RESULTS

Effect of NaCl salinity and various concentrations of putrescine on shoot growth of rice

Sodium chloride salinity adversely affected growth of rice plants. NaCl, at 12 dS/m salinity level, decreased the linear growth and dry weight of the shoot system by 37 and 60% respectively of the control at the end of 30 days of salinization (Table 1). Among various concentrations of putrescine tested, a significant increase in the linear growth and dry matter production of shoot system under saline condition was obtained from 10^{-5} and 10^{-4}M putrescine treatments. The maximum stimulation of shoot growth, an increase of 30% in linear growth and 39% in dry matter accumulation, as compared to salt control was observed under 10^{-5}M putrescine treatment. In non-stressed plants also 10^{-5} and 10^{-4}M putrescine treatments significantly increased the dry matter production of the shoot system. The highest (10^{-3}M) and the lowest (10^{-6}M) concentrations of putrescine failed to make any significant change in shoot growth under saline condition. However, the shoot growth of non-salinized plants (control) was markedly reduced by putrescine at 10^{-3}M concentration. Since 10^{-5}M putrescine treatment gave maximum stimulation of growth under saline condition, this concentration was employed in all subsequent experiments.

Table 1. Effect of different concentrations of putrescine on extension growth (cm) and dry weight (g) of shoot system of rice after 30 days of salinization.

Treatments	Shoot length	Dry weight
Control	57	1.62
NaCl	36b	0.64b
NaCl + 10^{-6}M putrescine	40	0.70
NaCl + 10^{-5}M putrescine	47a	0.89a
NaCl + 10^{-4}M putrescine	44a	0.80a
NaCl + 10^{-3}M putrescine	39	0.61
10^{-6}M putrescine	56	1.57
10^{-5}M putrescine	60	1.85b
10^{-4}M putrescine	58	1.77b
10^{-3}M putrescine	52	1.35b

'a' significantly different from salt control ($P < 0.05$).

'b' significantly different from pure control ($P < 0.05$).

Plate 1. Effect of NaCl salinity (12 dS/m) and putrescine (10^{-5}M) on growth of rice.

PLATE : I

Plate 2. Effect of NaCl salinity (12 dS/m) and GA_3 (10 ppm) on growth of rice.

PLATE : 2

Extension growth, fresh weight and dry weight of shoot and root systems

Extension growth of shoot and root systems (Tables 2 and 4) of control plants progressively increased until day 30; the growth rate, however, declined considerably thereafter. Fresh weight and dry weight of shoot and root systems (Tables 6, 8, 10 and 12) continued to increase even after the cessation of elongation growth of both the plant parts. The fresh weight and dry weight accumulation of shoot and root systems, however, showed a marked decline from day 50 onwards. Plants grown under various other treatments also followed almost the same pattern of growth as that of the control. On day 60, the height, fresh weight and dry weight of shoot system (Tables 2,6 and 10) of plants grown in the presence of NaCl were only 55, 49 and 35% of the control respectively. Similarly the length, fresh and dry weights of root system (Tables, 4, 8 and 12) were also reduced to 64, 53 and 43% of the control respectively at the end of day 60.

Application of putrescine, however, enhanced the extension growth of shoot and root systems (Tables 2 and 4) of salinized plants by 35 and 23% respectively over the salt control on day 60. The shoot and root systems of salt-stressed plants, as a result of putrescine application, produced 49 and 25% respectively more fresh weight than the salt control at the end of the experiment (Tables 6 and 8).

Table 2: Effect of NaCl salinity (12 dS/m) and putrescine (10^{-5}M) on extension growth (cm) of shoot system of rice

Treatments	Days after salinization							
	0	5	10	20	30	40	50	60
Control	28	34a	44c	53c	62c	64.6c	64c	65.2c
NaCl	28	30a	32a	34.6a	36.1a	35.9a	36.2a	36a
NaCl + putrescine	28	31a	36.1b	43b	45b	46.7b	48b	48.6b
Putrescine	28	35a	46.3c	57c	60.1c	61c	62.5c	63.4c

In each column values with different letters differ significantly ($P < 0.05$)

Table 3: Effect of NaCl salinity (12 dS/m) and GA_3 (10 ppm) on extension growth (cm) of shoot system of rice

Treatments	Days after salinization							
	0	5	10	20	30	40	50	60
Control	28	34a	44c	53c	62c	64.6c	64c	65.2c
NaCl	28	30a	32a	34.6a	36a	35.9a	36.2a	36a
NaCl+GA_3	28	33a	39.8b	52b	58.3b	59b	59.5b	59.7b
GA_3	28	39b	50d	64d	72.8d	74.3d	75d	75.5d

In each column values with different letters differ significantly ($P < 0.05$).

Table 4 : Effect of NaCl salinity (12 dS/m) and putrescine (10^{-5} M) on extension growth (cm) of root system of rice

Treatments	Days after salinization							
	0	5	10	20	30	40	50	60
Control	10.5	13.3a	16.7b	21.2c	23.5c	24.2c	24.4c	26c
NaCl	10.5	11.5a	13.8a	14.6a	15a	16.2a	16.3a	16.7a
NaCl + Putrescine	10.5	12.3a	16ab	17.3b	19.2b	20.5b	21.3b	20.5b
Putrescine	10.5	14.2a	18.5b	23c	25.2c	27c	27.2c	28.2c

In each column values with different letters differ significantly ($P < 0.05$)

Table 5 : Effect of NaCl salinity (12 ds/m) and GA_3 (10 ppm) on extension growth (cm) of root system of rice.

Treatments	Days after salinization							
	0	5	10	20	30	40	50	60
Control	10.5	13.3a	16.7b	21.2c	23.5c	24.2c	24.4c	26c
NaCl	10.5	11.5a	13.8a	14.6a	15a	16.2a	16.3a	16.7a
NaCl + GA_3	10.5	13a	17b	18.5b	20.3b	21.5b	21b	21.7b
GA_3	10.5	13.5a	17.3b	22.2c	25c	26.2c	26.5c	27.3c

In each column values with different letters differ significantly ($P < 0.05$)

Table 6 : Effect of NaCl salinity (12 dS/m) and putrescine (10^{-5} M) on fresh weight (g) of shoot system of rice

Treatments	Days after salinization							
	0	5	10	20	30	40	50	60
Control	0.95	1.62b	3.07c	5.36c	7.87c	10.09c	10.29c	11.49c
NaCl	0.95	1.44a	1.94a	2.85a	4.05a	5.56a	5.60a	5.68a
NaCl+putrescine	0.95	1.51ab	2.40b	3.62b	5.71b	7.71b	8.11b	8.46b
Putrescine	0.95	1.83c	3.47d	6.43d	8.94d	11.1d	12.33d	12.83d

In each column values with different letters differ significantly ($P < 0.05$)

Table 7 : Effect of NaCl salinity (12 dS/m) and GA_3 (10 ppm) on fresh weight (g) of shoot system of rice

Treatments	Days after salinization							
	0	5	10	20	30	40	50	60
Control	0.95	1.62b	3.07c	5.36c	7.87c	10.09c	10.29c	11.49c
NaCl	0.95	1.44a	1.94a	2.85a	4.05a	5.56a	5.60a	5.68a
NaCl + GA_3	0.95	1.62ab	2.71b	4.27b	6.85b	8.91b	9.4b	9.65b
GA_3	0.95	2.53c	4.42d	7.83d	10.97d	13.43d	13.9d	14.28d

In each column values with different letters differ significantly ($P < 0.05$).

Table 8 : Effect of NaCl salinity (12 dS/m) and putrescine (10^{-5} M) on fresh weight (g) of root system of rice

Treatments	Days after salinization							
	0	5	10	20	30	40	50	60
Control	0.52	0.63b	0.79b	1.04c	1.51c	1.82c	2.04c	2.07c
NaCl	0.52	0.56a	0.63a	0.76a	0.87a	0.99a	1.04a	1.09a
NaCl + Putrescine	0.52	0.57a	0.66a	0.86b	0.99b	1.18b	1.29b	1.36b
Putrescine	0.52	0.66b	0.76b	1.12c	1.63c	1.73c	1.94c	2.21c

In each column values with different letters differ significantly ($P < 0.05$).

Table 9 : Effect of NaCl salinity (12 dS/m) and GA_3 (10 ppm) on fresh weight (g) of root system of rice

Treatments	Days after salinization							
	0	5	10	20	30	40	50	60
Control	0.52	0.63bc	0.79cb	1.04c	1.51c	1.82c	2.04c	2.07c
NaCl	0.52	0.56a	0.63a	0.76a	0.87a	0.99a	1.04a	1.09a
NaCl + GA_3	0.52	0.60ac	0.72b	0.95b	1.13b	1.48b	1.55b	1.58b
GA_3	0.52	0.65b	0.81c	1.12c	1.49c	1.79c	1.96c	2.02c

In each column values with different letters differ significantly ($P < 0.05$)

Table 10: Effect of NaCl salinity (12 dS/m) and putrescine (10^{-5} M) on dry weight (g) of shoot system of rice

	Days after salinisation							
Treatments	0	5	10	20	30	40	50	60
Control	0.27	0.44b	0.79c	1.21c	1.68c	2.11c	2.27c	2.36c
NaCl	0.27	0.29a	0.32a	0.49a	0.62a	0.74a	0.79a	0.82a
NaCl + Putrescine	0.27	0.34a	0.49b	0.68b	0.85b	1.1b	1.16b	1.18b
Putrescine	0.27	0.51b	0.83c	1.36c	1.92d	2.45d	2.66d	2.67d

In each column values with different letters differ significantly ($P < 0.05$)

Table : 11 : Effect of NaCl salinity (12 dS/m) and GA_3 (10 ppm) on dry weight (g) of shoot system of rice

Treatments	Days after salinization							
	0	5	10	20	30	40	50	60
Control	0.27	0.44c	0.79c	1.21c	1.68c	2.11c	2.27c	2.3bc
NaCl	0.27	0.29a	0.32a	0.49a	0.62a	0.74a	0.79a	0.82a
NaCl + GA_3	0.27	0.38b	0.53b	0.80b	1.16b	1.44b	1.56b	1.52b
GA_3	0.27	0.53c	0.91d	1.45d	2.08d	2.59d	2.78d	2.9d

In each column values with different letters differ significantly ($P < 0.05$).

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Table 12 : Effect of NaCl salinity (12 dS/m) and putrescine (10^{-5} M) on dry weight (mg) of root system of rice

Treatments	Days after salinization							
	0	5	10	20	30	40	50	60
Control	65	77ab	93b	140c	211c	258c	286c	294c
NaCl	65	69a	74a	89a	105a	121a	123a	125a
NaCl + Putrescine	65	73ab	80a	101b	127b	148b	159b	161b
Putrescine	65	80b	97b	146c	220c	255c	277c	286c

In each column values with different letters differ significantly ($P < 0.05$)

Table 13 : Effect of NaCl salinity (12 dS/m) and GA_3 (10 ppm) on dry weight (mg) of root system of rice

Treatments	Days after salinization							
	0	5	10	20	30	40	50	60
Control	65	77b	93c	140c	211c	258c	286c	294c
NaCl	65	69a	74a	89a	105a	121a	123a	125a
NaCl + GA_3	65	72ab	82b	107b	132b	160b	166b	171b
GA_3	65	76b	95c	145c	205c	249c	281c	290c

In each column values with different letters differ significantly ($P<0.05$).

Similarly putrescine-treated salt-stressed plants showed an increase in their dry weight of shoot and root systems by 44 and 29% respectively over the salt control on the 60th day (Tables 10 and 12).

GA_3 administration also significantly increased the growth of shoot and root systems of plants under saline condition. Plants treated with GA_3 showed a better growth of shoot system than the putrescine - treated ones under saline as well as non-saline conditions. On day 60 the linear growth, fresh weight and dry weight of shoot system of GA_3 - treated salinized plants were (Tables 3, 7, and 11), respectively, 66, 70 and 85% more than the salt-stressed plants. However, the fresh and dry weights accumulation of GA_3 - treated salt-stressed plants was much less compared with control plants. Gibberellic acid also had a pronounced effect in increasing the elongation of shoot system of rice grown under culture conditions without NaCl. Shoot elongation was 16% more in GA_3 - treated control plants compared with untreated controls on day 60 (Table 3). The growth of root system of GA_3 - treated salinized plants was much less compared with shoot growth. On day 60, the linear growth, fresh and dry weights of the root system of GA_3 - treated salinized plants registered an increase of 30, 45 and 37% respectively over the salt control (Tables 5, 9 and 13).

Table 14: Effect of NaCl salinity (12 dS/m) and putrescine (10^{-5} M) on total leaf area (cm^2) of rice

Treatments	Days after salinization					
	C	5	10	25	40	55
Control	185	201a	233c	320c	435c	457c
NaCl	185	190a	201a	226a	251a	263a
NaCl + putrescine	185	196a	217b	243b	302b	318b
Putrescine	185	204a	238c	336c	448c	471c

In each column values with different letters differ significantly ($P < 0.05$).

Table 15 : Effect of NaCl salinity (12 dS/m) and GA_3 (10 ppm) on total leaf area (cm^2) of rice.

Treatments	Days after salinization					
	0	5	10	25	40	55
Control	185	201a	233c	320d	435c	457c
NaCl	185	190a	201a	226a	251a	263a
NaCl + GA_3	185	205a	226bc	288b	359b	401b
GA_3	185	217a	261d	357c	488d	516d

In each column values with different letters differ significantly ($P < 0.05$).

Table 16. Effect of NaCl salinity (12 dS/m) and putrescine (10^{-5}M) on total chlorophyll content (mg per plant) of rice.

Treatments	Days after salinization					
	0	5	10	25	40	55
Control	2.4	3.1b	4.3c	7.2c	9.4c	7.7c
NaCl	2.4	2.5a	2.9a	3.5a	4.0a	3.3a
NaCl + putrescine	2.4	2.9ab	3.5b	5.0b	6.1b	4.5b
Putrescine	2.4	3.7c	5.6d	9.2d	11.3d	8.6d

In each column values with different letters differ significantly ($P < 0.05$).

Table 17: Effect of NaCl salinity (12 dS/m) and GA_3 (10 ppm) on total chlorophyll content (mg per plant) of rice

Treatments	Days after salinization					
	0	5	10	25	40	55
Control	2.4	3.1 ab	4.3 c	7.2 c	9.4 c	7.7 c
NaCl	2.4	2.5 a	2.9 a	3.5 a	4.0 a	3.3 a
NaCl + GA_3	2.4	2.9 a	3.7 b	6.1 b	7.3 b	5.4 b
GA_3	2.4	3.5 b	6.1 d	10.3 d	12.0 d	9.5 d

In each column values with different letters differ significantly ($P < 0.05$).

Total leaf area

The total leaf are (Table 14) of plants increased steadily until day 40 and their rate of increase declined thereafter. A similar trend was observed in the salt-stressed plants as well. Soil salinity reduced the total leaf area to 58% of the control on day 55. But the application of both growth regulators resulted in a considerable alleviation of salt-induced inhibition of leaf growth in rice. Treatment with putrescine increased the leaf area of salinized plants by 21% of the salt control by day 55 (Table 14).

GA_3 proved to be more effective in promoting leaf growth than putrescine under stressed condition. GA_3 treatment considerably increased the leaf area of salinized plants which was 52% more than that of the salt control on the 55th day (Table 15). GA_3 application resulted in a pronounced increase in the leaf area (13% more than control on day 55) in non-stressed control plants also.

Total chlorophyll content

Changes in the chlorophyll content of plants subjected to various treatments are presented in Tables 16 and 17. The maximum content of chlorophyll was present on day 40 in control as well as in salinized plants. Treatments with putrescine or GA_3 did not change the pattern of chlorophyll accumulation either in stressed or in control plants. The total chlorophyll content in the salt-stressed plants, as observed in the case of leaf area, also considerably decreased compared with control. Plants grown under saline condition showed only 43% of the control at the end of the experiment (Table 16). However, by day 55, this level was increased by 36% more than that of the salt control as a result of putrescine administration (Table 16). Treatment with GA_3 also enhanced the chlorophyll content of salinized plants. Again, as with the leaf area, GA_3 was found to be more effective in maintaining maximum chlorophyll content (65% more than that of the salt control on day 55) under salt-stressed condition (Table 17). A noticeable increase in the chlorophyll content of non-stressed plants was observed in response to putrescine and GA_3 treatments. Both putrescine and GA_3 also reduced the NaCl induced senscence associated symptoms such as yellowing of older leaves, necrosis of leaf margins etc.

<u>Sodium, chloride and potassium contents</u>

Figures 1, 3 and 5 show the concentrations of Na^+, Cl^- and K^+ in shoot and root tissues following salinization during the period of growth. During exposure to salinity shoot and root tissues accumulated very large amounts of Na^+ and Cl^- but the K^+ content was found decreased. Na^+ and Cl^- concentrations increased with time and a major portion of these ions accumulated within 10 days of salinization in both the plant parts. In the last determination

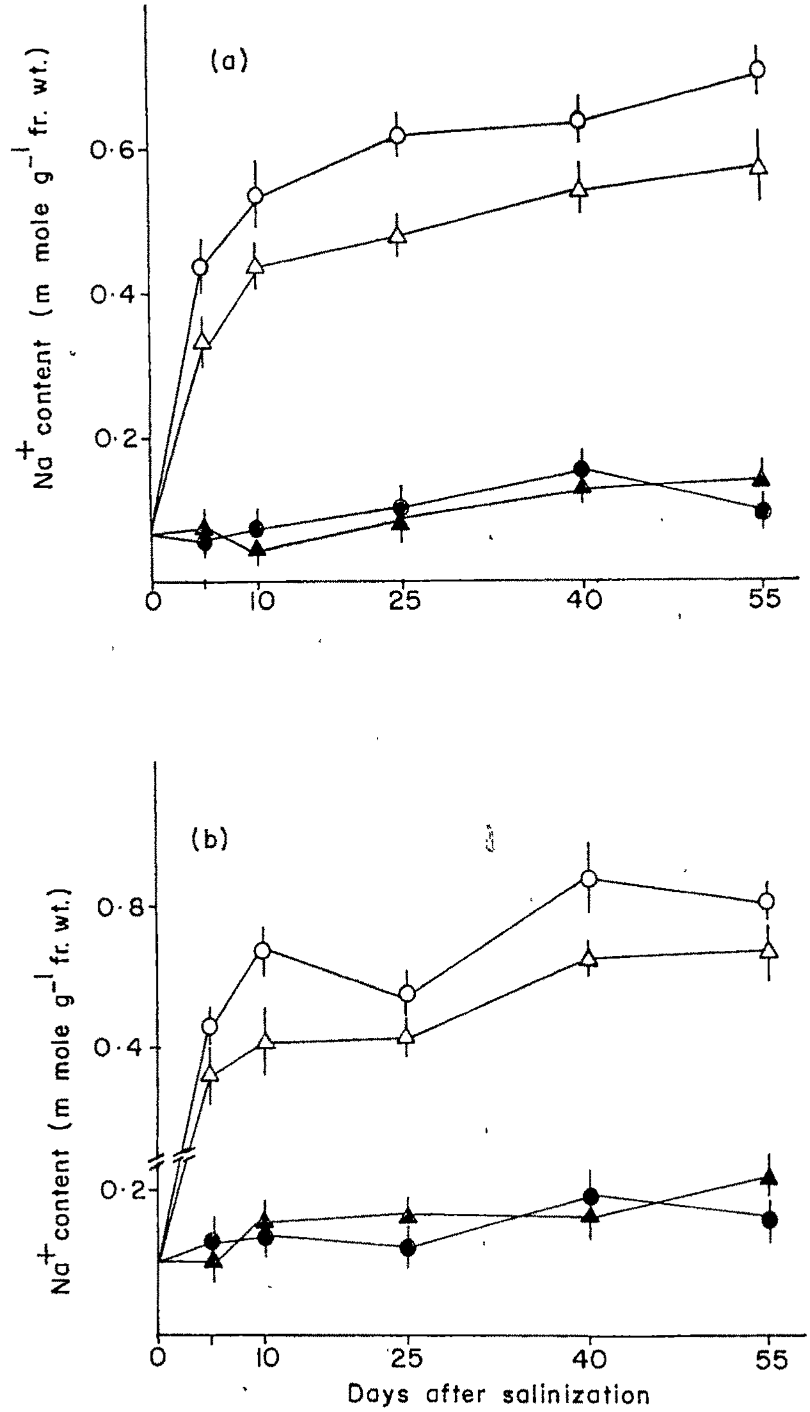


Fig. 1. Effect of NaCl salinity (12 dS/m) and putrescine (10^{-5}M) on the content of Na^+ in the shoot (a) and root (b) systems of rice. Control(●), NaCl (○), NaCl+putrescine (△), putrescine (▲). Vertical bars represent S.E. of the mean.

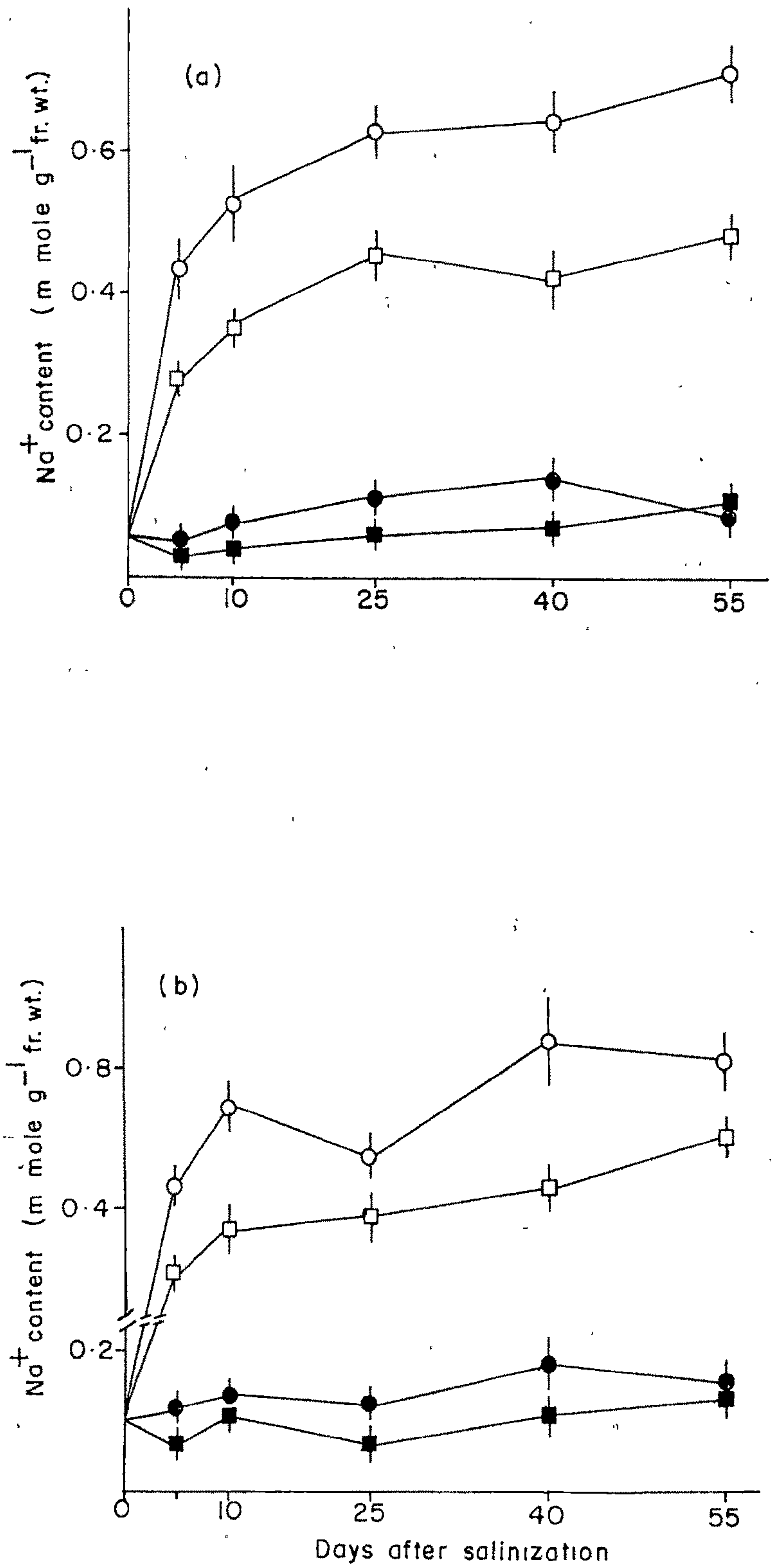


Fig. 2. Effect of NaCl salinity (12 dS/m) and GA_3 (10ppm) on the content of Na^+ in the shoot (a) and root (b) systems of rice. Control (●), NaCl (○), NaCl+GA_3(□), GA_3(■). Vertical bars represent S.E. of the mean.

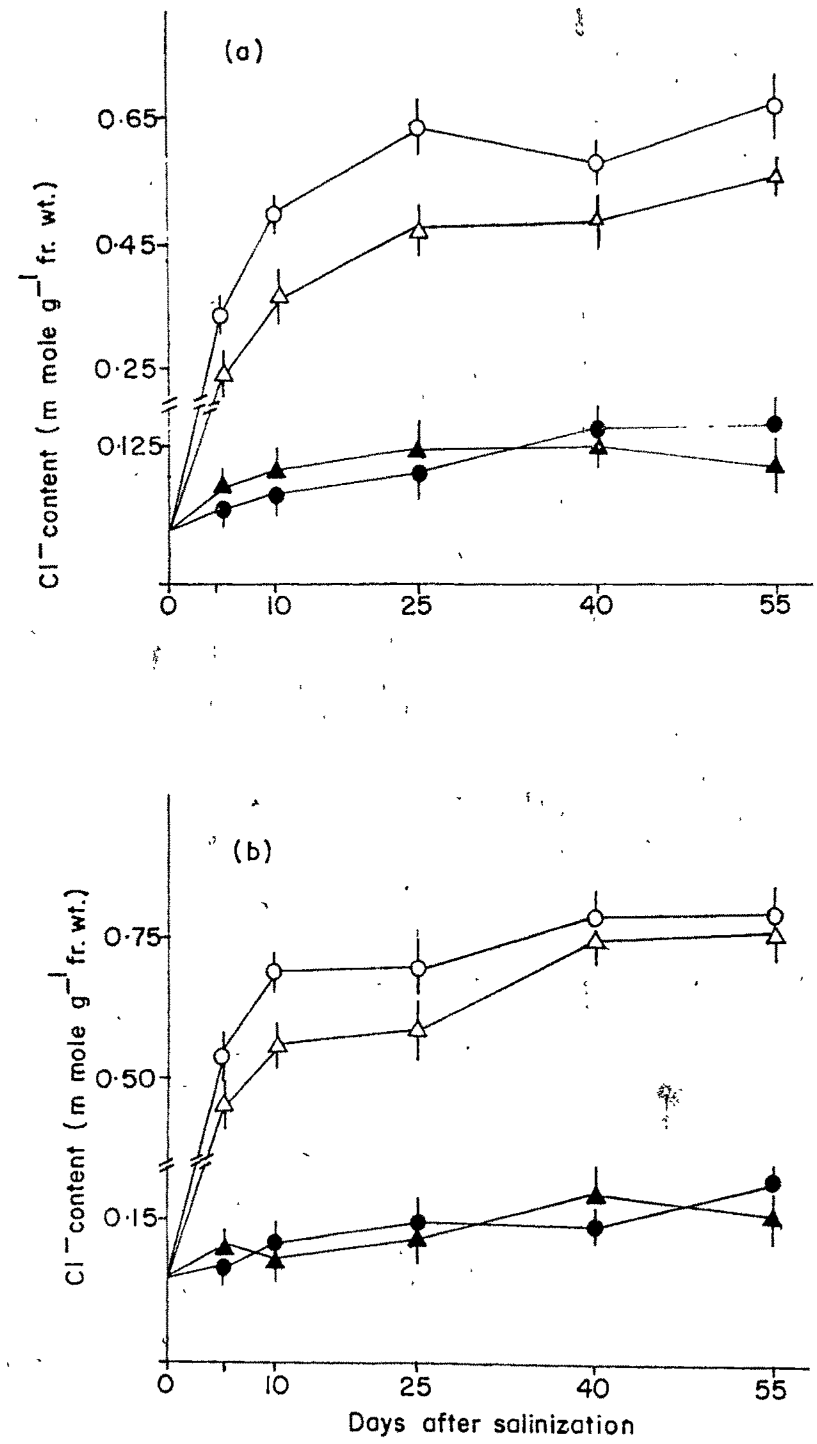


Fig. 3. Effect of NaCl salinity (12 dS/m) and putrescine (10^{-5}M) on the content of Cl^- in the shoot (a) and root (b) systems of rice. Control (●), NaCl (○), NaCl+putrescine (△), putrescine (▲). Vertical bars represent S.E. of the mean.

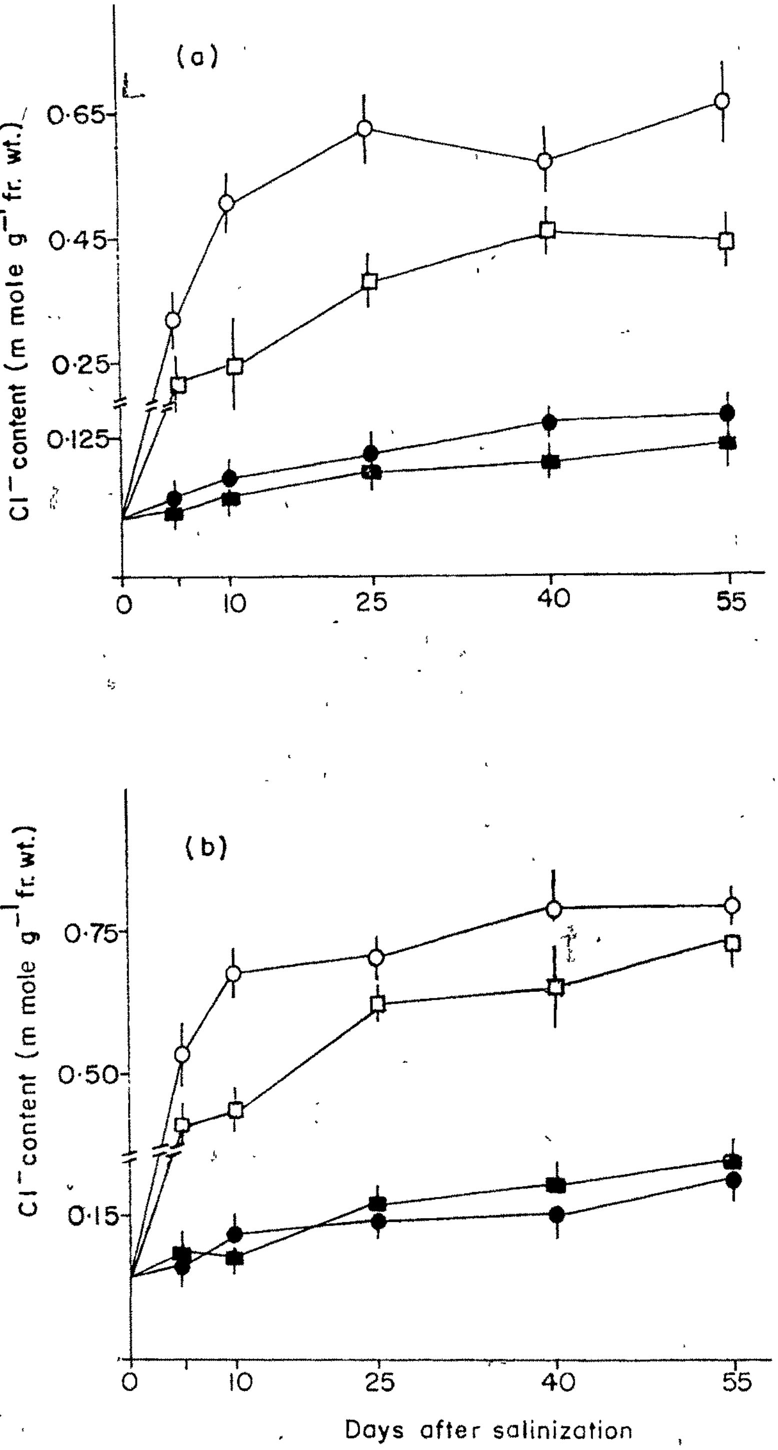


Fig. 4. Effect of NaCl salinity (12 dS/m) and GA_3 (10 ppm) on the content of Cl^- in the shoot (a) and root (b) systems of rice. Control (●), NaCl (○), NaCl+GA_3 (□), GA_3 (■). Vertical bars represent S.E. of the mean.

(on day 55) level of Na^+ in the shoot and root tissues of salinized plants registered 7, and 5.1 fold increase respectively over the control values (Fig. 1a and b). Accumulation of Na^+ in shoot and root tissues was considerably limited by the treatment of putrescine or GA_3. At the end of 55th day the levels of Na^+ in shoot and root tissues of putrescine - treated salinized plants were 20 and 15% respectively less than that of salt control (Fig. 1a and b). The shoot system of GA_3-treated salinized plants contained much less Na^+ (31% less than that of the salt control on day 55) than the putrescine - treated salt-stressed plants (Fig.2a). The root Na^+ content of GA_3 - treated salt-stressed plants showed a reduction of only 23% compared with salt control on day 55 (Fig. 2b).

The results of the Cl^- analyses indicate that shoot and root tissues of rice plants stressed with NaCl maintained high amounts of Cl^- which were respectively 5.1 and 4 fold more than the control on day 55 (Fig. 3a and b). Administration of putrescine reduced the level of Cl^- in the shoot system by 19% on day 55 as compared with salt control (Fig. 3a). However the root system of salinized plants did not show any great reduction in its Cl^- content in response to putrescine treatment. Compared to putrescine application Cl^- accumulation was found to be more sensitive to GA_3 treatment. A reduction in the level of Cl^- to the tune of

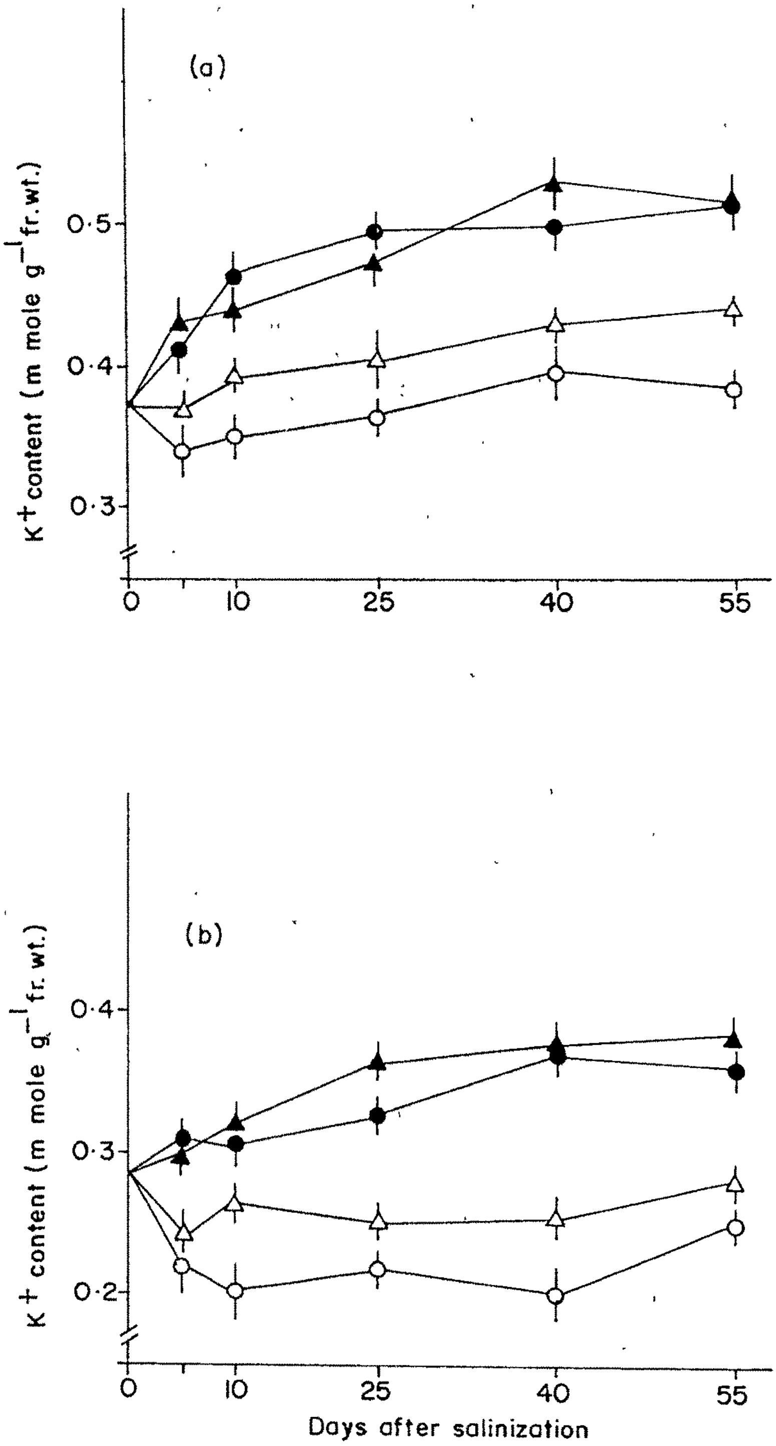


Fig. 5. Effect of NaCl salinity (12 dS/m) and putrescine (10^{-5}M) on the content of K^+ in the shoot (a) and root (b) systems of rice. Control (●), NaCl (○), NaCl+putrescine (△), putrescine (▲). Vertical bars represent S.E. of the mean.

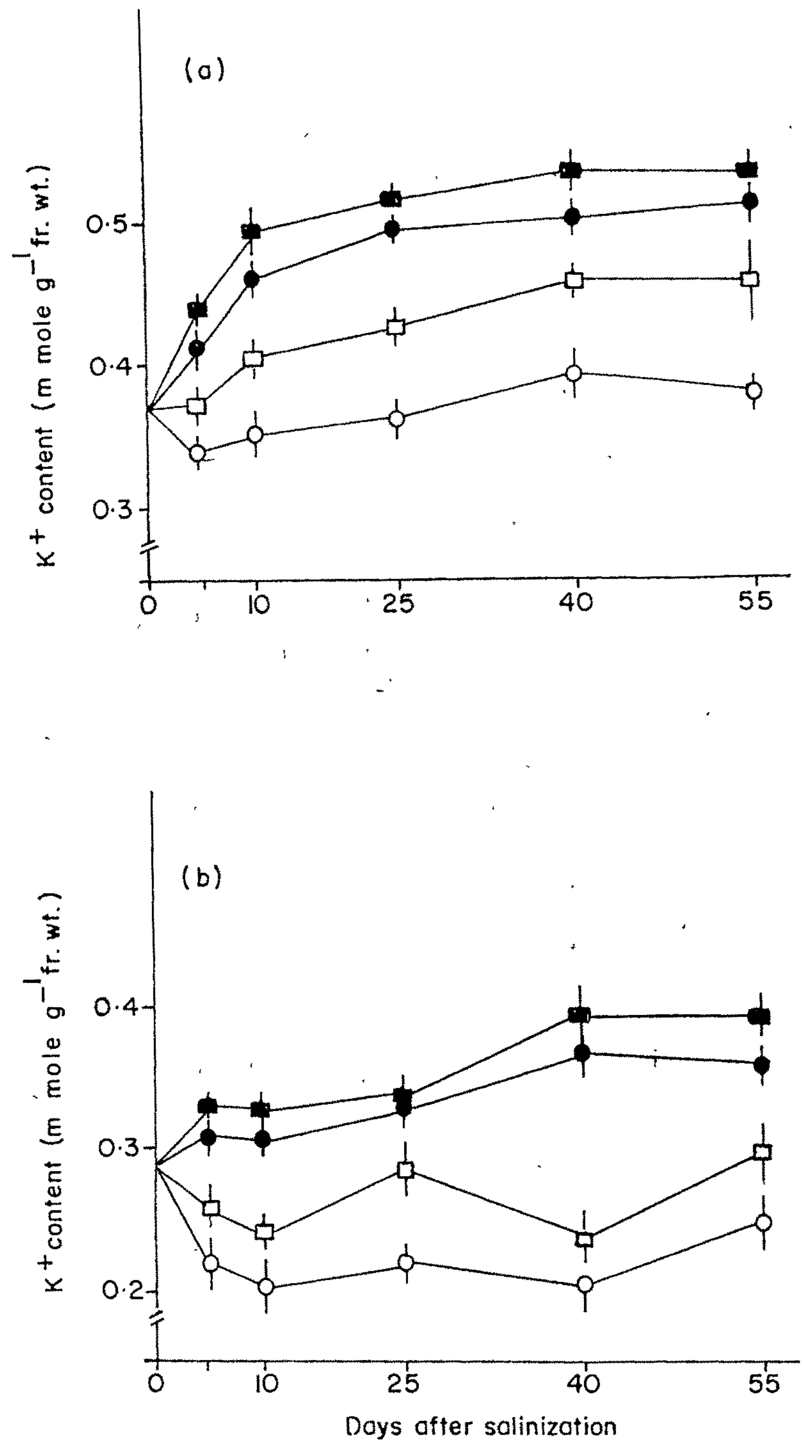


Fig. 6. Effect of NaCl salinity (12 dS/m) and putrescine GA$_3$ (10 ppm) on the content of K^+ in the shoot (a) and root (b) systems of rice. Control (●), NaCl (○), NaCl+GA$_3$ (□), GA$_3$(■). Vertical bars represent S.E. of the mean.

30% was noticed in the shoot system of GA_3-treated salinized plants compared with salt control on day 55 (Fig. 4a). A considerable inhibition in Cl^- accumulation in the root system of salt-stressed plants by GA_3 was noticed until day 25 but this effect was not discernible later on (Fig. 4b).

The K^+ contents of shoot and root tissues (Figs. 5) were 0.375 and 0.28 mmole g^{-1} fresh weight respectively prior to the imposition of salinity. Within five days of salinization the levels of K^+ dropped to lower values which did not show any dramatic alteration till the end of the experiment. The reduction in the level of K^+ in shoot and root tissues on day 55 was, respectively, 25 and 31% of the control (Fig. 5a and b). The K^+ content of the shoot and root systems of salinized plants on day 55, registered an increase of 16 and 12% respectively over the salt control as a result of putrescine application (Fig. 5a and b). However, treatment of control plants with putrescine failed to bring about any significant change in the content of K^+ in their shoot and root systems. The salinized plants with respect to K^+ content showed a better response to GA_3 application as compared to putrescine. The shoot and root tissues of GA_3 - treated salt-stressed plants accumulated 21 and 18% respectively more K^+ than that of the salt control on day 55 (Fig. 6a and b). The level of K^+ in the shoot system of control plants also exhibited a trend towards increase under the influence of GA_3.

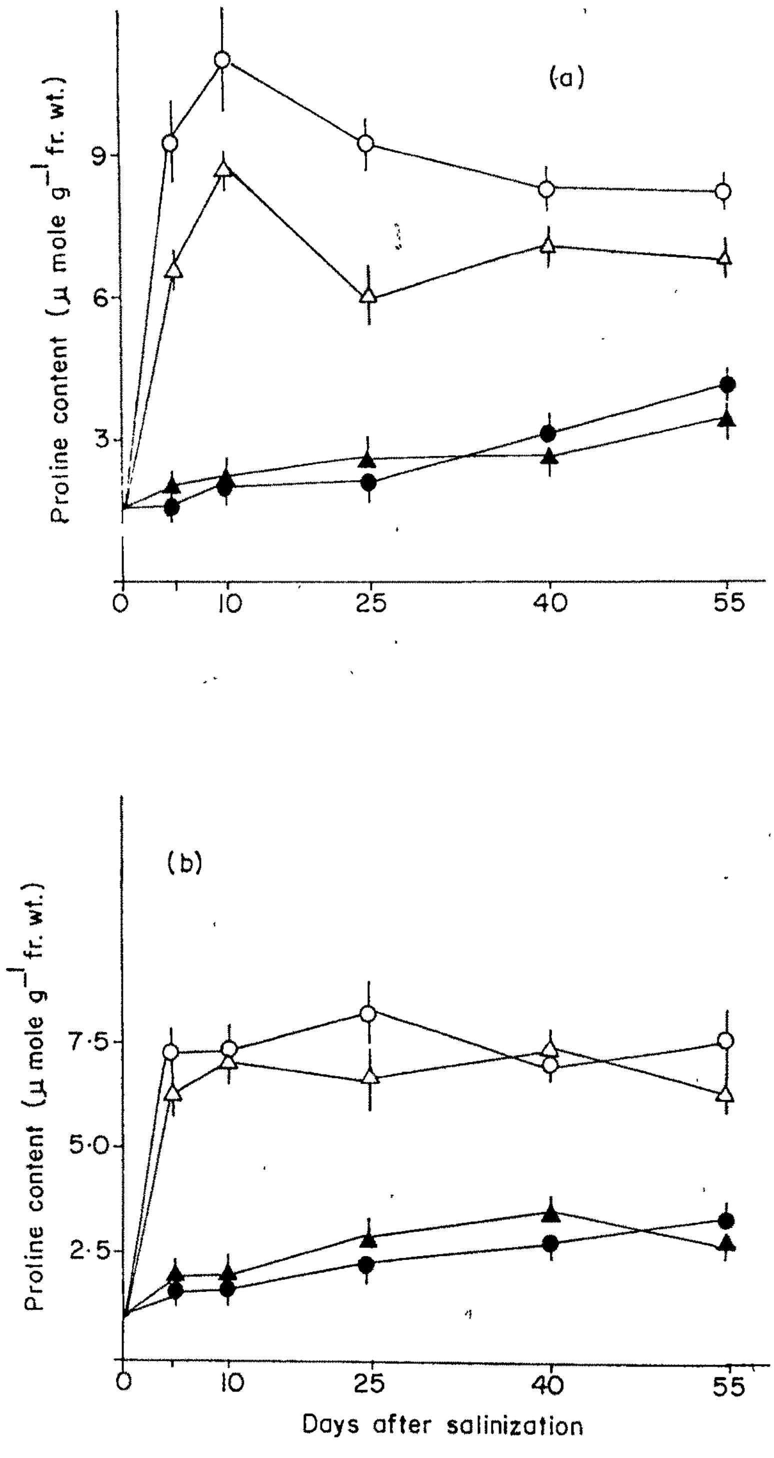
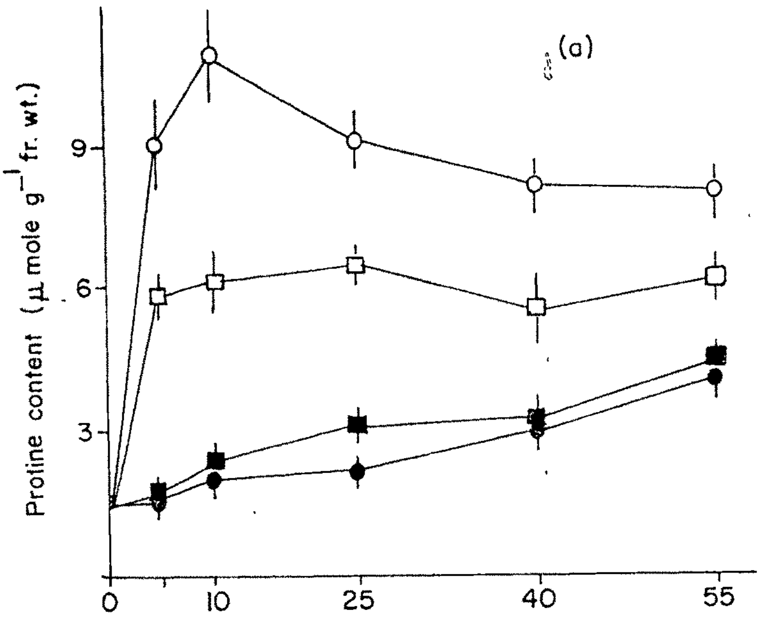


Fig. 7. Effect of NaCl salinity (12 dS/m) and putrescine (10^{-5}M) on the content of proline in the shoot (a) and root (b) systems of rice. Control(●), NaCl (○), NaCl+ putrescine (△), putrescine (▲). Vertical bars represent S.E. of the mean.



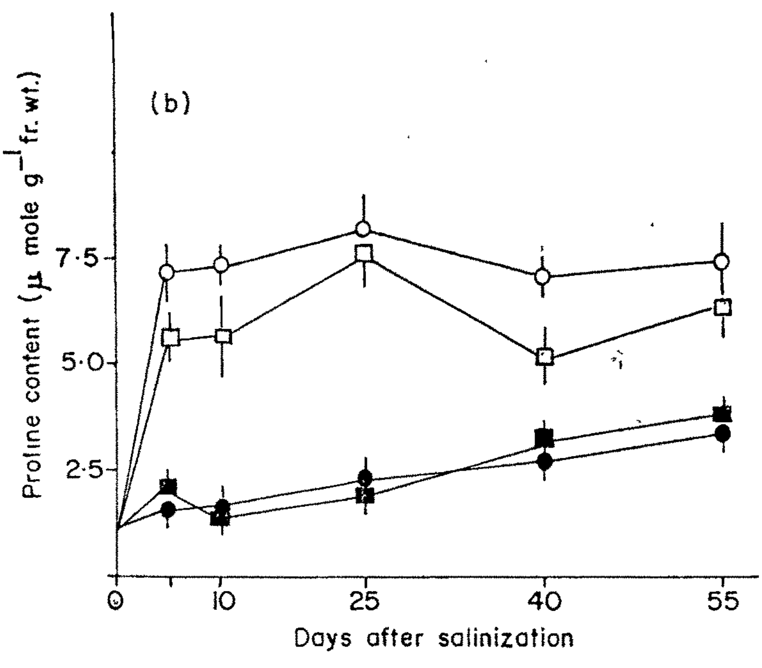


Fig. 8. Effect of NaCl salinity (12 dS/m) and GA_3 (10 ppm) on the content of proline in the shoot (a) and root(b) systems of rice. Control (●), NaCl(○), NaCl+GA_3(□), GA_3 (■). Vertical bars represent S.E. of the mean.

Free proline content

The free proline contents of shoot and root systems of control plants were very low(1.6 and 1.2 μmole g^{-1} fresh weight respectively) prior to the imposition of salt treatment (Fig. 7a and b). This level rose by 6 and 4.5 fold respectively on the fifth day of NaCl treatment. In the shoot system of salinized plants the proline content built up further, though at a lower rate, until day 10 of salinization and declined during the subsequent growth period. The root system, however, did not show any drop in its proline content as observed in the case of shoot system (Fig. 7b). Putrescine application resulted in a considerable diminution of proline content of the shoot system (Fig. 7a) of salinized plants (16% less than the salt control on day 55 following salinization), however, no such change was detected in the root tissues (Fig. 7b).

Administration of GA_3 resulted in a more conspicuous fall in the proline content of the shoot system of salt-stressed plants (27% less than the salt control at the end of 55 day period of NaCl treatment) than that observed under putrescine treatment (Fig. 8a). Proline concentration of root system of GA_3 - treated salt-stressed plants (Fig. 8b), on the other hand, registered a small reduction compared to the salt control, but this reduction was not found significant on days 25 and 55. Putrescine as well as GA_3 treatments failed to make any significant alteration in the proline content in non-stressed plants.

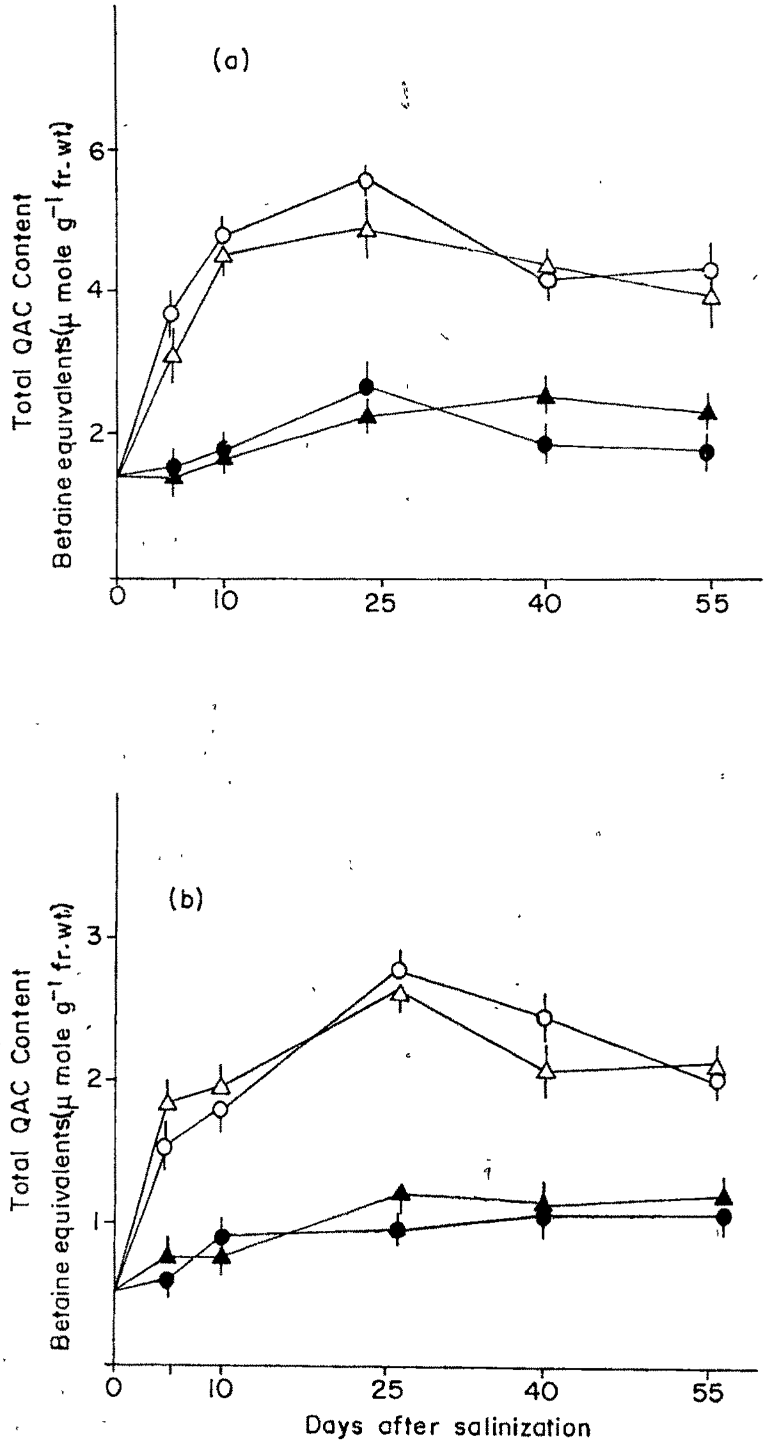


Fig. 9. Effect of NaCl salinity (12 dS/m) and total putrescine (10^{-5}M) on the content of total QAC in the shoot (a) and root (b) systems of rice. Control (●), NaCl(○), NaCl+putrescine (△), putrescine (▲). Vertical bars represent S.E. of the mean.

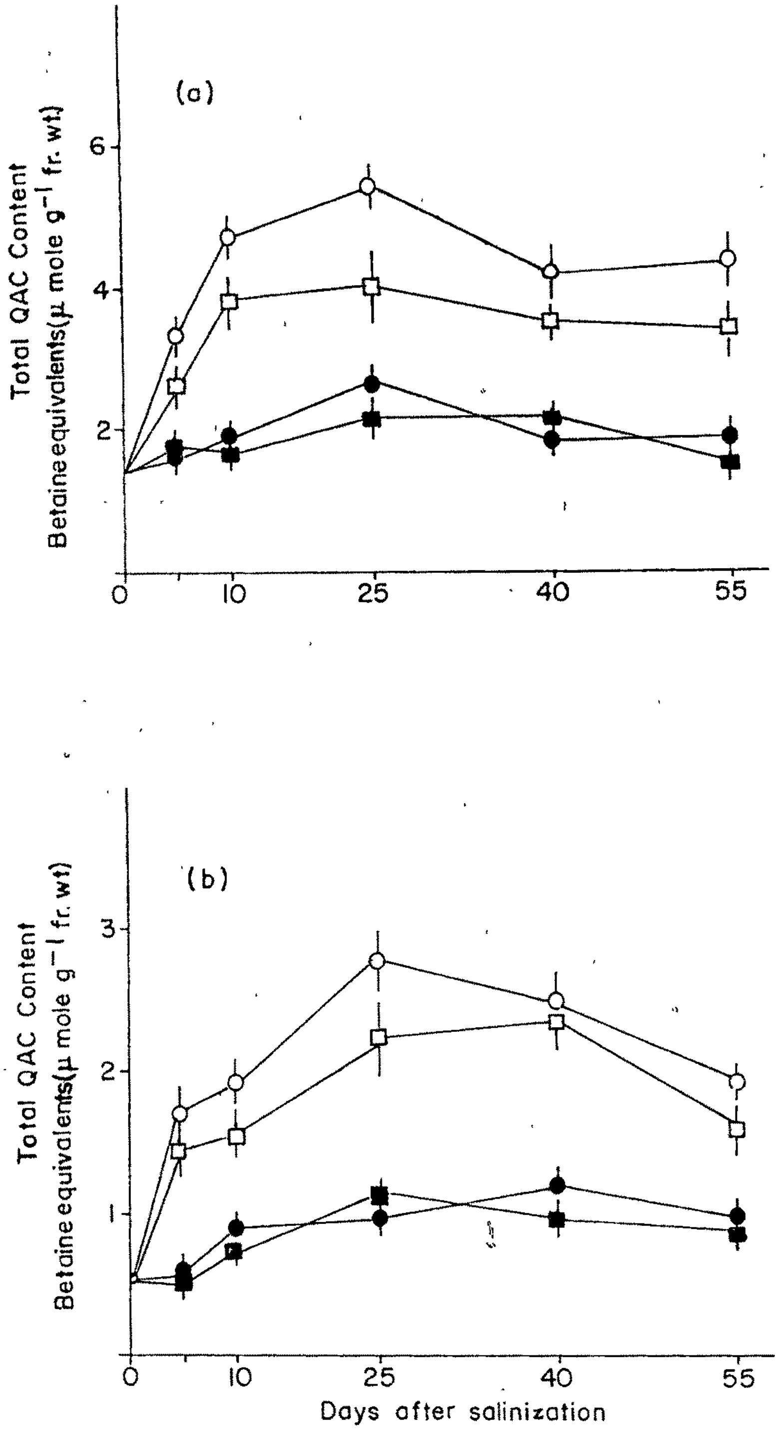


Fig. 10. Effect of NaCl salinity (12 dS/m) and GA_3 (10 ppm) on the content of total QAC in the shoot (a) and root (b) systems of rice. Control (●), NaCl (○), NaCl+GA_3 (□), GA_3(■). Vertical bars represent S.E. of the mean.

Content of total quaternary ammonium compounds (QAC)

Total QAC levels in unstressed plants did not rise above 2.7 μmole g^{-1} fresh weight during the 55 day experimental period (Fig. 9a). Like proline the level of QAC also rapidly increased in shoot and root tissues in response to salinization and it continued to rise until day 25. On day 25 following salinization, QAC levels in shoot and root systems were, respectively 2.1 and 2.7 times more than that of the corresponding control values (Fig.9a and b). Subsequently the level of these compounds reached lower value in both the plant parts. Growth regulator treatments, except in the shoot system of GA_3 - treated salt-stressed plants, could not bring about any considerable change in total QAC content either in stressed or in non-stressed plants (Figs.9 and 10). Application of GA_3 to stressed plants decreased the level of total QAC of the shoot system by 21% of the salt control on day 55 (Fig. 10a).

Indole acetic acid (IAA) content

The figures 11 and 12 illustrate the endogenous levels of free IAA at varying periods of time in shoot and root systems of rice plants subjected to different treatments. The level of IAA in the shoot system of control plants increased during the initial stages of growth (up to day 10 of the experiment) and remained steady until day 25, after which the IAA content declined to lower levels (Fig 11 a).

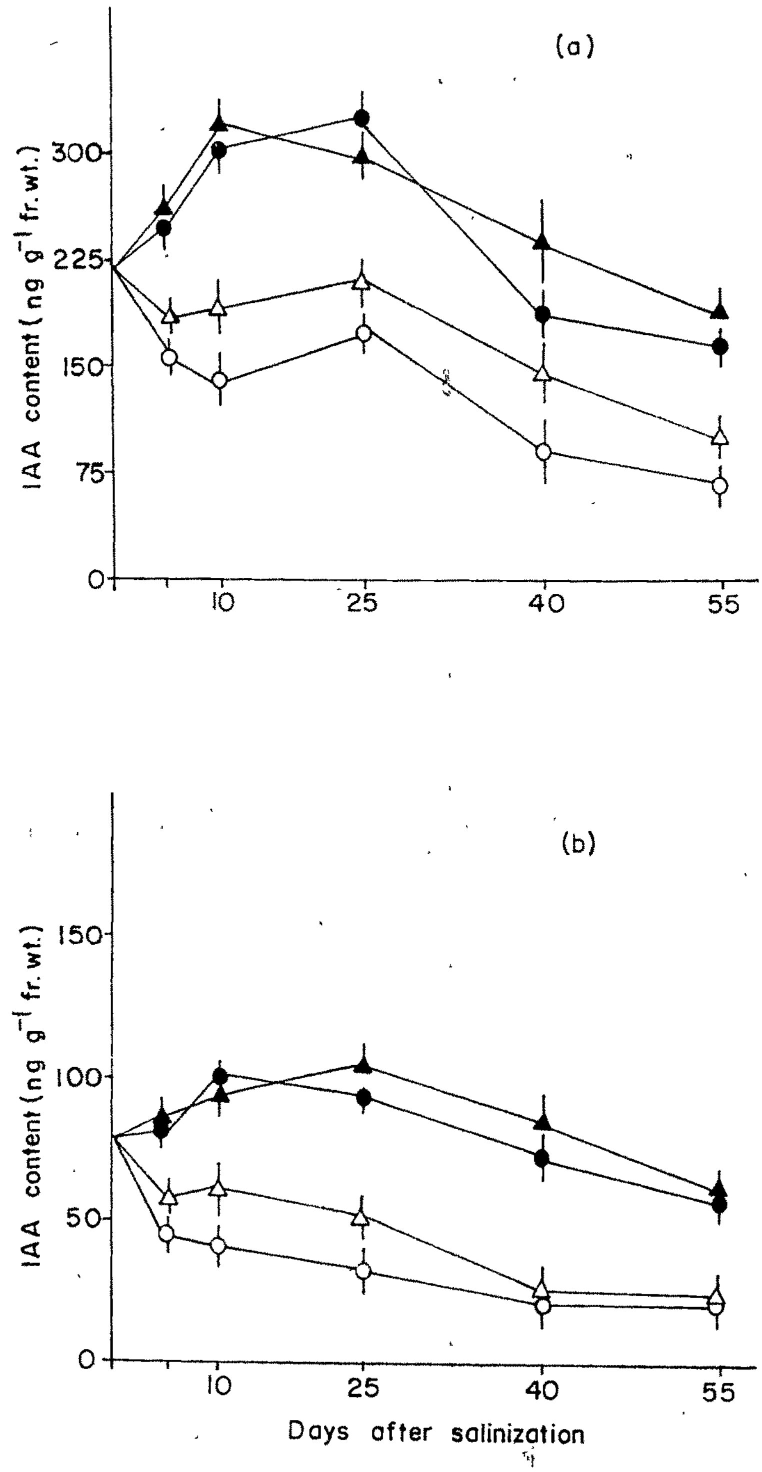


Fig. 11. Effect of NaCl salinity (12 dS/m) and putrescine (10^{-5}M) on the content of IAA in the shoot (a) and root(b) systems of rice. Control(●), NaCl(○), NaCl+putrescine(△), putrescine (▲). Vertical bars represent S.E. of the mean.

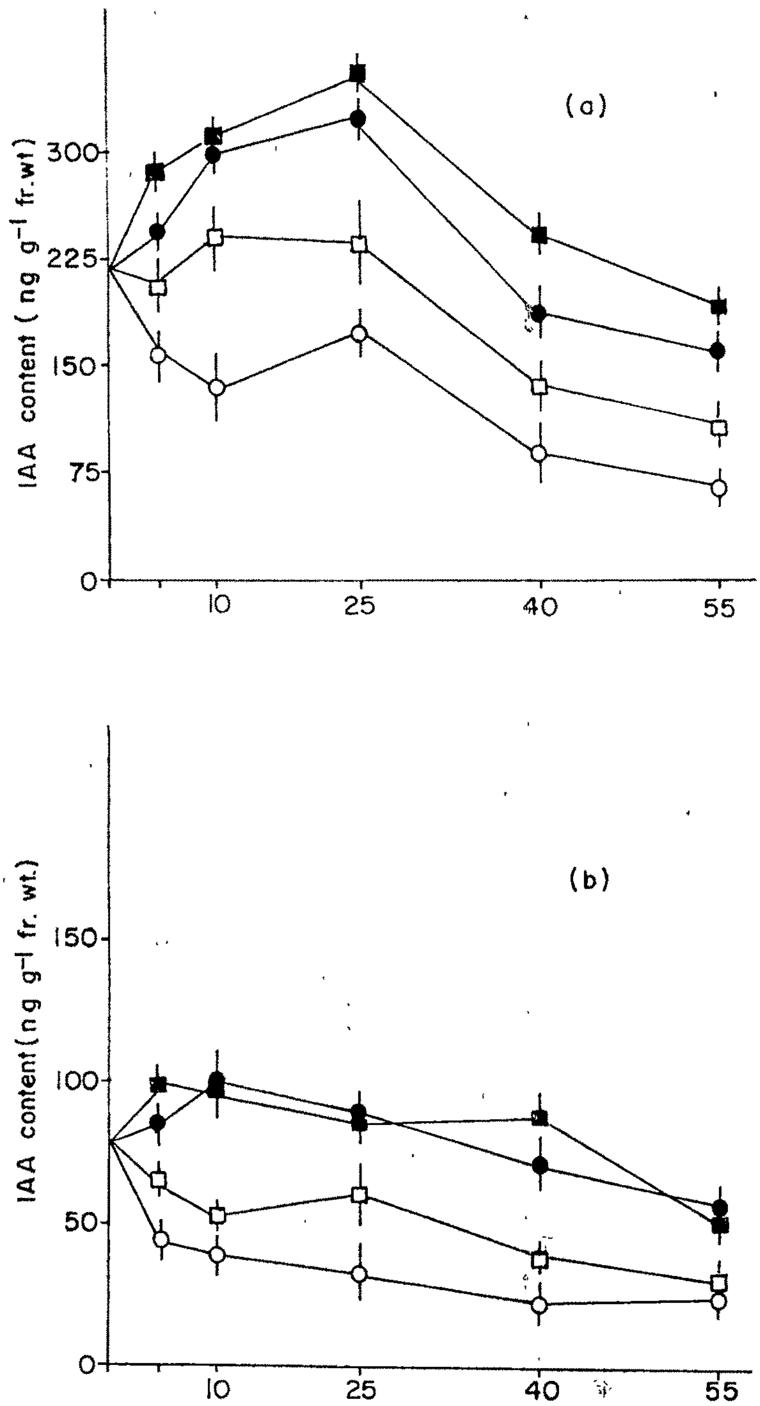


Fig.12. Effect of NaCl salinity (12 dS/m) and GA_3 (10 ppm) on the content of IAA in the shoot (a) and root(b) systems of rice. Control (●), NaCl(○), NaCl+GA_3 (□), GA_3(■). Vertical bars represent S.E. of the mean.

In the case of root system, IAA content increased during first 10 days of growth and registered a declining trend thereafter (Fig. 11b). Apparently in rice plants salinity reduced the amount of auxin available for growth. The free IAA contents in shoot and root tissues of salt-stressed plants were only 45 and 40% respectively of the control on day 55 (Fig. 11 a and b). An appreciable improvement in the content of IAA (35% more than that of salt control on day 55) was recorded in the shoot system of putrescine-treated salt-stressed plants while the root system displayed a significant increase in its IAA content only till the 25th day (Fig. 11 a and b).

Both shoot and root tissues of GA_3-treated salt-stressed plants showed higher levels of IAA than those of putrescine-treated salt-stressed plants. (Fig.12 a and b). On day 55 shoot system of GA_3-treated salt-stressed plants contained 53% more of IAA than that of the salt control (Fig.12a). A noticeable increase in the IAA content of the root system of salt-affected GA_3-treated plants was discernible only upto the 40th day (Fig.12b). No marked change in IAA content was found in non-stressed plants in response to putrescine administration, whereas GA_3 slightly enhanced the IAA level in the shoot system.

Content of GA-like substances

GA-like substance (Fig.13) in the shoot system of control plants progressively increased parallel to growth and attained

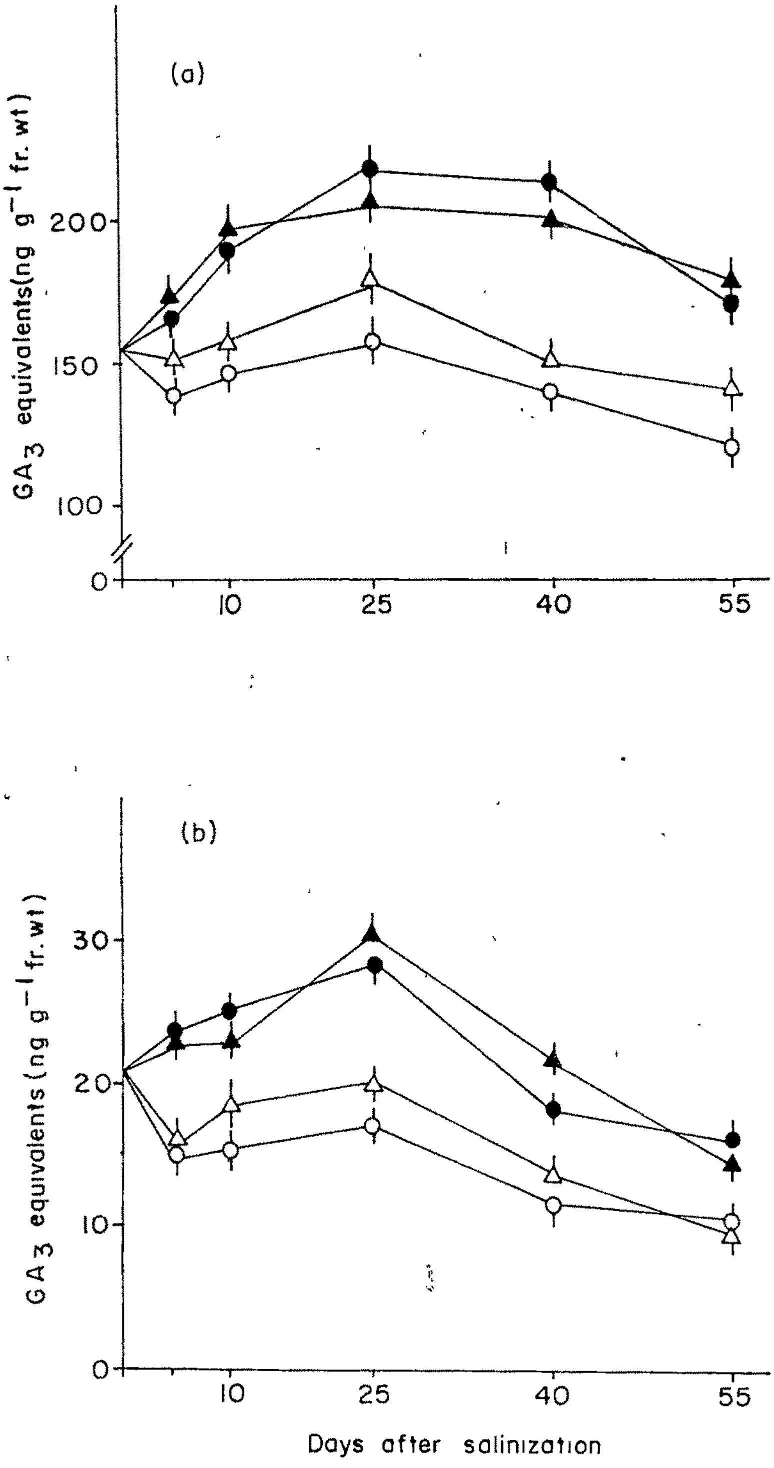


Fig. 13. Effect of NaCl salinity (12 dS/m) and putrescine (10^{-5}M) on the content of gibberellic acid like substances in the shoot(a) and root(b) systems of rice. Control(●), NaCl(○), NaCl+putrescine (△), putrescine (▲). Vertical bars represent S.E. of the mean.

its maximum level by day 25 and maintained that level until day 40 (Fig. 13a). The content of GA-like substances considerably decreased subsequently. As in the case of shoot the maximum content of GA-like substances in the root system of control plants was detected on day 25, however its level greatly reduced later on (Fig. 13b). Salinization of growing medium substantially reduced the content of GA-like substances in both shoot and root (29 and 33 % respectively less than the control value on day 55) systems (Fig.13). Administration of putrescine slightly enhanced the level of GA-like substances in the shoot system of salt-stressed plants whereas it could not make any change in the root system of salt-affected plants. The content of GA-like substances in the shoot system of putrescine-treated NaCl-stressed plant was 14% more than that of the salt control on day 55 (Fig.13a).

Abscisic acid (ABA) content

The content of free ABA in control plants was very low during the active growth phase but slowly increased to higher values in both shoot and root systems as their rate of growth decreased (Fig.14). When plants were subjected to salt stress free ABA content of shoot tissue rose rapidly for 5 days and reached its maximum level which was 7 times more than the corresponding control value (Fig.14a). The ABA content then declined but remained consistently higher than that of non-salinized plants throughout the experiment. The level of ABA

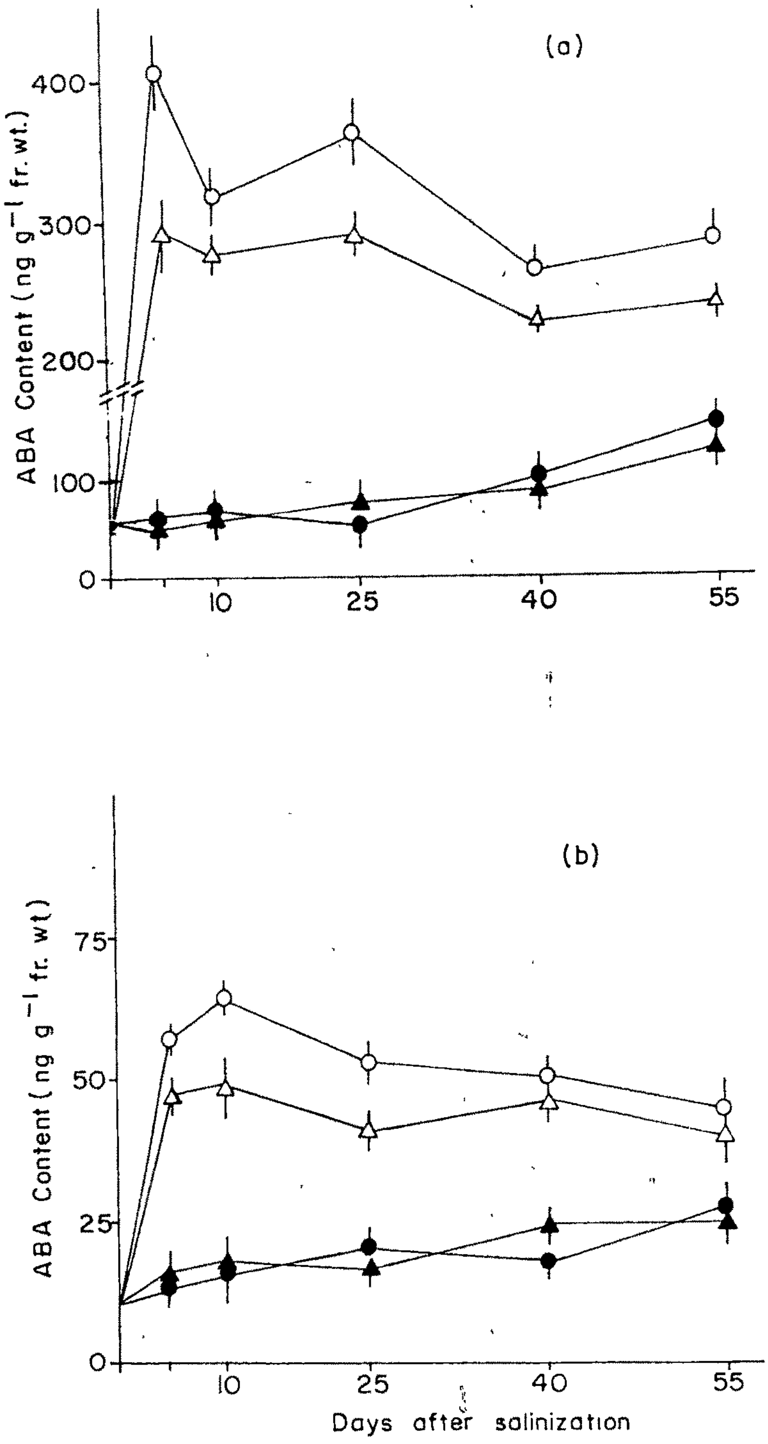


Fig. 14. Effect of NaCl salinity (12 dS/m) and putrescine (10^{-5}M) on the content of ABA in the shoot (a) and root (b) systems of rice. Control (●), NaCl (○), NaCl+putrescine (△), putrescine (▲). Vertical bars represent S.E. of the mean.

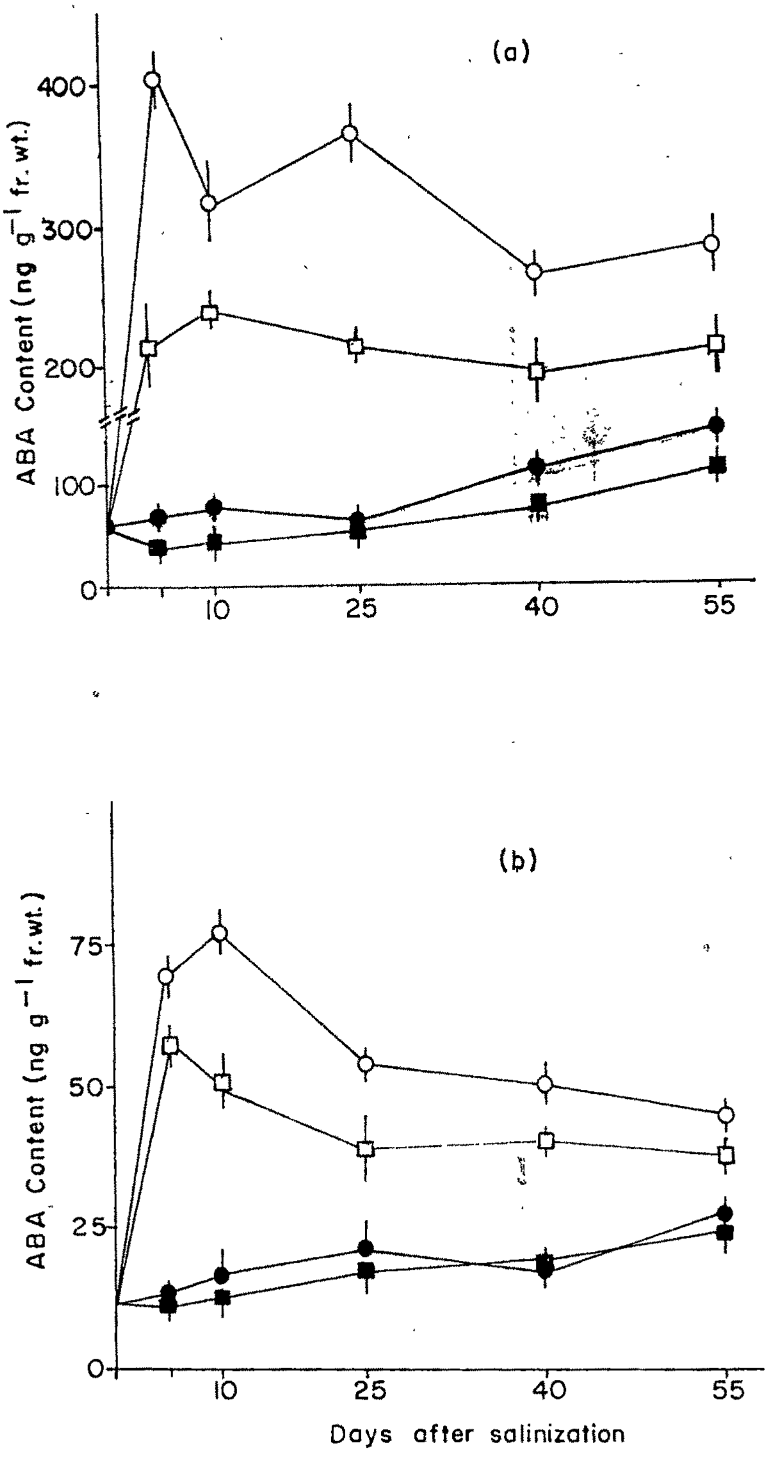
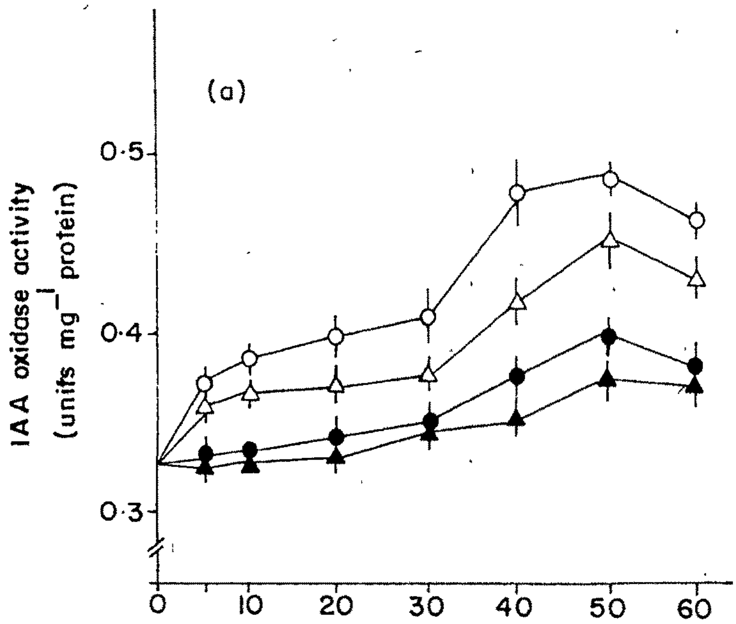


Fig. 15. Effect of NaCl salinity (12 dS/m) and GA_3 (10 ppm) on the content of ABA in the shoot (a) and root (b) systems of rice. Control (●), NaCl (○), NaCl+GA_3 (□), GA_3(■). Vertical bars represent S.E. of the mean.

in the root system of salt-stressed plants, after a rapid and conspicuous hike during the first 5 days of experiment, continued to increase and attained the maximum level by day 10 which was 5 times more than that of the control value. The ABA level declined gradually thereafter (Fig. 14 b).

NaCl induced accumulation of ABA in the shoot system was markedly influenced by putrescine application. Treatment of plants with putrescine supressed the build up of free ABA in the shoot system of salinized plants by 14% (of the salt control) at the end of day 55 (Fig. 14a). The root system of putrescine - treated salt - stressed plants on the other hand, showed a significant reduction in its ABA content only until day 25 (Fig. 14 b). Consequently the ABA content shot up and reached a value near to that of the salt control. Gibberellic acid was found more effective in counteracting ABA accumulation in rice plants exposed to NaCl. At the end of the experiment the shoot and root systems of GA_3 - treated salt - stressed plants contained, respectively, 26 and 15% less ABA than the salt control (Fig. 15 a and b). No considerable variation in the ABA content in control plants could be noticed despite their treatment with putrescine whereas a slight decrease in the ABA content was evident in the shoot system of GA_3 - treated control plants.



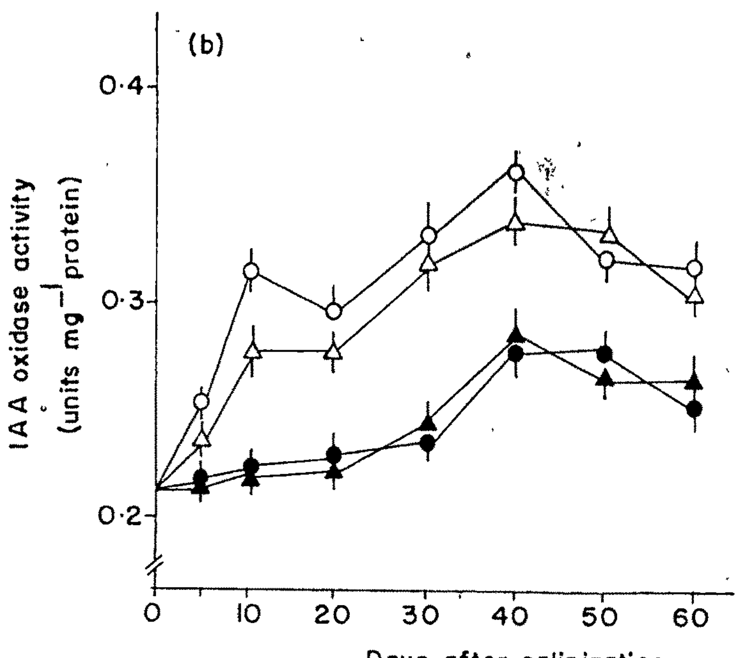
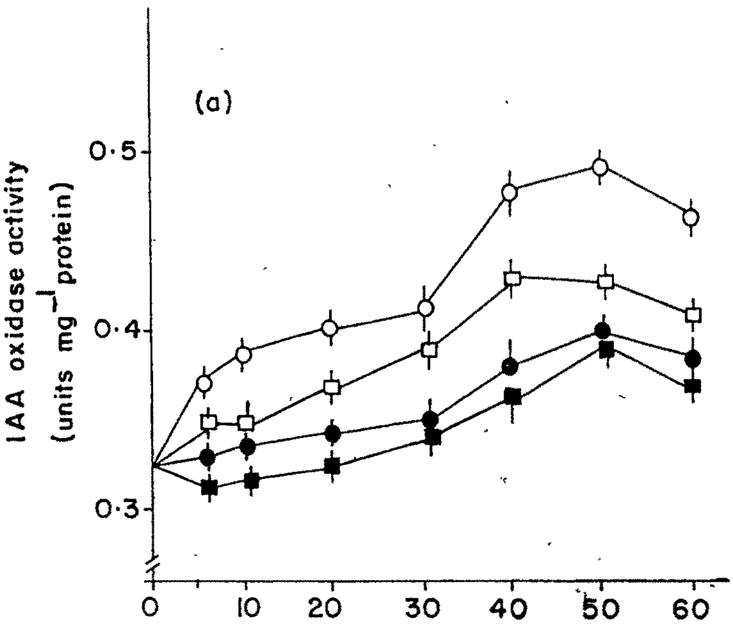


Fig. 16. Effect of NaCl salinity (12 dS/m) and putrescine (10^{-5}M) on the activity of IAA oxidase in the shoot (a) and root (b) systems of rice. Control (●), NaCl (○), NaCl+putrescine (△), putrescine(▲). Vertical bars represent S.E.of the mean.



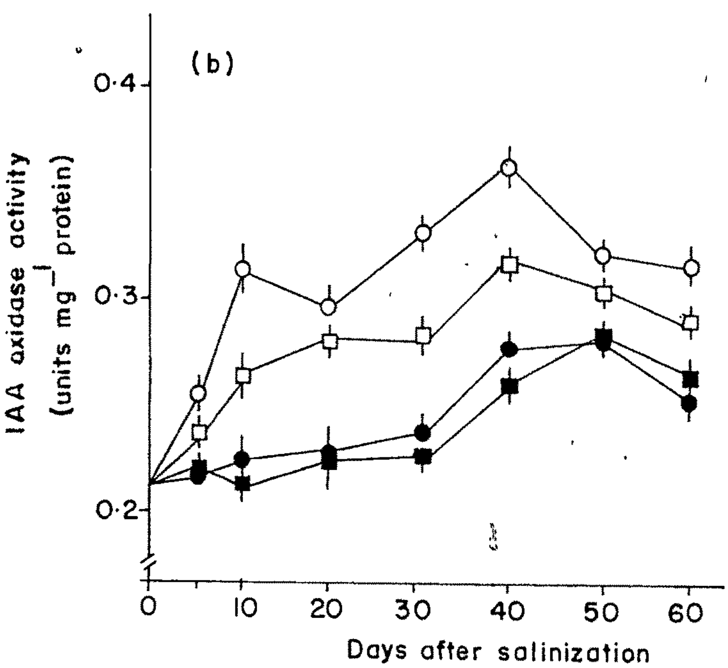
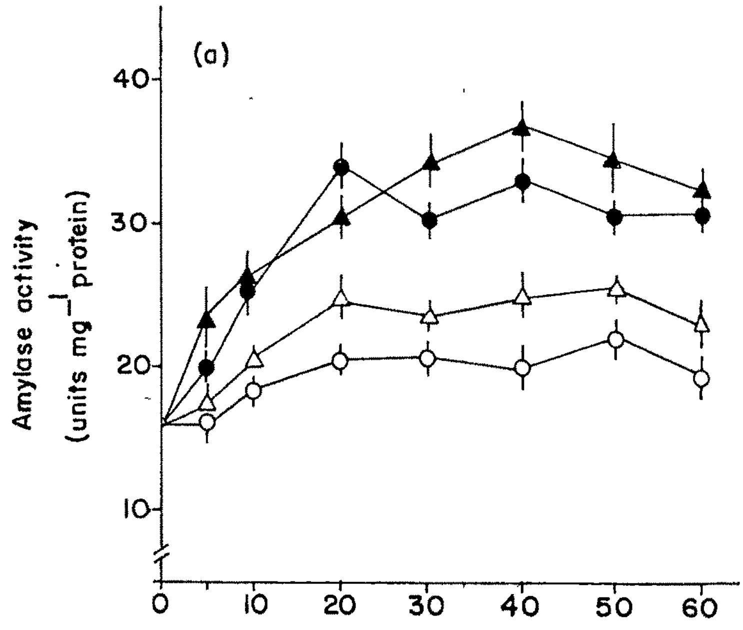


Fig. 17. Effect of NaCl salinity (12 dS/m) and GA_3 (10 ppm) on the activity of IAA oxidase in the shoot (a) and root (b) systems of rice. Control (●), NaCl (○), NaCl+GA_3 (□), GA_3 (■). Vertical bars represent S.E. of the mean.

IAA oxidase activity

The influence of salinity and the growth regulators (putrescine and GA_3) on the activity of IAA oxidase during the growth of rice was examined. The shoot and root systems of salinized plants exhibited a very high activity of IAA oxidase throughout the study period compared with control (Fig. 16). The enzyme activity though declined in shoot and root systems of salinized plants to a lower level at the end of the experiment, it was still 1.2 and 1.3 times respectively more than the corresponding control values (Fig. 16). The individual supply of putrescine and GA_3 suppressed the IAA oxidase activity of shoot system of salt-stressed plants but the inhibition due to putrescine was not as great as that found with GA_3. Putrescine treatment decreased the IAA oxidase activity in the shoot system of salinized plants by 10% of the salt control on day 60, whereas no significant reduction in the IAA oxidase activity was detected in the root system at the same time (Fig. 16a and b). The activity of IAA oxidase in control plant was, however, not affected by putrescine. Under NaCl treatment, GA_3 notably diminished the salt-induced stimulation of IAA oxidase activity in both shoot and root systems of salinized plants (14 and 10% respectively less than the salt control on day 60) throughout the experiment (Fig. 17a and b). A slight reduction in the IAA oxidase activity was noticed in



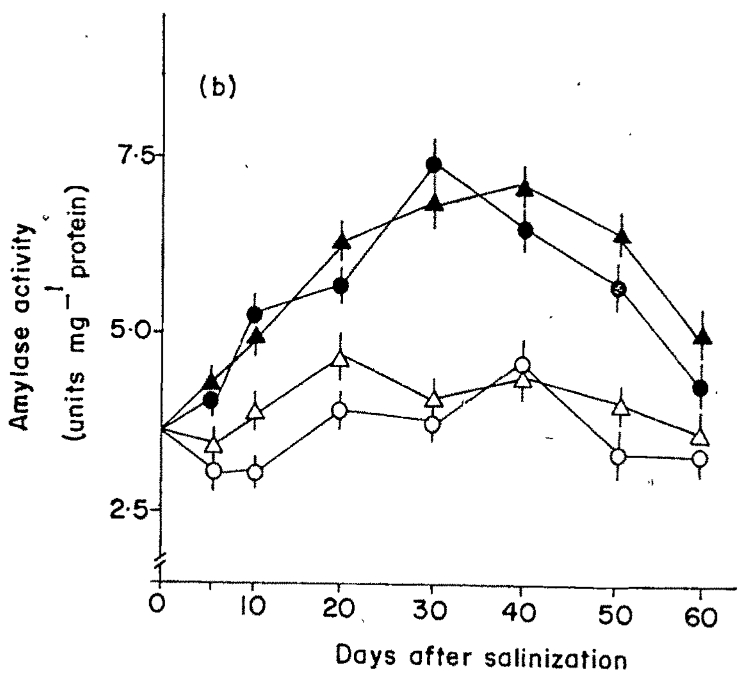


Fig. 18. Effect of NaCl salinity (12 dS/m) and putrescine (10^{-5}M) on the activity of total amylase in the shoot (a) and root (b) systems of rice. Control (●), NaCl (○), NaCl+putrescine(△), putrescine (▲). Vertical bars represent S.E. of the mean.

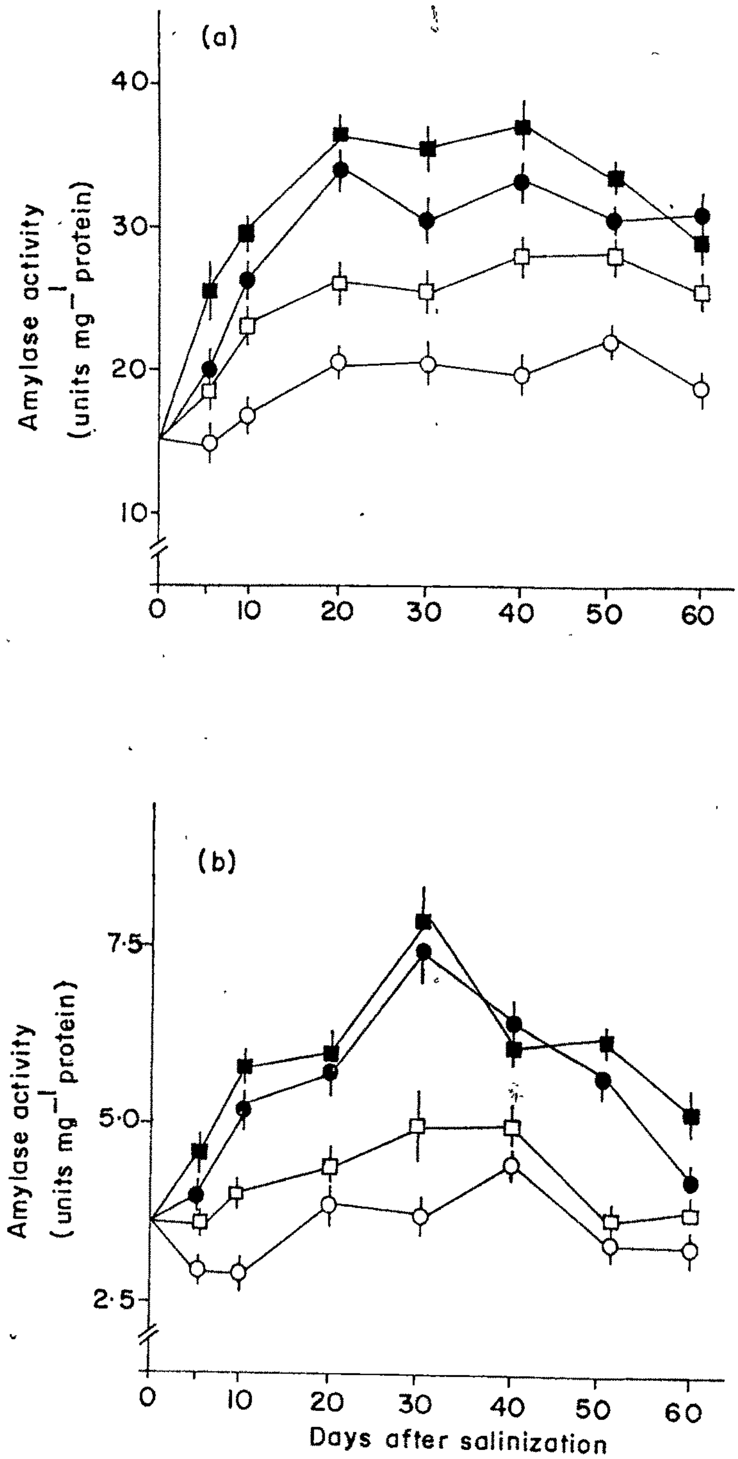


Fig. 19. Effect of NaCl salinity (12 dS/m) and GA_3 (10 ppm) on the activity of total amylase in the shoot (a) and root (b) systems of rice. Control (●), NaCl (○), NaCl+GA_3 (□), GA_3 (■). Vertical bars represent S.E. of the mean.

the shoot system of GA_3 - treated non-stressed plants through days 1 to 20 of hormone treatment.

Total amylase activity

Figures 18 and 19 illustrate the effect of putrescine and gibberellic acid on the activity of total amylase in shoot and root tissues of plants grown under saline or non-saline conditions. The activity of amylase rose progressively parallel to growth in both shoot and root tissues of control plants (Fig. 18). NaCl was found inhibitory to amylase since the activity of enzyme decreased in the shoot and root tissues by 36 and 23% respectively of the salinized plants (Fig. 18a and b) on day 60. Administration of putrescine as well as GA_3 significantly stimulated the amylase activity in the shoot system under stress condition. On day 60, amylase activity of the shoot system of putrescine or GA_3-treated salt-stressed plants was respectively 21 and 34% more than that of the salt control (Figs. 18a and 19a). A considerable rise in the activity of amylase was evident in the shoot system of non-stressed plants in response to GA_3 treatment. In the root system (Fig. 18b), putrescine could not enhance the enzyme activity to any appreciable extent except during the early stage of growth (until day 20 from salinization). A noticeable stimulation of amylase activity in the root system of GA_3-treated plants grown under saline condition was found upto day 40 of the experiment (Fig. 19b).

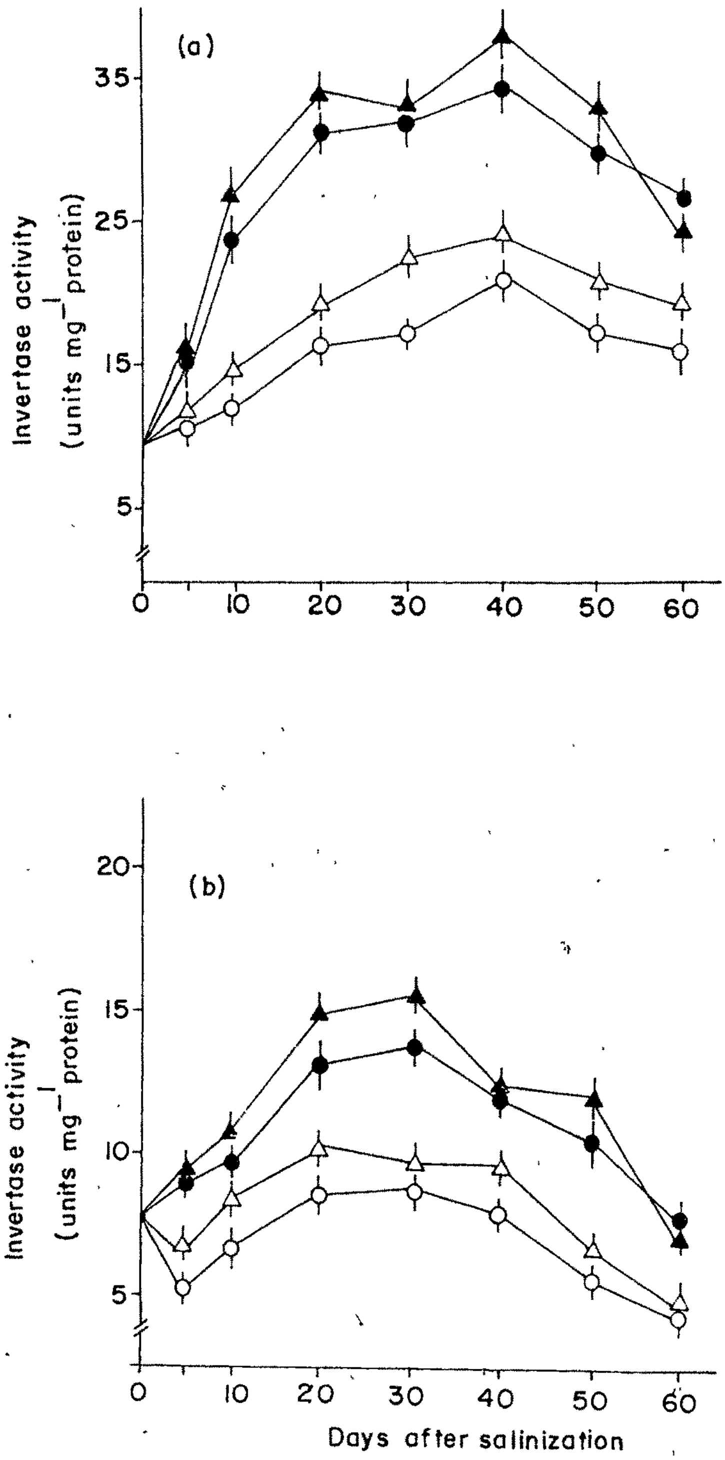


Fig. 20. Effect of NaCl salinity (12 dS/m) and putrescine (10^{-5}M) on the activity of invertase in the shoot (a) and root (b) systems of rice. Control (●), NaCl (○), NaCl+putrescine (△), putrescine(▲). Vertical bars represent S.E. of the mean.

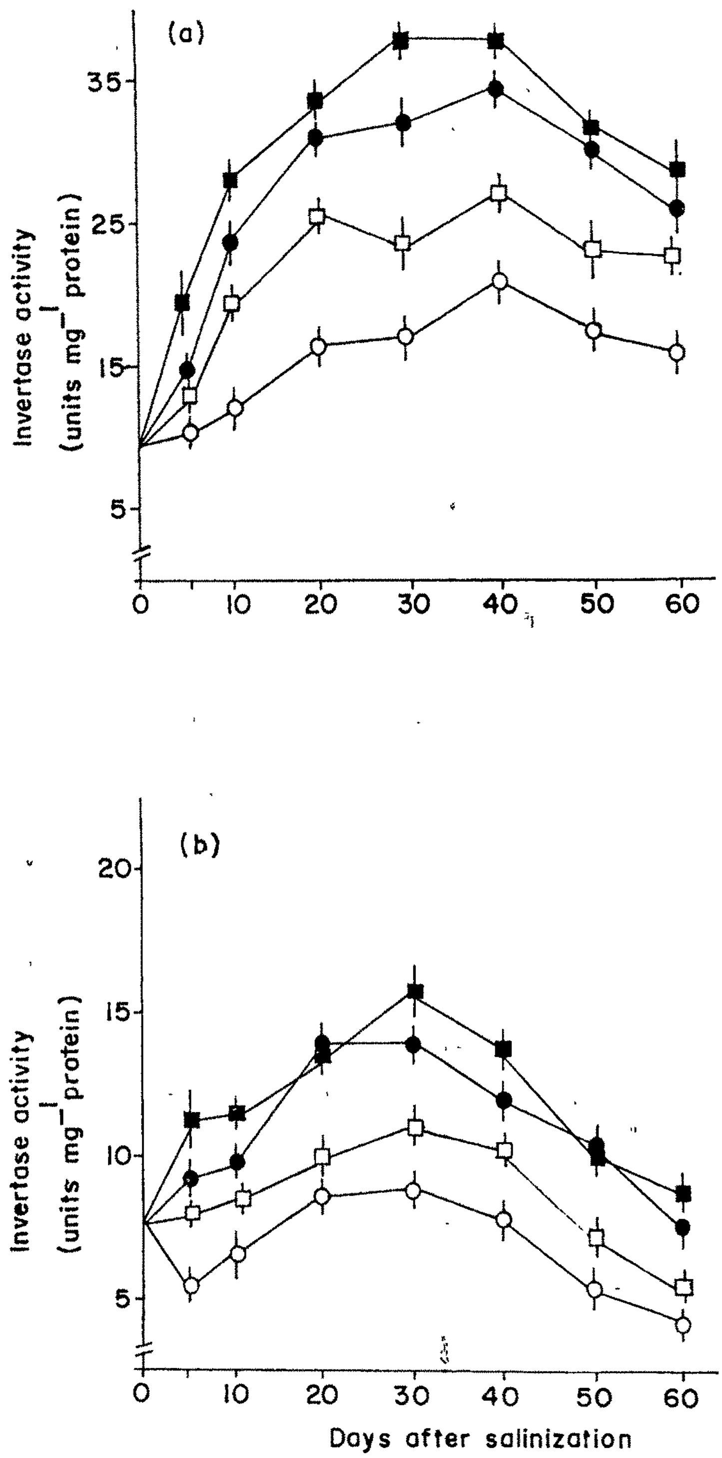


Fig. 21. Effect of NaCl salinity (12 dS/m) and GA_3 (10 ppm) on the activity of invertase in the shoot (a) and root (b) systems of rice. Control (●), NaCl (○), NaCl+GA_3 (□), GA_3 (■). Vertical bars represent S.E. of the mean.

Acid invertase activity

The activity of acid invertase in the shoot system of non-stressed salinized plants, when measured over the period of 60 days of treatment, recorded a steady increase until day 40 and declined therafter (Fig. 20a). In the root system of non-stressed plants also activity of invertase rose progressively, attained its maximum level by day 30 and reached a very low value by the end of the study period (Fig. 20b). Invertase activity in both the plant parts of salt-stressed plants followed almost the same pattern as that of the control but in contrast to IAA oxidase the activity decreased considerably throughout the study period. Treating the plants with putrescine or GA_3 elicited a marked enhancement in the enzyme activity under saline condition. Shoot system of putrescine-treated plants grown under saline condition recorded 19% more invertase activity than the salt control at the end of the study period (Fig. 20a). A slight enhancement in the activity of invertase was found in the root system of putrescine-treated salt-affected plants until 20th day.(Fig. 20b).

In GA_3-treated salt grown plants acid invertase levels rose substantially high in both shoot and root systems (Fig. 21a and b). By the end of the growth period, invertase activity of shoot system of GA_3-treated salt-stressed plants registered an increase of 40% over the salt control (Fig.21a). Unlike in the putrescine-treatment, a considerable enhance-

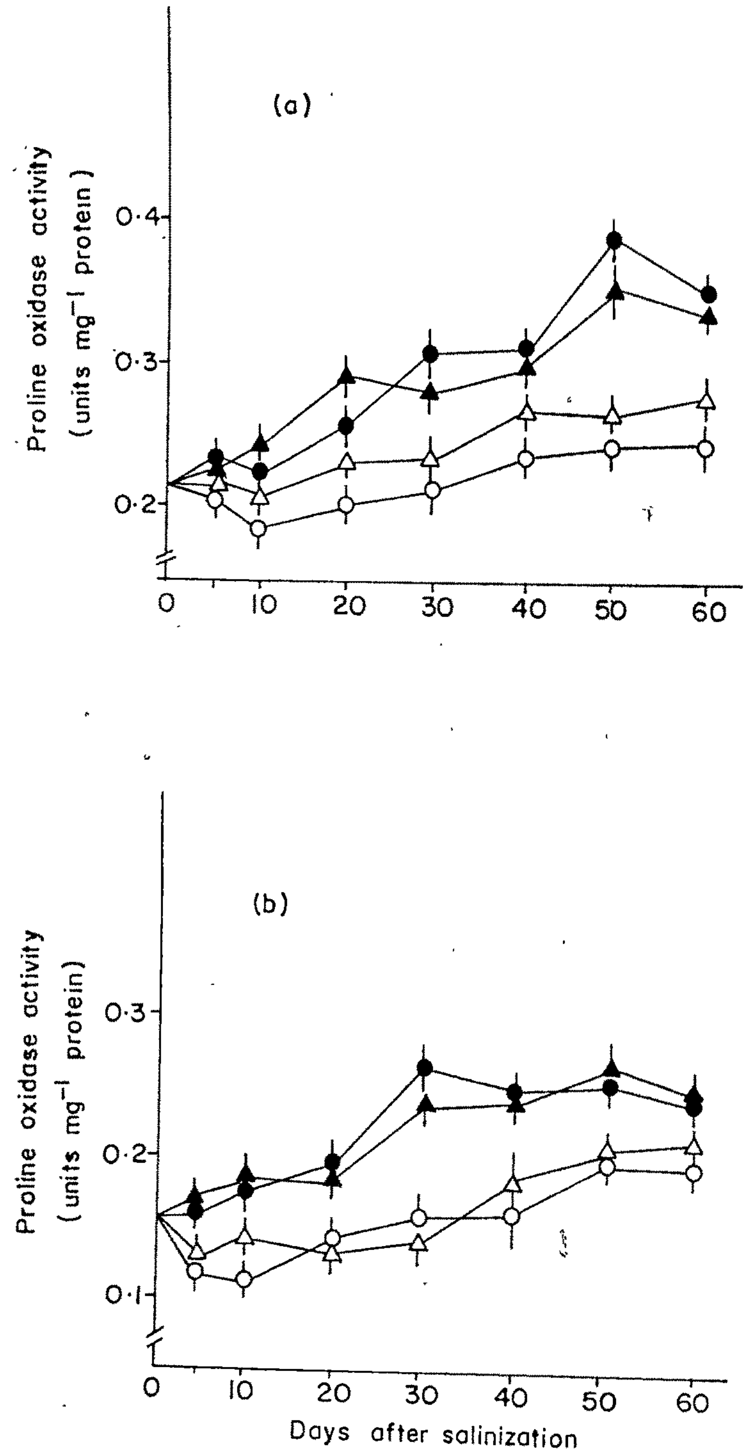


Fig. 22. Effect of NaCl salinity (12 dS/m) and putrescine (10^{-5}M) on the activity of proline oxidase in the shoot (a) and root (b) systems of rice. Control (●), NaCl (○), NaCl+putrescine(△), putrescine (▲). Vertical bars represent S.E. of the mean.

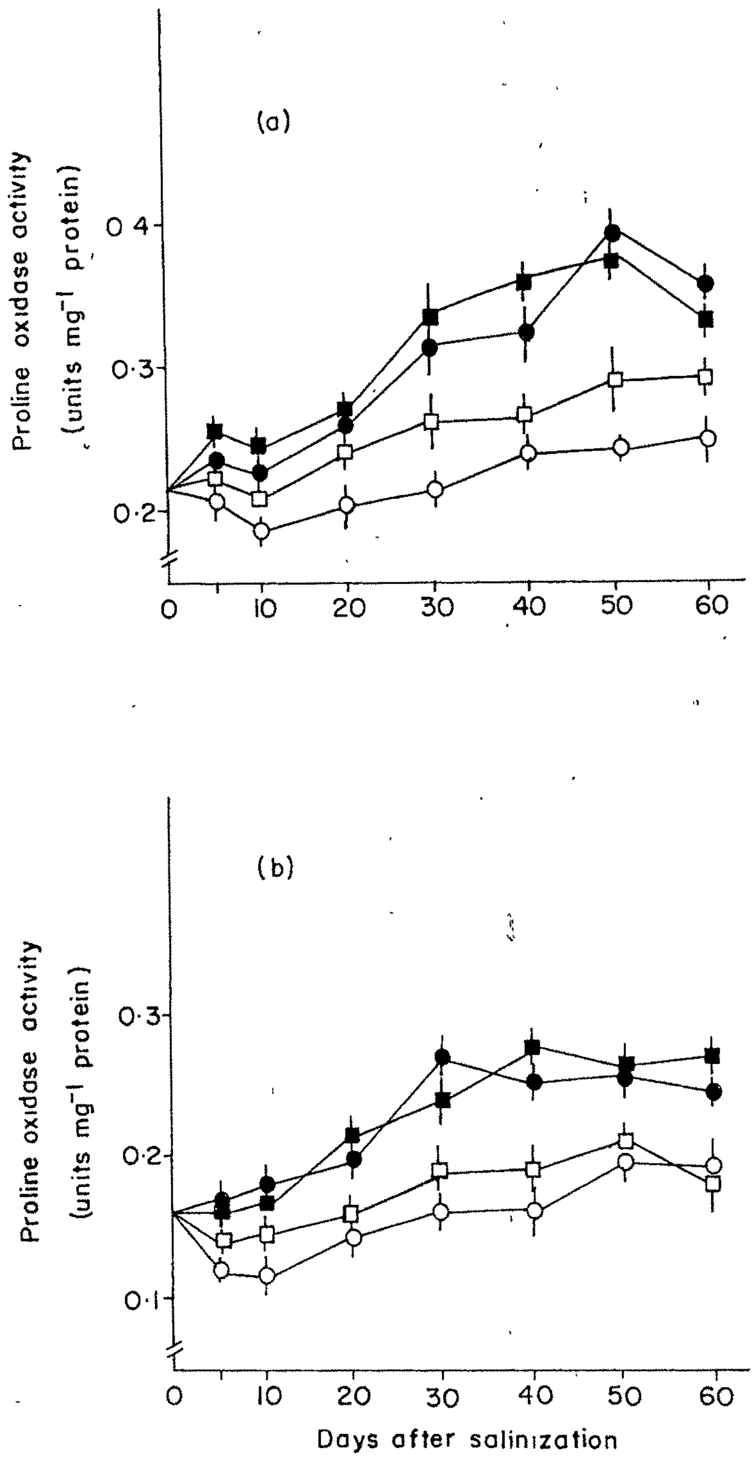


Fig. 23. Effect of NaCl salinity (12 dS/m) and GA_3 (10ppm) on the activity of proline oxidase in the shoot (a) and root (b) systems of rice. Control (●), NaCl(○), NaCl+GA_3 (□), GA_3 (■). Vertical bars represent S.E. of the mean.

ment in the activity of invertase was recorded in root system of GA_3- treated salinized plants compared with salt control (Fig. 21b). Invertase activity in the shoot system of non-stressed plants too displayed a measurable increase as a result of GA_3 application.

Proline oxidase activity

The shoot system showed a very low activity of proline oxidase till day 20 rise and registered very high level thereafter (Fig. 22a). NaCl noticeably diminished the activity in both shoot and root systems and the salt-induced inhibition of proline oxidase activity in the shoot system was slightly reversed by putrescine (Fig. 22a and b). A more pronounced enhancement in the activity of proline oxidase was found in the shoot tissue when salinized plants were treated with GA_3 (Fig. 23a). There was no change in proline oxidase activity in non-stressed plants due to putrescine or GA_3 application. GA_3 treatment, nevertheless, stimulated the proline oxidase activity slightly in the root system of salt-exposed plants during the early period (until day 10) of salinization (Fig. 23b).

Total protein

The shoot system of control plants displayed a progressive increase in its protein content until day 40 after which it receded to a lower level by the end of the growth period (Fig. 24a). Shoot system of non-stressed plants treated with putrescine or GA_3 also exhibited similar

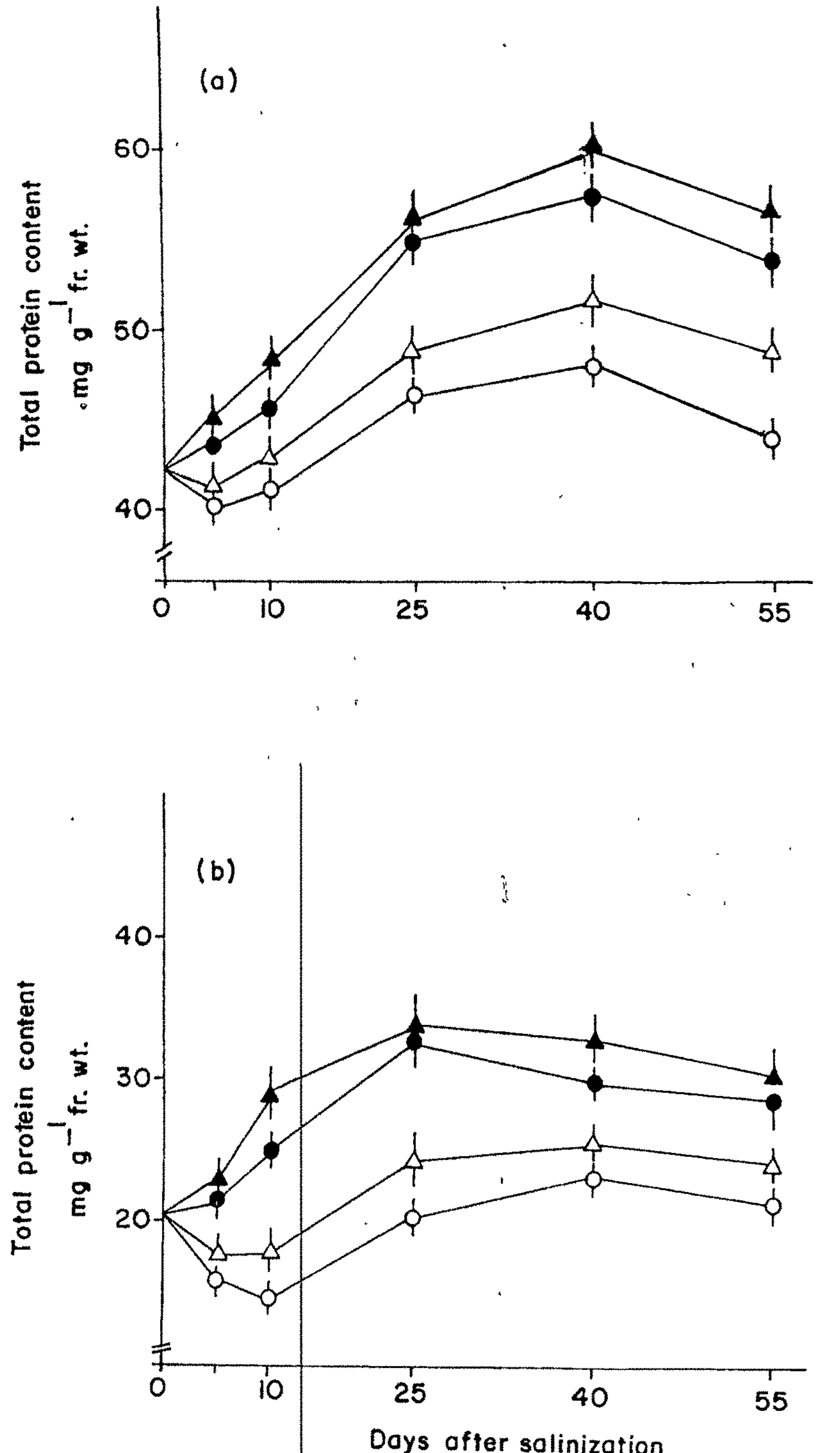


Fig.24. Effect of NaCl salinity (12 dS/m) and putrescine (10^{-5}M) on the content of total protein in shoot(a) and root (b) systems of rice. Control (●), NaCl (○), NaCl+putrescine (△), putrescine (▲). Vertical bars represent S.E. of the mean.

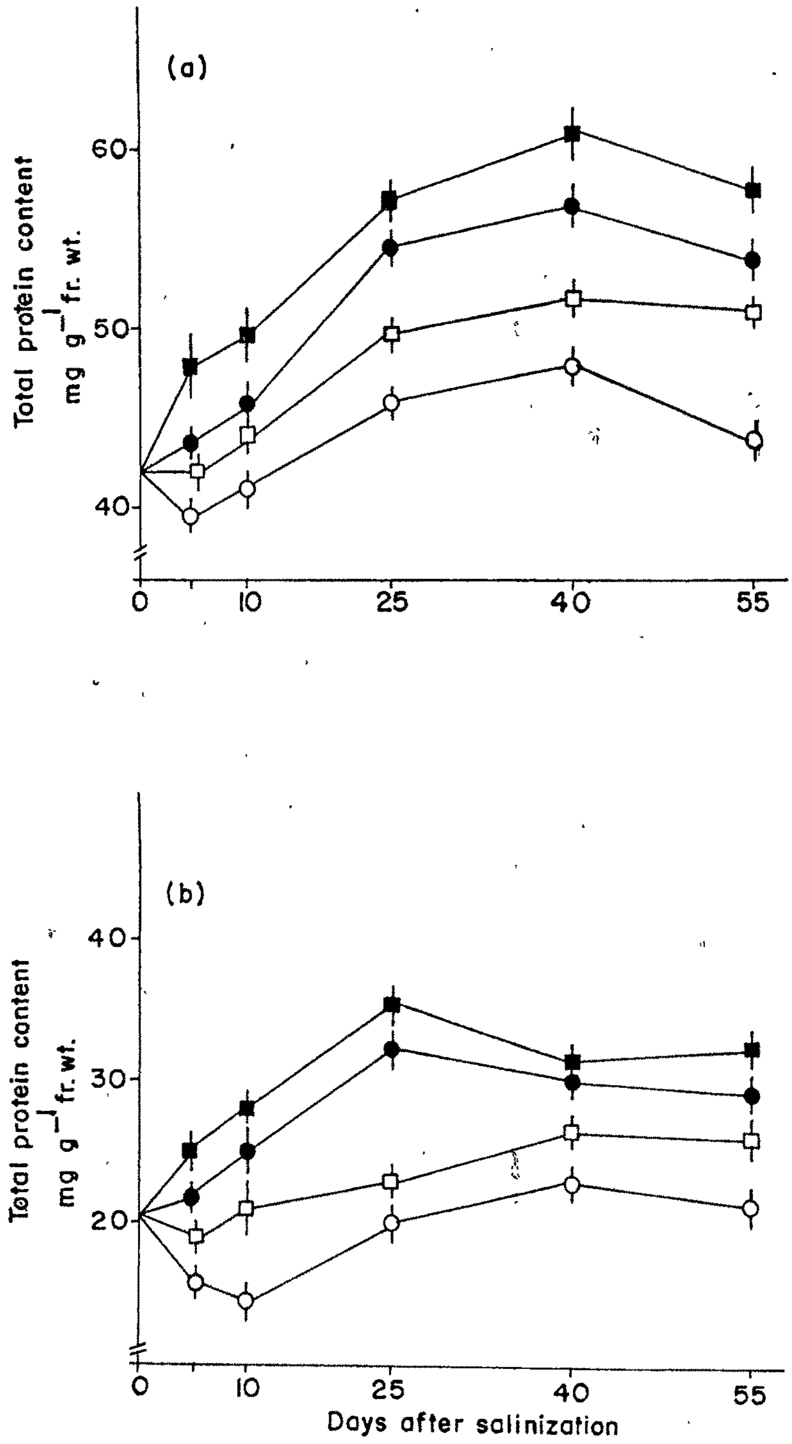


Fig. 25. Effect of NaCl salinity (12 dS/m) and GA_3 (pp (10 ppm) on the content of total protein in shoot (a) and root (b) systems of rice. Control (●), NaCl (○), NaCl + GA_3(□), GA_3(■). Vertical bars represent S.E. of the mean.

trend of the control, though the protein content was slightly higher than the control (Fig. 24a and 25a). Shoot and root systems of salt-stressed plants, however, suffered a considerable loss of protein throughout the growth period following salinization (Fig.24a and b). Putrescine treatment significantly enhanced the level of protein in rice plants. Protein content of the shoot system of putrescine - treated salt-stressed plants, on day 55, was 10 % more than that of the salt control (Fig. 24a). A similar but more pronounced effect on protein content was found in the shoot system of salt-stressed plants supplied with gibberellic acid (Fig.25a).

The protein content of the root system also continuously increased until day 25 and decreased gradually to lower level at the end of the experiment (Fig.24b). In the root system also, as observed in the case of shoot system, NaCl salinity brought about a considerable reduction in the protein content (Fig. 24b). Administration of putrescine as well as GA_3 appreciably mullified the salt-induced diminution of protein content of the root system under saline condition all through the experiment (Figs. 24b and 25b).

Effect of NaCl Salinity and Growth Regulators (Putrescine and GA_3) on Leaf Growth of Rice

Leaf growth and chlorophyll content

The study of leaf growth began when leaves were less than 10% of their final length. Leaves took about 15 days

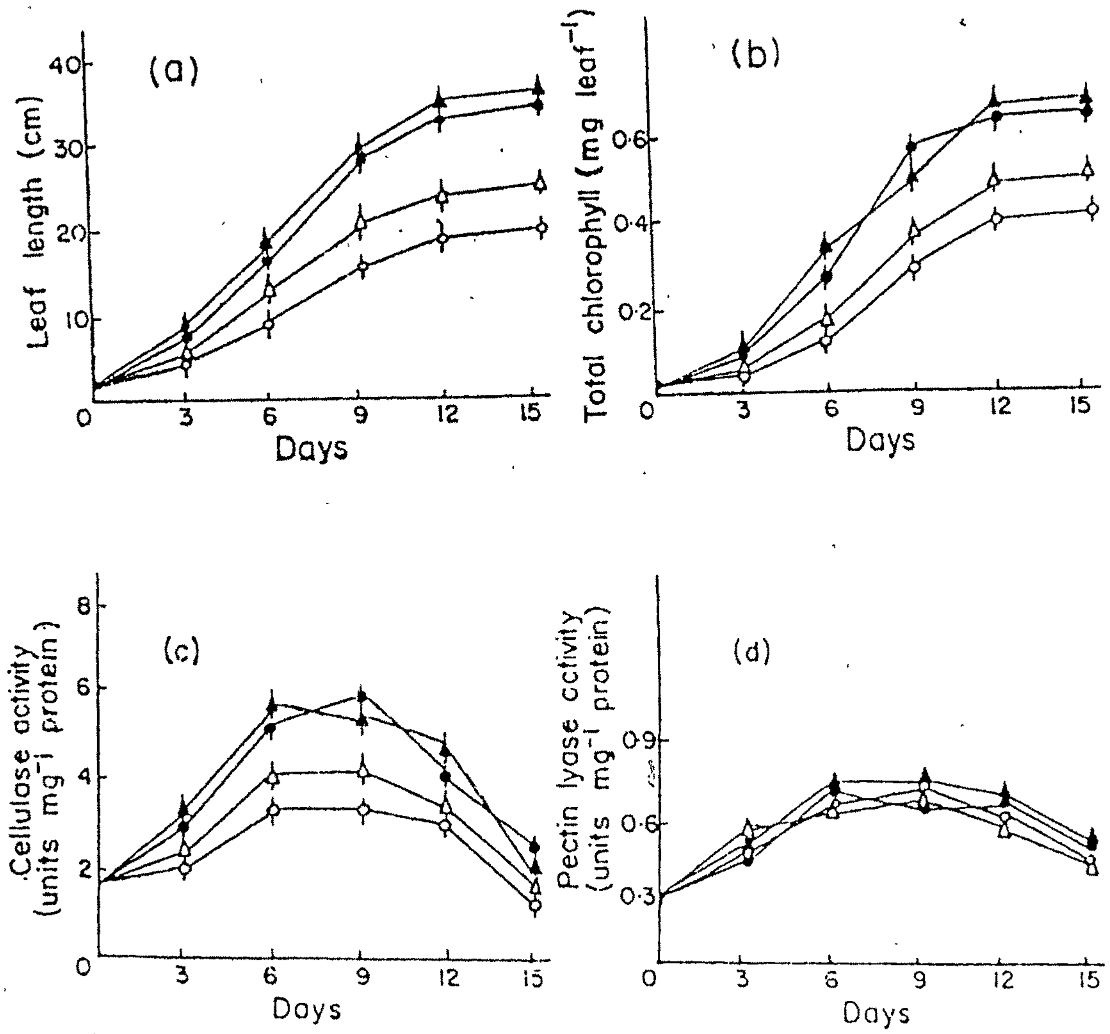


Fig. 26. Effect of NaCl salinity (12 dS/m) and putrescine (10^{-5}M) on length (a), total chlorophyll content (b) and the activities of cellulase (c) and pectin lyase (d) during extension growth of rice leaf. Control (●), NaCl (○), NaCl + putrescine (△) and putrescine (▲). Vertical bars represent S.E. of the mean.

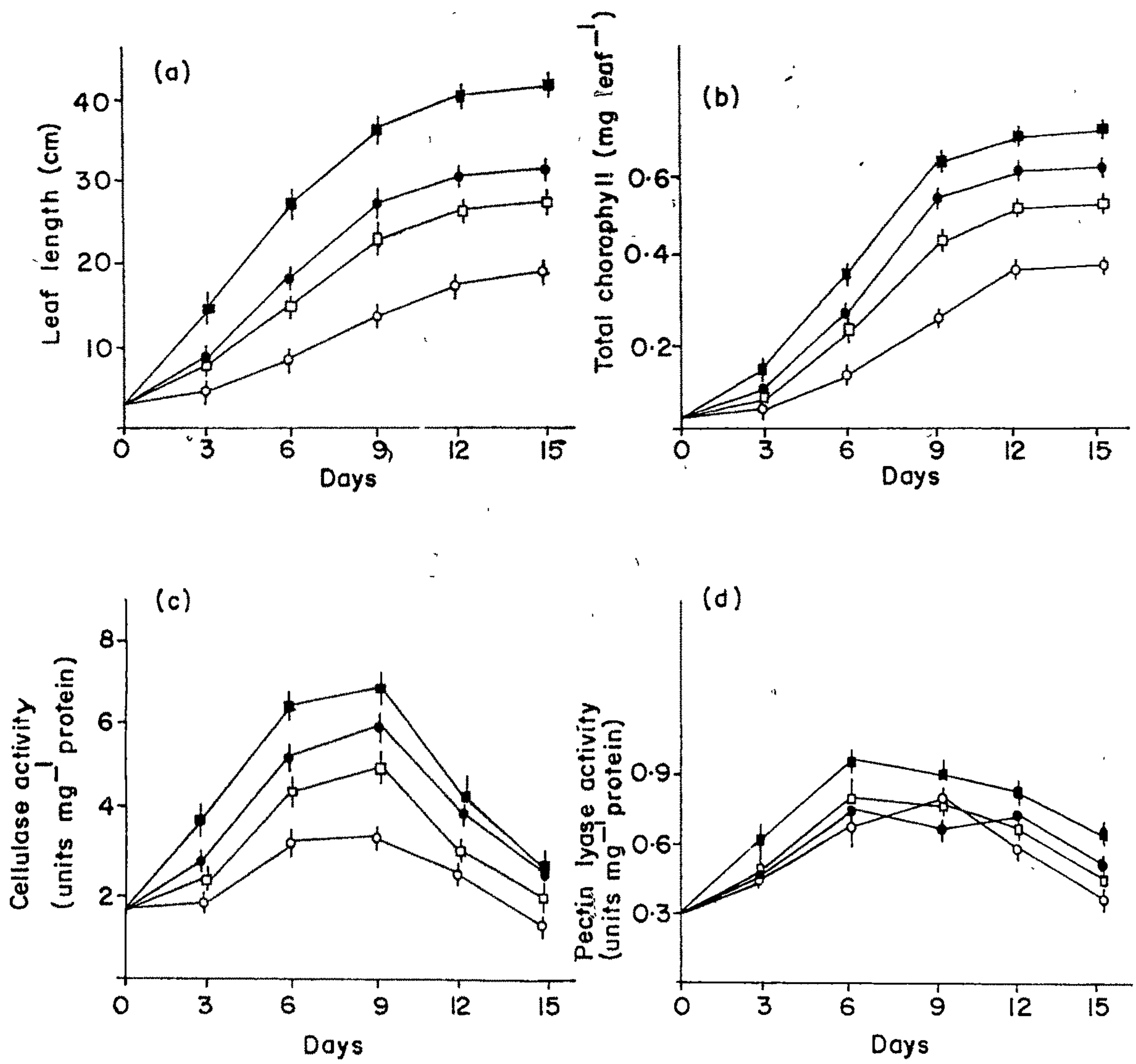


Fig. 27. Effect of NaCl salinity (12 dS/m) and GA_3 (10 ppm) on length (a) total chlorophyll content (b) and the activities of cellulase (c) and pectin lyase (d) during extension growth of rice leaf. Control (●), NaCl (○), NaCl+GA_3 (□), GA_3 (■). Vertical bars represent S.E. of the mean.

to reach full length. One of the most notable effects of salinity on leaf development was the suppression of linear growth of leaves (Fig. 26a). Also, leaves of salinized plants had low amount of chlorophyll compared with control (Fig.26b). On day 15, when the growth was completed leaf length and chlorophyll content were respectively 45 and 60% of the control (Fig. 26a and b). As can be seen from the Fig.26a putrescine application enhanced the extension growth by 27% of the salt control on day 15 while gibberellic acid (Fig.27a) brought about an increase of 53% in leaf length as compared to that of the salt control at the end of day 15. A considerable improvement in the chlorophyll content, an increase of 24 % of the salt control, was observed in salt-stressed leaves as a result of putrescine administration (Fig.26b). Like linear growth, chlorophyll content was also much higher in GA_3 - treated salt-stressed leaves (34% more than the salt control on day 15) compared to that observed in putrescine treatment (Fig. 27b). In non-stressed plants, putrescine did not bring about any change in leaf growth whereas administration of GA_3 caused a substantial increment in the final length of leaves compared with control. Amount of chlorophyll was also higher in GA_3 - treated as compared to putrescine-treated ones.

Cellulase activity

The activity of cellulase during leaf growth of rice subjected to various treatments is shown in Fig.26c.

Cellulase exhibited a high activity during the active period of leaf growth and it declined thereafter. Thus the activity showed a positive correlation with the rate of leaf growth. Cellulase activity in salt-stressed leaves also followed a similar trend as that of control but a noticeable reduction in the activity was observed. Evidently both growth regulators enhanced the cellulase activity though putrescine evoked only a slight stimulation in the activity under saline condition (26c). In the leaves of GA_3-treated NaCl - stressed plants the enzyme cellulase registered a considerably high activity compared with salt control (27c). In non-stressed leaves also the enzyme activity rose measurably high in response to GA_3 treatment.

Pectin lyase activity

Over the 15 day period of growth of the leaves no significant difference in pectin lyase activity was detected in salt-stressed leaves compared with control (Fig. 26d). A low activity of pectin lyase was recorded in the leaves just before salinization (day 0), while on day 3, it shot up to a higher value. The enzyme activity registered an increasing trend until day 6 and the activity remained at or near that level until day 12 and decreased later on. Putrescine treatment failed to bring about any significant alteration in the activity of pectin lyase in leaf tissue irrespective

Table 18. Effect of NaCl salinity (12 dS/m) and putrescine (10^{-5}M) on IAA content (ng g^{-1} fresh weight) during different stages of leaf growth.

	Days after salinization			
Treatments	0	5	10	15
Control	106 ± 5.3	194 ± 4.7	151 ± 5.8	91.5 ± 4.1
NaCl	106 ± 5.3	123 ± 5.5	94.5 ± 6.2	60 ± 3.9
NaCl + putrescine	106 ± 5.3	147 ± 5.9	114 ± 4.4	77 ± 4.7
Putrescine	106 ± 5.3	179 ± 5.1	163 ± 6.1	104 ± 5.5

Values are means ± SE; n = 4.

Table 19. Effect of NaCl salinity (12 dS/m) and GA_3 (10 ppm) on IAA content ($ng\ g^{-1}$ fresh weight) during different stages of leaf growth

Treatments	Days after salinization			
	0	5	10	15
Control	106 ± 5.3	194 ± 4.7	151 ± 5.8	91.5 ± 4.1
NaCl	106 ± 5.3	123 ± 5.5	94.5 ± 6.2	60 ± 3.9
NaCl + GA_3	106 ± 5.3	161 ± 7.5	129 ± 5.4	84.5 ± 6.1
GA_3	106 ± 5.3	228 ± 6	160 ± 8.7	119 ± 5.5

Values are means ± SE; n = 4.

of its source (Fig.26d) whereas GA_3 administration notably stimulated the enzyme activity in non-stressed leaves during the elongation phase of leaf growth.(Fig.27d).

Indole acetic acid (IAA) content

Time-course changes in the endogenous level of IAA (free) are summarized in Table 18. Free endogenous IAA level was high during the active phase of leaf growth which declined during maturation. The data indicate that auxin content was always lower in salt-stressed leaves. The level of auxin in salinized leaves on day 5, the time at which the control leaves contained the highest amount of IAA, was only 63 % of the control. A considerable enhancement in the IAA content, (20% more than salt control on day 5) was noticed in putrescine-treated salt-stressed leaves compared to the corresponding salt control value. GA_3 antagonized the depressive effect of salinity on auxin content more effectively (recorded 31% more auxin content than salt control on day 5) than putrescine (Table-19).

Changes induced by NaCl salinity and GA_3 on the contents of Polyamines and the activity of Agmatine deiminase during the growth of rice:

Contents of polyamines

The levels of polyamines were measured in the shoot and root tissues of rice plants for a period of 60 days

Fig. 29.

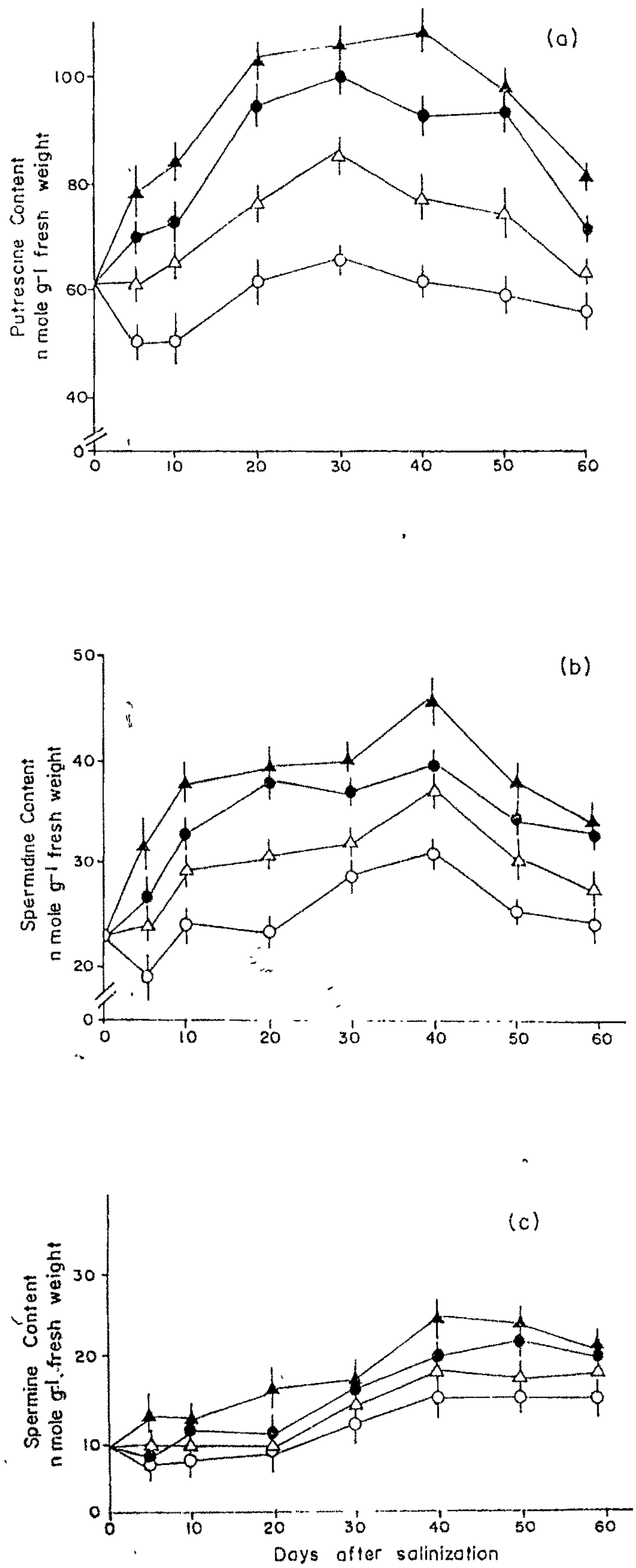

(a)
Putrescine Content
n mole g⁻¹ fresh weight
100
80
60
40
0
0
10
20
30
40
50
60
(b)
Spermidine Content
n mole g⁻¹ fresh weight
50
40
30
20
0
(c)
Spermine Content
n mole g⁻¹.fresh weight
30
20
10
Days after salinization

Fig. 29.

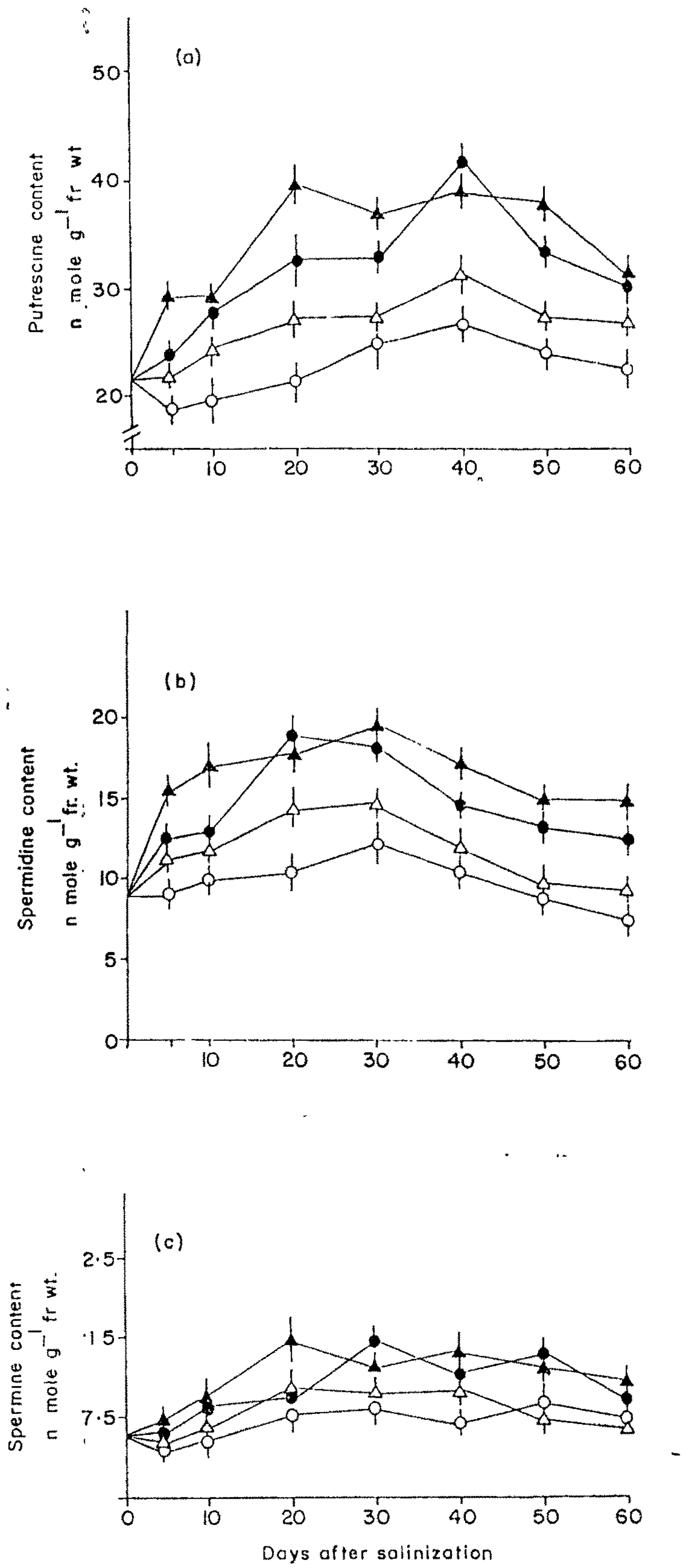

(a)
Putrescine content
n mole g^{-1} fr wt
50
40
30
20
0
10
20
30
40
50
60
(b)
Spermidine content
n mole g^{-1} fr. wt.
20
15
10
5
0
10
20
30
40
50
60
(c)
Spermine content
n mole g^{-1} fr wt.
2·5
·15
7·5
0
10
20
30
40
50
60
Days after salinization

Fig. 29. Effect of NaCl salinity (12 dS/m) and GA_3 (10 ppm) on the contents of putrescine(a), spermidine (b) and spermine (c) in the root system of rice. Control (●), NaCl (○), NaCl+GA_3 (△), GA_3 (▲). Vertical bars represent S.E. of the mean.

starting from salinization and GA_3 treatment. Though the original levels of the three polyamines were different at the beginning of salinization, putrescine and spermidine progressively accumulated parallel to plant growth (Figs.28 and 29). Putrescine which showed a concentration of about 60 ng g^{-1} fr.wt. in the shoot when determined just prior to stress imposition (on day 0 of the experiment) continued to increase and recorded the maximum content by day 30 (Fig.28a). Consequently, putrescine content declined to lower values during the rest of the period. The content of putrescine in the root system also followed some what a similar trend as observed in the shoot system (Fig. 29a). Like growth, putrescine content in both the plant parts was adversely affected by salinization. In the last sampling the levels of putrescine in shoot and root tissues of salinized plants were 25 and 20 % respectively less than that of the corresponding control values (Figs.28a and 29a). Application of GA_3 brought about a significant increase in the putrescine content in both shoot and root systems (14 and 19 % respectively more than salt control on day 60) of plants grown under saline condition. GA_3 caused an enhancement of putrescine content in the shoot system of non-stressed plants as well.

The analysis of shoot tissue showed that spermidine content as in the case of putrescine, progressively increases until day 30 and maintains that level for another 10 more days before start declining to lower values (Fig. 28b), On the other hand, spermidine content of the root tissue after attaining its peak level on day 20, decreased slowly till the end of day 60.(Fig. 29b). Exposure of plants to salt-stress resulted in a remarkable drop in the spermidine content in shoot and root tissues which was about 25 and 38 % respectively of the control at the end of the experiment (Fig. 28b and 29b). Treatment of plants with GA_3 partially reversed the salt-induced inhibition of spermidine level in shoot system (15 % more than salt control on day 60) of salt-affected plants whereas a significant recovery of spermidine level in the root system of GA_3-treated salt-stressed plants was recorded only upto day 30. GA_3 augmented the spermidine content of the shoot system of non-stressed plants also.

Unlike putrescine and spermidine, spermine in shoot and root system (Figs. 28c and 29c) of control plants did not show any dramatic change during the early stages of growth. However it exhibited a trend towards increase in the later stages of growth. Spermine level followed almost the said pattern in all other treatments. But the amount of spermine has been reduced by soil salinity in both shoot and root tissues. No noticeable alteration in the amount of spermine was detected in response to GA_3 treatment either in control or in NaCl-stressed plants.

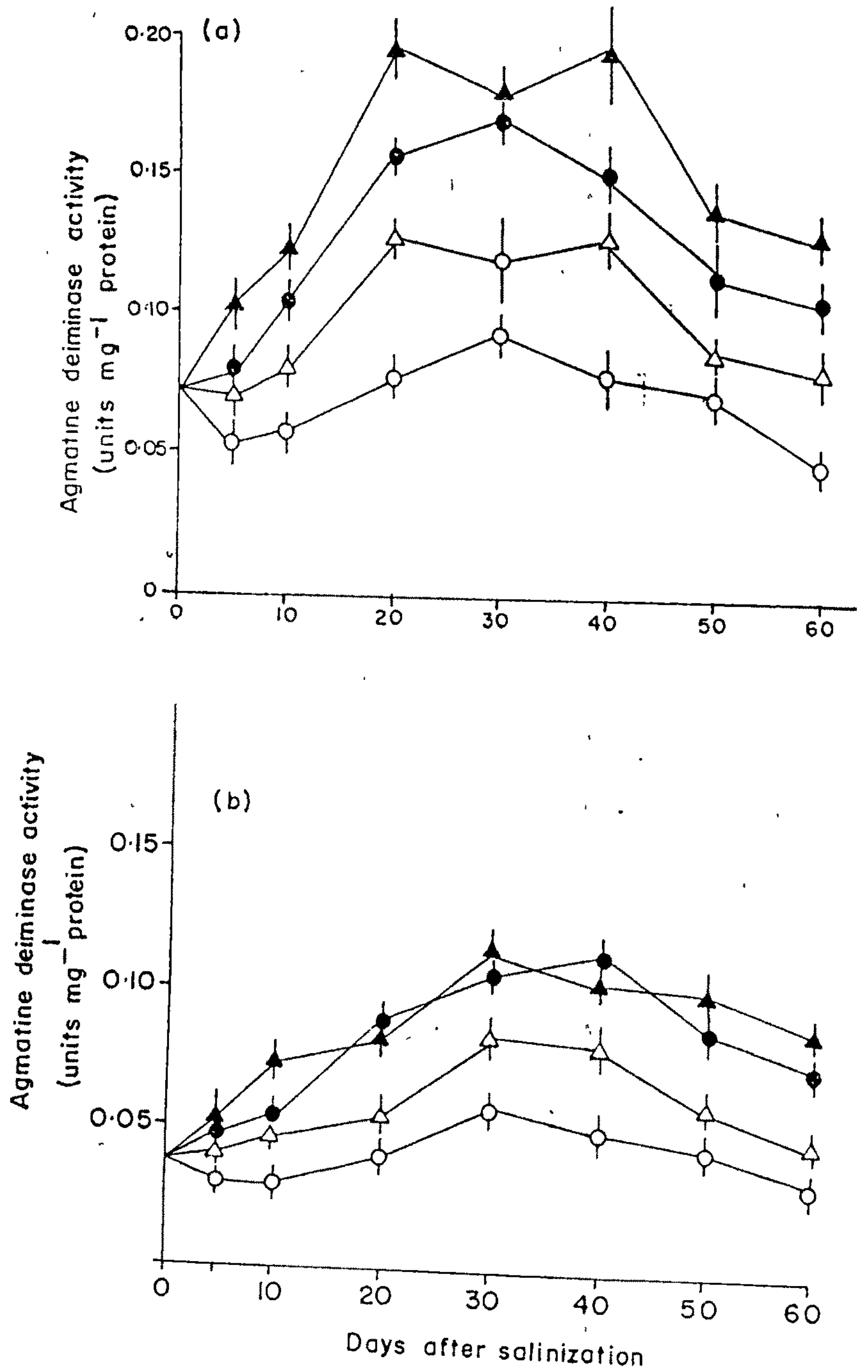


Fig. 30. Effect of NaCl salinity (12dS/m) and GA_3 (10 ppm) on the activity of agmatine deiminase in the shoot (a) and root (b) systems of rice. Control (●), NaCl (○), NaCl+GA_3 (△), GA_3(▲). Vertical bars represent S.E. of the mean.

Agmatine deiminase activity

The activity of agmatine deiminase during shoot and root growth of rice as affected by NaCl and GA_3 is illustrated in Fig. 30a and b. The activity in the shoot system of control plants (Fig.30a) increased steadily, registered the peak on day 30 and declained thereafter. In the root system of control plants, the enzyme activity, however, continued to increase until day 40 and decreased later on(Fig 30b). NaCl salinity brought about a marked reduction in agmatine deiminase activity in both the plant parts examined though it followed almost similar patterns as observed in control. GA_3 administration dramatically influenced the enzyme activity under saline condition. The enzyme activity of GA_3-treated salt-affected shoot and root tissues recorded a considerable recovery of inhibition induced by NaCl. For instance, in the last measurement (on day 60), the agmatine deiminase activity was, respectively, 45 and 33% more in the shoot and root systems of GA_3-treated salt-stressed plants compared with the control values. GA_3 also enhanced agmatine deiminase activity in the shoot system of control plants.

Grain yield

There was a considerable reduction in the grain yield (Table 20) when rice plants were exposed to NaCl salinity. Soil salinity reduced the total number and weight of filled grains per plant and 1000 grain weight to 26, 20 and 76 % respectively of the control values. Both putrescine and GA_3

Table 20. Effect of NaCl salinity (12 dS/m) and putrescine (10^{-5}M) on grain yield of rice.

Treatments	Total number of filled seeds per plant	Total number of unfilled seeds per plant	Total weight of filled seeds(g) per plant	Weight of 1000 seeds (g)
Control	152c	23a	2.92c	19.2c
NaCl	39a	45b	0.57a	14.62a
NaCl + putrescine	60b	39b	0.95b	15.8b
Putrescine	159c	27a	3.02c	19.0c

In each column figures with different letters differ significantly ($P < 0.05$).

Table 21. Effect of NaCl salinity (12 dS/m) and GA_3 (10 ppm) on grain yield of rice

Treatments	Total number of filled seeds per plant	Total number of unfilled seeds per plant	Total weight of filled seeds (g) per plant	Weight of 1000 seeds (g)
Control	152c	23a	2.92c	19.2c
NaCl	39a	45b	0.57a	14.62a
NaCl + GA_3	72b	42b	1.18b	16.4b
GA_3	161d	26a	3.11c	19.32c

In each column values with different letters differ significantly ($P < 0.05$).

were found to be effective in counter-acting the inhibitory effect on grain out-put to a considerable extent(Tables-20, 21). Application of putrescine significantly increased the total number and weight of filled grains per plant by 54 and 67% respectively over the corresponding values of the salt control.

GA_3 had a more pronounced effect in enhancing the total number of filled grains per plant (85 % more than the salt control) under saline condition. Total weight of filled grains was doubled by gibberellin treatment under saline condition. However, the yield out-put was much less in GA_3 or putrescine-treated salt-stressed plants compared with control. Putrescine and GA_3 treatments slightly improved the 1000 grains weight also of salt-affected plants.