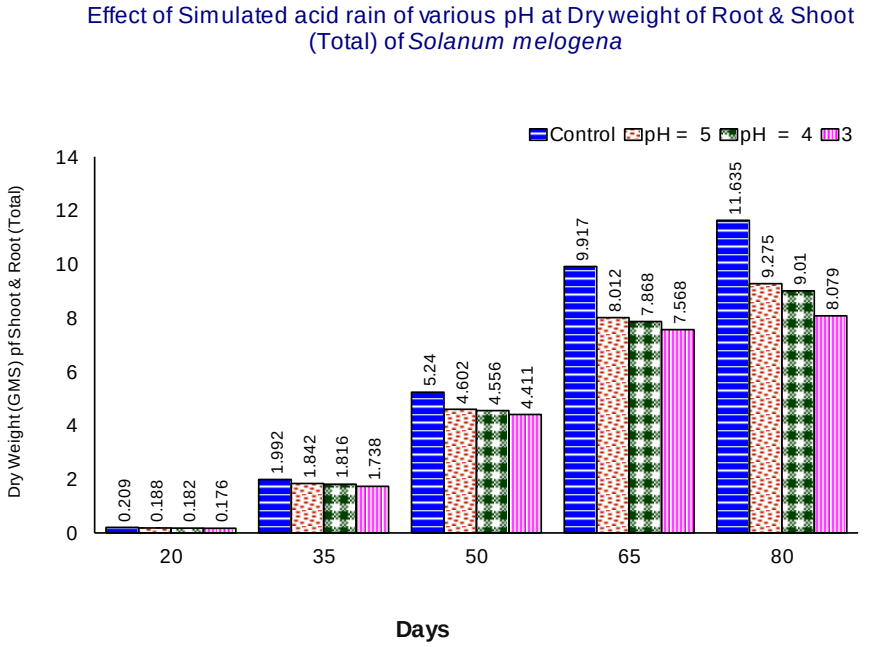
Effect of Simulated acid rain of various pH at number of leaves/plant of *Solanum melogena*



Effect of Simulated acid rain of various pH at No. of buds/ Plant of *Solanum melogena*







REFERENCES

Evans, L.S.; Curry, T.M. and Lewin, K.F. (1981). Responses of levels of *Phaseolus Vulgaris* Cultiver University of Idabo-III to simulated acid - rain, New Phytol, **88** : 403-420.

Evans, L.S.; Gmur, N.F. and De Costa, F. (1978). Leaf Surface and Foliar perturbations of Leaves of *Phaseolus Vulgaris* and *Helianthus annus* after exposure to simulated acid-nain. Amer. J. Bot., **64**: 903-913.

Ferrenhaugh, R.W. (1976). Effect of simulated acid rain on *Phaseolus Vulgaris* L-(Fabaceae). Amer. J. Bot., **63** : 383-388.

Hindawi, I. J; Rea J. A. and Griffis, W.L. (1980). Response of bush bean (*Phaseolus Vulgaris* Cultivar Condender) exposed to acid mist. Amer. J. Bot. **67** : 168-172.

Irving, P.M. and Miller, J.E. (1981). Productivity of field grown soyabeans (Glycine max. cultivar willis) exposed to acid rain and sulphur dioxide alone and in combination. J. Environ. Quality **10** : 473-478.

Johnston, J.W. Jr.; Spriner, D.S.; Klarer, C.I. and Lodge, D.M. (1982). Effect of rain pH on senescence, growth and yield of bush bean (*Phaseolus Vulgaris* Cultivar Blue - Lake 274). Environ. Exp. Bot. **22** : 324-338.

Keever, G.J. and Jacobson, J.S. (1983). Simulated acid rain effects on Zinnia (*Zinnia elegans*) as influenced by available nutrients. J. Am. Soc. Hortic. Sci. **108** : 80-83.

Lee, J.J., Neely, G.E., Perrigan, S.C. and Grotheus, L.C. (1981). Effect of simulated acid rain on yield, growth and foliar injury of several Crops. Environ. Exp. Bot. **21** : 171-185.

Likens, G.E. (1984). Acid rain : the smokestack as in the "smoking gun". Garden **8** (4) : 12-18.

Sharma, M. and Sharma, V.P. (2011). Effect of acid rain on the contents of leaves of *Solanum melongena*, Journal of Plant Development Sciences. **3** (1 & 2) : 169-173.

Wardlaw, I.F. (1968). The control and Pattern of movement of carbon hydrate in plants. Bot. Rev. **34** : 79-105.

Weathers, K.C. and Likens, G.E. (2006). Acid rain. pp. 1549-1561. In : W. N. Rom (ed.). Environmental and Occupational Medicine. Lippincott - Raven Publ., Philadelphia. Fourth Edition.