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Short communication

Foliar application of *Azatobactor chroococcum* increases leaf yield under saline conditions in mulberry (*Morus* spp.)

K. Vijayan [a,*], S.P. Chakraborti [b], P.D. Ghosh [c]

[a] *Institute of Plant and Microbial Biology, Academia Sinica, Taipei 115, Taiwan, ROC*
[b] *Central Sericultural Research and Training Institute, Berhampore, West Bengal 742101, India*
[c] *Department of Botany, University of Kalyani, Nadia, West Bengal 741235, India*

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Abstract

In this study, the effect of two nitrogenous fertilizers such as urea and the bacterial bio-fertilizer '*Azatobactor chroococcum*' on growth and development along with leaf quality was studied under various levels of NaCl in mulberry. Performance of four mulberry varieties, two tolerant and two susceptible to salt, were studied in pot culture. NaCl at different concentrations (0.0%, 0.25%, 0.50%, 0.75% and 1.00%) was applied to the pots and the required EC (1.58, 6.50, 10.10, 14.10 and 19.20 dS m^{-1}, respectively) was maintained through regular monitoring of the soil saturation extract. Urea was applied to the soil while the bacterial bio-fertilizer *A. chroococcum* was applied in two different ways such as soil application and spraying on the leaves. The results showed that salinity affects the growth and development of mulberry, however, application of nitrogenous fertilizer mitigates the harmful effects of salinity significantly in both salt tolerant and susceptible varieties. Significant variations on the response of the varieties to all treatments and their interactions were also observed. Foliar application of bacterial fertilizer was found better than soil application. Both biochemical and morphological characters showed significant level of improvement when *A. chroococcum* was sprayed on the leaves.

Keywords: Mulberry; Biofertilizer; Salinity; Leaf; Growth

1. Introduction

Soil salinity is an important growth-limiting factor for most non-halophytic plants. Salts inhibit plant growth by osmotic stress, nutritional imbalance, and specific ion toxicity (Cornillon and Palliox, 1997). Worldwide, about one-third of irrigated arable land is already affected and that level is still rising (Lazof and Bernstein, 1999; Singla and Garg, 2005). Among the several measures being used to sustain agriculture in the saline affected areas, the most attractive one is the use of salt tolerant varieties with appropriate agronomic practices. Application of nitrogenous fertilizers reduces the adverse effect of salinity on plant growth and development (Shen et al., 1994; Magdalena et al., 2003). However, over fertilization with nitrogenous fertilizer may contribute to soil salinization and increasing the negative effect of soil salinity on plant growth (Magdalena et al., 2003).

Mulberry (*Morus* spp.; Moraceae) is an economically important plant being cultivated for fruits and leaves, though in sericulture the emphasis is on leaves to feed the silkworm (*Bombyx mori* L.). Since the cost of mulberry leaf production was estimated to be more than 60% of the total cost of silkworm cocoon production (Das and Krishnaswami, 1965), efforts are being done to develop new varieties and agronomic practices to increase the leaf productivity to sustain profitability in sericulture. The general requirement of urea for mulberry plantation in India was estimated as 330 kg/ha year (Ray et al., 1973). This excessive use of chemical fertilizers has been found deleterious to the silkworm growth and developments in addition to the soil degradation it causes. Therefore, recently emphasis has been shifted to replace chemical fertilizers with biological materials (Sudhakar et al., 2000). Beneficial effect of application of *Azatobactor* in mulberry leaf production was established and demonstrated by Das et al. (1990, 1994, 1996) and Gangwar and Thengavelu (1992). Advantages of foliar application of bacterial biofertlizer on mulberry leaf production was also reported by Sudhakar et al. (2000). However, no information is available on the effect of nitrogenous fertilizers

* Corresponding author. Tel.: +886 227899590 427; fax: +886 22782 7954.
E-mail address: kvijayan01@yahoo.com (K. Vijayan).

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on the growth and development of mulberry under salinity, though India is having more than 7.61 Mha of saline affected land. Therefore, the objective of the study is to understand whether application of nitrogenous fertilizers, particularly the biofertilizer, *Azatobactor chroococcum*, alleviates or aggravates the detrimental effects of salinity on the growth and developments in mulberry.

2. Materials and methods

Six-month-old saplings of four mulberry varieties comprising two salt tolerant (C776 and Rotundiloba) and two salt sensitive (Mandalaya and Tollygunj), identified through *in vitro* and *in vivo* assessments (Vijayan et al., 2003), were planted on earthen pots containing about 35 kg of well sieved sandy loam soil thoroughly mixed with Farm Yard Manure (60:40). In each pot, a single sapling was planted. The experimental design was a three-factor (variety × salinity × fertilizer) randomized complete block design with three replications. The pots were arranged in blocks and each block contained one replicate of each treatment. When the saplings attained 3 months growth in the pot, salinity was imposed gradually, by dissolving the required NaCl in the water and irrigating the pots, until it reached the required level of EC (1.58, 6.50, 10.10, 14.10 and 19.20 dS m^{-1} for 0.0%, 0.25%, 0.5%, 0.75% and 1.00% NaCl, respectively). Once the required EC was attained on the soil, the EC of the soil was maintained at the required level by measuring the EC of soil saturation extract on every alternative day. The upper portions of the pots were covered with black polythene sheets to prevent excess evaporation of the water due to heating by sunlight. Upon attaining the required EC in the soil, the plants were pruned at a height of 10 cm above the ground. One week after sprouting of the plant the recommended dose of urea 330 kg/ha year in five split dose (Ray et al., 1973) and *Azatobacter* 150 kg N in five split dose + 200 kg/ha year urea in two split doses (Sudhakar et al., 2000) were applied. The bacterial biofertilizer was applied in two separate ways as in one method it was applied directly to the soil and in the other method it was sprayed on the shoots of the plant. Leaf yield and other related characters, along with biochemical contents of the leaf, were recorded after 60 days of growth. Number of branches sprouted from each stump recorded on 75 days of the treatment (60 days before pruning and 15 days after pruning, as the plants were pruned on day 60 for recording other data) The experiment was repeated three times (Spring, Summer and Autumn) in a single year.

Table 1
Effect of urea and *A. chroococcum* on morphological characters of mulberry under different NaCl concentrations

NaCl	Branches (numbers)				Height (cm)				Leaf size (cm^2)				Leaf yield/plant/(g)			
	Urea	AS	AF	C	Urea	AS	AF	C	Urea	AS	AF	C	Urea	AS	AF	C
Mandalaya																
0.00	3.33	6.00	5.33	5.00	49.67	52.00	51.00	47.00	125.34	92.42	125.46	90.02	17.80	24.65	26.57	12.25
0.25	4.00	6.33	4.33	4.33	37.33	48.67	43.00	44.33	110.20	69.80	87.38	86.38	15.37	22.32	20.91	15.72
0.50	3.00	2.67	3.33	2.67	48.33	39.33	36.67	26.33	93.97	68.50	49.26	43.53	10.32	13.81	12.90	6.12
0.75	2.33	2.00	2.67	2.00	38.00	27.33	32.67	25.33	41.42	47.09	41.02	28.72	6.46	8.27	8.44	3.38
1.00	1.67	1.67	2.33	1.33	27.33	18.00	19.33	12.67	27.12	27.62	27.14	15.66	3.80	3.93	4.03	1.74
Mean	2.87 a	3.73 b	3.60 ab	3.07 ab	40.13	37.07	36.53	31.13	79.61	61.09	66.06	52.90	10.75 b	14.59 c	14.57 c	7.84 a
C776																
0.00	5.00	5.00	4.00	4.00	48.00	46.33	53.33	45.67	134.39	126.23	157.54	111.42	19.82	16.74	21.91	17.22
0.25	5.00	3.67	3.67	3.00	45.00	43.67	43.00	39.33	106.26	142.66	123.72	106.15	16.85	18.42	17.77	20.74
0.50	5.00	3.67	3.67	2.67	36.00	40.33	35.67	32.00	94.09	87.95	98.35	72.58	14.66	12.74	15.74	8.39
0.75	3.00	2.33	2.33	2.33	28.00	35.00	30.33	31.33	60.23	74.69	70.87	45.99	11.61	8.51	9.75	5.89
1.00	2.00	1.67	2.00	1.67	22.67	17.67	15.00	19.00	44.22	48.15	49.88	39.89	5.62	6.50	6.25	3.84
Mean	4.00 b	3.27 ab	3.13 ab	2.73 a	35.93	36.60	35.47	33.47	87.84	95.94	100.07	73.61	13.65 b	12.58 ab	14.28 b	11.22 a
Rotundiloba																
0.00	6.67	8.00	11.00	5.00	43.33	38.33	41.33	37.67	86.17	106.15	82.75	90.91	15.85	13.01	18.15	13.52
0.25	5.33	7.00	7.00	4.00	43.67	31.33	37.67	34.33	85.69	75.68	72.79	75.78	12.90	9.54	15.05	2.61
0.50	4.00	4.67	5.00	2.33	29.00	26.00	29.00	20.67	62.13	42.81	52.78	56.99	7.40	5.60	9.44	3.81
0.75	2.33	3.3	4.33	2.00	22.67	24.33	27.33	18.33	39.33	28.66	36.12	38.90	4.96	3.99	7.54	3.14
1.00	2.00	2.00	2.33	1.67	16.00	18.00	17.33	13.33	29.46	22.04	31.22	17.01	3.40	2.68	5.08	2.10
Mean	4.07 b	5.00 c	5.93 d	3.00 a	30.93	27.60	30.50	25.07	60.56	55.07	55.13	55.92	8.90 b	6.96 ab	11.05 c	5.04 a
Tollygunj																
0.00	4.00	5.67	5.67	3.67	45.33	48.00	57.33	43.33	65.49	66.22	81.43	51.17	3.68	13.26	17.12	7.19
0.25	2.67	3.67	4.67	3.33	33.00	38.33	41.67	26.67	33.61	63.18	68.57	24.87	4.00	8.17	12.07	4.74
0.50	2.33	2.67	3.67	2.67	21.67	29.33	37.67	26.33	24.60	32.96	52.73	17.36	1.88	3.76	6.02	2.48
0.75	2.33	2.67	2.67	2.33	19.33	20.33	23.00	21.67	20.08	16.87	39.81	17.27	1.38	2.14	4.48	2.00
1.00	1.33	1.33	1.67	1.67	8.67	13.00	19.67	13.33	10.89	11.78	18.05	11.91	0.84	1.67	3.14	0.66
Mean	2.53 a	3.20 ab	3.67 b	2.73 ab	25.60	29.80	35.87	25.67	30.94	38.20	52.12	24.52	2.90 a	5.80 b	8.57 c	3.41 ab
Mean	3.37 b	3.80 bc	4.13 bc	2.88 a	32.79 ab	34.55 ab	36.07 b	30.20 a	70.21	67.93	72.72	56.30	9.80 ab	10.88 ab	13.04 b	7.49 a

Values with same letters are not significantly different at $P > 0.05$.

Data on number of primary branches sprouted, height of the longest shoot, single leaf size and leaf yield were recorded on the 60th day of pruning. Total leaf yield was recorded after 60 days of growth by plucking the leaf. For all biochemical studies, leaf samples were collected on the day 60 of the pruning. The fifth leaf from the top of each twig was used for the study. Chlorophyll, total sugar and soluble protein of the leaf were estimated following Arnon (1949), Morris (1948) and Lowry et al. (1951), respectively. The Na^+ and K^+ ions were estimated by triacid (nitric acid, perchloric acid and sulphuric acid in 10:4:1 ratio) digestion followed by estimation on a flame photometer using NaCl and KCl as standards.

Data were subjected to three-way (variety × salinity × ferti- fertilizer) analysis of variance. Means were compared between treatments by LSD (least significant difference) at the 0.05 confidence level.

3. Results and discussion

The results showed that nitrogenous fertilizers, both urea and *A. chroococcum* alleviates the detrimental effects of salinity (Tables 1–3). Salinity induced growth reduction was evident in all the four varieties studied, though it was less severe in salt tolerant varieties like C776 and Rotundiloba (Table 1). The leaf yield reduced sharply with increasing salt concentrations in Mandalya; at 0.5% NaCl the reduction was 47% and at 1.00% NaCl it was 91% where as in C776, the same at 0.5% and 1.00% NaCl was only 30% and 70%, respectively. The growth reduction under higher salinity can be attributed to the osmotic and toxic effects of the excessive salt accumulated in and around the root zone of plant (Munns, 1993). Salinity induced growth reduction can also occur due to the decrease in plastic extensibility of the growing cell wall (Cramer, 1992; Pritchard et al., 1993). The change in the cell wall permeability in mulberry under various salt concentrations, reported by Vijayan et al. (2002), indicated that under higher salinity the plasma membrane injury was more than 74% in susceptible varieties while it was only 54% in salt tolerant varieties. Nevertheless, application of nitrogenous fertilizers mitigated the salt induced injury significantly as evidenced from the mean performance of the four varieties. The overall means of the number of primary branches, plant height and leaf yield were significantly higher in plants supplied with *A. chroococcum* through foliar spraying. However, leaf size did not show any significant effect of fertilizers. Khan et al. (1997) also reported similar results in alfalfa where application of nitrate into the nutrient solution

Table 2
Effect of urea and *Azatobactor chroococccum* on leaf pigments of mulberry under different NaCl concentrations

NaCl	Chlorophyll-a (mg/g fr wt)				Chlorophyll-b (mg/g fr wt)				Carotenoid (mg/g fr wt)				Total chlorophyll (mg/g fr wt)			
	Urea	AS	AF	C	Urea	AS	AF	C	Urea	AS	AF	C	Urea	AS	AF	C
Mandalaya																
0.00	1.82	1.57	1.21	1.11	1.28	1.35	1.36	0.91	0.49	0.47	0.49	0.32	3.10	2.92	2.58	2.02
0.25	1.62	1.41	1.27	1.04	0.87	1.08	1.10	0.69	0.45	0.38	0.37	0.24	2.49	2.50	2.37	1.73
0.50	1.61	1.10	0.95	0.71	0.64	0.92	0.69	0.36	0.32	0.31	0.32	0.22	1.80	1.02	1.64	1.07
0.75	0.72	0.80	0.79	0.76	0.34	0.66	0.73	0.14	0.19	0.30	0.25	0.18	1.06	1.46	1.52	0.90
1.00	0.51	0.53	0.54	0.58	0.36	0.41	0.40	0.17	0.22	0.21	0.24	0.17	0.88	0.94	0.94	0.75
Mean	1.17 d	1.08 c	0.96 b	0.84 a	0.70 b	0.88 c	0.85 c	0.45 a	0.33 b	0.33 b	0.33 b	0.23 a	1.87 c	1.97 d	1.81 b	1.29 a
C776																
0.00	1.13	1.31	1.53	1.30	1.48	1.32	0.83	0.86	0.49	0.47	0.38	0.36	2.61	2.63	2.36	2.16
0.25	1.13	1.73	1.64	1.07	1.47	1.32	0.84	0.96	0.38	0.37	0.51	0.37	1.60	3.04	2.49	2.03
0.50	1.05	1.13	0.90	0.59	0.89	1.05	0.75	0.85	0.27	0.30	0.44	0.28	1.94	2.19	1.66	1.44
0.75	0.74	0.93	0.51	0.47	0.76	0.82	0.93	0.40	0.19	0.25	0.31	0.18	1.50	1.75	1.44	0.87
1.00	0.57	0.81	0.61	0.41	0.58	0.58	0.32	0.29	0.19	0.19	0.19	0.17	1.15	1.39	0.93	0.70
Mean	0.72 a	1.18 c	1.04 b	0.77 a	1.04 c	1.02 c	0.74 b	0.67 a	0.30 b	0.32 b	0.36 bc	0.27 a	1.76 b	2.20 c	1.77 b	1.44 a
Rotundiloba																
0.00	1.73	1.66	1.78	1.67	0.96	0.96	1.17	0.70	0.49	0.53	0.65	0.53	2.69	2.62	2.95	2.36
0.25	1.99	1.79	1.75	1.70	0.87	0.58	1.21	0.44	0.44	0.49	0.53	0.38	2.86	2.37	2.96	2.13
0.50	1.40	1.67	1.49	1.20	0.63	0.97	0.96	0.47	0.33	0.34	0.45	0.33	2.03	2.64	2.44	1.94
0.75	1.02	1.11	1.24	1.12	0.60	0.61	0.50	0.47	0.34	0.34	0.35	0.30	1.62	1.72	1.73	1.59
1.00	0.74	1.01	1.12	1.07	0.39	0.49	0.47	0.12	0.31	0.31	0.32	0.27	1.13	1.51	1.59	1.19
Mean	1.38 a	1.45 b	1.47 b	1.35 a	0.69 b	0.72 c	0.86 d	0.49 a	0.38 a	0.40 a	0.46 b	0.36 a	2.06 b	2.17 c	2.34 d	1.84 a
Tollygunj																
0.00	1.12	1.14	1.28	1.31	0.82	0.89	0.74	0.50	0.44	0.41	0.52	0.41	1.94	2.03	2.03	1.81
0.25	1.38	1.22	1.11	0.93	0.83	1.05	0.52	0.24	0.41	0.34	0.38	0.29	2.21	2.27	1.63	1.17
0.50	1.05	1.02	0.65	0.70	0.66	0.45	0.62	0.26	0.31	0.24	0.32	0.22	1.71	1.47	1.26	0.96
0.75	0.73	0.54	0.69	0.54	0.57	0.22	0.60	0.27	0.34	0.18	0.27	0.20	1.30	0.76	2.09	0.80
1.00	0.50	0.37	0.53	0.49	0.28	0.30	0.51	0.20	0.26	0.21	0.25	0.20	0.78	0.67	1.04	0.69
Mean	0.96 c	0.86 b	0.85 b	0.79 a	0.63 bc	0.58 b	0.60 b	0.29 a	0.35 b	0.28 a	0.35 b	0.27 a	1.59 c	1.44 b	1.45 b	1.09 a
Mean	1.13 b	1.14 b	1.08 ab	0.94 a	0.76 b	0.80 b	0.76 b	0.47 a	0.34 b	0.33 b	0.38 c	0.28 a	1.82 b	1.90 b	1.88 b	1.42 a

Values with same letters are not significantly different at $P > 0.05$.

Table 3
Effect of urea and *Azatobactor chroococccum* on sugar, protein, Na^+ and K^+ of mulberry under different NaCl concentrations

NaCl	Soluble sugar (mg/g fr wt)				Protein (mg/g fr wt)				Na^+ (mg/g fr wt)				K^+ (mg/g fr wt)			
	Urea	AS	AF	C	Urea	AS	AF	C	Urea	AS	AF	C	Urea	AS	AF	C
Mandalaya																
0.00	38.41	42.77	36.77	35.29	27.02	23.41	27.33	16.72	1.37	1.50	1.20	1.70	46.67	45.33	50.67	44.00
0.25	41.30	41.55	32.74	45.17	26.39	28.21	24.29	18.37	1.70	1.97	1.63	2.73	60.33	56.00	70.00	45.67
0.50	42.67	50.95	38.78	39.29	15.39	20.25	2.46	13.57	3.07	3.93	3.30	5.57	75.67	64.33	87.00	57.00
0.75	46.94	53.02	38.80	33.11	14.33	15.69	17.31	9.35	6.60	6.90	4.67	7.97	82.67	83.00	95.67	66.33
1.00	48.94	54.32	51.13	31.37	13.87	12.9	16.09	10.96	8.30	8.57	7.10	11.17	90.67	87.67	115.67	83.00
Mean	43.62 b	48.52 c	39.65 a	36.84 a	19.40 b	20.10 b	21.10 bc	13.80 a	4.21 b	4.57 c	3.58 a	5.83 d	71.20 c	67.27 b	83.80 d	59.20 a
C776																
0.00	45.61	37.92	39.12	43.33	28.08	29.39	30.31	23.10	1.50	1.40	1.20	1.70	43.0	40.00	52.33	48.67
0.25	38.45	48.73	42.21	46.64	24.93	27.34	27.93	23.75	3.93	4.10	2.73	4.50	67.00	51.67	56.00	65.67
0.50	51.45	55.10	43.13	44.09	21.32	21.66	22.42	17.07	4.47	4.50	2.57	6.43	79.00	74.67	62.00	75.33
0.75	46.18	59.12	56.52	58.40	18.18	13.88	20.03	13.40	5.93	5.73	4.97	7.90	83.33	86.33	89.33	95.67
1.00	54.65	43.67	54.16	50.19	13.60	10.74	15.8	10.59	6.40	5.80	6.13	7.73	90.67	90.67	113.00	104.67
Mean	47.29 a	48.91 a	47.03 a	48.53 a	21.22 b	20.60 b	23.31 bc	17.58 a	4.45 c	4.31 b	3.52 a	5.65 d	73.00 b	68.67 a	74.53 b	78.00 c
Rotundiloba																
0.00	24.68	29.31	31.42	26.77	21.55	25.97	29.28	24.09	1.80	1.27	1.20	2.07	37.67	39.67	46.33	35.00
0.25	30.24	29.27	33.36	29.49	19.11	27.12	28.10	20.06	1.60	2.47	1.43	3.00	38.00	44.33	57.33	42.00
0.50	34.66	31.33	38.58	32.23	16.69	21.71	22.33	17.73	5.20	3.63	1.97	5.27	40.33	36.67	55.67	47.00
0.75	40.63	35.96	43.45	39.27	14.93	17.25	18.32	12.59	4.40	6.10	4.23	6.57	58.33	64.00	65.33	63.00
1.00	42.43	33.02	43.67	41.49	13.28	11.99	11.21	10.35	5.60	7.33	4.77	7.47	70.67	81.33	78.00	69.00
Mean	34.53 a	31.78 a	38.09 b	33.85 a	17.11 a	20.81 b	21.85 b	16.96 a	3.24 b	4.16 c	2.72 a	4.87 d	49.00 a	53.20 a	60.53 b	51.20 a
Tollygunj																
0.00	26.66	25.08	28.95	26.39	22.26	25.33	24.76	18.55	1.90	1.90	1.60	1.93	23.00	20.00	16.00	26.67
0.25	27.78	29.51	30.91	34.02	14.93	26.10	26.14	19.16	2.47	2.93	2.37	2.90	15.33	27.00	23.33	24.00
0.50	28.72	30.17	37.08	37.16	13.69	10.39	20.27	12.61	7.40	3.80	3.47	5.07	33.00	26.33	30.67	29.67
0.75	33.29	33.45	42.08	27.57	10.61	9.19	17.75	10.35	9.27	6.37	5.47	7.13	32.67	36.67	39.00	39.33
1.00	24.34	27.80	28.06	23.65	10.63	7.57	15.24	7.35	5.1	8.53	8.17	10.83	40.67	44.67	51.33	40.00
Mean	28.06 a	29.20 a	33.42 b	29.76 a	14.42 a	15.72 a	20.83 b	13.61 a	5.28 c	4.71 b	4.21 a	5.57 d	28.93 a	30.93 a	32.07 a	31.73 a
Mean	38.40 a	39.60 a	39.55 a	37.25 a	18.04 a	19.31 ab	20.87 b	15.49 a	4.40 b	4.44 b	3.51 a	5.48 c	55.43 a	55.02 a	62.73 b	55.08 a

Values with same letters are not significantly different at $P > 0.05$.

ameliorated many of the salinity-induced changes in ionic compositions and subsequent growth reductions.

The detrimental effects of salinity and the mitigating effects urea and *A. chroococcum* on the salt injuries on the major leaf pigments were evident from the results (Table 2). The chlorophyll contents showed a mild increase under low salinity, but it reduced sharply under higher salinity. This reduction in the chlorophyll contents was more apparent in salt susceptible varieties. These kinds of initial increases and subsequent sharp reductions in the chlorophyll contents were in complete agreement with the earlier findings of Ramanjulu et al. (1993) in mulberry, Winicov and Seemann (1990) in alfalfa and Sleptsova and Balashova (1986) in tomato. The enhanced chlorophyll contents in the leaves is reported to help overcome the stress induced by the salt through production and allocation of more metabolites to counter act the osmotic stress (Bethke and Drew, 1992; Jimenez et al., 1997). Further, presence of higher content of chlorophyll-a than chlorophyll-b was reported to be an indication of higher adaptability of the plant to salinity (Sleptsova and Balashova, 1986). In the present study also, it could be seen that chlorophyll-a was much higher in the tolerant genotypes. This increased chlorophyll content under salinity in salt tolerant genotypes indicates the possibility of using the chlorophyll content as a preliminary selection criterion in mulberry for salinity stress as indicated by Jimenez et al. (1997). Regarding the mitigating effect of urea and *A. chroococcum*, it was clear that in all varieties plants supplied with *A. chroococcum* contained more leaf pigments than the control and plants supplied with urea. Between the soil and foliar application, foliar application was found more effective in alleviating the salt induced injury.

The results further showed that soluble sugar contents in the leaf increased with salinity up to 10 dS m^{-1} in salt tolerant varieties and up to 6.50 dS m^{-1} in salt susceptible varieties (Table 3). The application of fertilizers did not show any significant effect on the sugar contents in the leaf. Leaf protein, the most important leaf constituents as far as silkworm rearing is concerned, reduced considerably under higher salt concentrations and its reduction was greater in salt sensitive varieties (Table 3). The protein content of the salt sensitive varieties dropped drastically even at 0.25% NaCl, where as in salt tolerant varieties the same amount of reduction was observed only at 0.75% NaCl. Application *A. chroococcum* on the leaf surface has significantly reduced the salt induced protein reduction in mulberry as is evidenced from the over all mean performance of the varieties. The Na^+ contents increased, as expected, under higher salinity, but the increase was less in salt tolerant varieties as compared to that in the susceptible verities.

Application of *A. chroococcum* on the leaf surface has significantly reduced the Na^+ accumulation in all the varieties. K^+ also showed an increase under higher salinity but the increase was much low as compared with that of Na^+. Application of *A. chroococcum* on the leaf surface has significantly increased the K^+ accumulation in all the varieties.

Thus, it is clear that salinity decreased plant growth and leaf yield in mulberry and the response of the varieties to different salt concentrations varied according to their level of tolerance to salinity. Application of urea and *A. chroococcum* alleviated the growth inhibiting effects of salinity significantly. *A. chroococcum* was found much better than urea under salinity. Regarding the mode of treatments, *A. chroococcum* applied through foliar spraying resulted in enhanced growth and leaf yield than that applied in the soil. This better performance of the foliar application of *A. chroococcum*, could be due to the fixation of sufficient atmospheric nitrogen by the bacteria on the phylloplane as well as production of plant growth promoters such as auxins, gibberellins and cytokinins; which could be absorbed by the plant from the leaf as reported by Vasantharajan and Bhatt (1968) and Saxena and Tilak (1994). However, so far no work has been carried out on the application of biofertilizers in mulberry under abiotic stress conditions. In the present study, for the first time, we could demonstrate the beneficial effect of foliar application of *A. chroococcum* on mulberry leaf production under stress conditions like salinity. Further, the findings of the present study point to the possibility of expanding mulberry cultivation to salt affected regions through plantation of salt tolerant varieties and adoption of appropriate agronomic practices.

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