RESULTS

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Sodium chloride tried at all concentrations, significantly reduced the rate of emergence of seeds (Table 1). However, the final percentage of germination was not significantly affected by the salt upto 0.1 M concentration. Salt at 0.15 and 0.2 M concentrations markedly reduced the final percentage of germination by 17 and 78% respectively.

Growth of root and shoot systems of 5-day old seedlings was adversely affected by salt at all levels tried (Table 2). The growth of root and shoot systems showed a steady decrease with increase in the concentration of salt. Salt at concentrations of 0.1 M and above significantly reduced the growth of root system. Salt at all concentrations tried significantly reduced the growth of shoot system.

Since the maximum inhibition of germination of seeds and growth of seedlings was observed at 0.2 M NaCl, further studies have been carried out employing this particular concentration.

Table : 1. Effect of sodium chloride (NaCl) on germination (%) of seeds of paddy.

NaCl M	Duration of germination in hours				
	24	48	72	96	120
0.00	0.0	16.8	94.4	97.6	99.2
0.05	0.0	12.8	84.8*	99.2	99.2
0.075	0.0	4.6**	72.8**	94.4	96.8
0.10	0.0	1.6**	47.2**	90.4*	93.6
0.15	0.0	0.8**	27.2**	80.0**	83.2**
0.20	0.0	0.0**	4.8**	21.6**	22.4**
LSD at					
5% level	0.0	4.8	9.5	6.4	5.8
1% level	0.0	6.5	12.9	8.7	7.9

Figures show percentage.

* Significant at 5% level.

** Significant at 1% level.

Table : 2. Effect of sodium chloride (NaCl) on growth of 5-day old seedlings of paddy.

NaCl M	Growth	
	Root mm	Shoot mm
0.00	44.28	28.08
0.05	40.80	23.44**
0.075	38.60	19.56**
0.10	36.40*	14.72**
0.15	17.98**	11.32**
0.20	3.60**	4.40**
LSD at		
5% level	6.32	1.88
1% level	8.62	2.57

Effect of different chemicals on germination of seeds and growth of seedlings under saline condition

Calcium chloride ($CaCl_2$)

Presowing soaking of seeds in $CaCl_2$ did not improve the final percentage of germination of seeds (Table 3). However, $CaCl_2$ at 0.2 and 0.3 M concentrations brought about a reduction in the rate of emergence of seeds at 48 and 72 hours of germination. Germination of seeds under saline condition was significantly enhanced by 0.1 M $CaCl_2$.

Treatment of seeds with 0.1 M $CaCl_2$ resulted in a slight stimulation of growth of root and shoot systems (Table 4). However, at 0.3 M concentration it significantly reduced the growth of shoot system. The growth of root system under the influence of salt was stimulated by $CaCl_2$ at all concentrations tried. But the growth of shoot system under saline condition was slightly stimulated only by 0.1 and 0.2 M $CaCl_2$.

Succinic acid

Treatment of seeds with succinic acid did not show any marked effect on germination of seeds. However, the germination of seeds under the influence of salt was significantly stimulated by succinic acid at all concentra-

Table : 3. Effect of $CaCl_2$ on germination of seeds of paddy under the influence of NaCl.

Concentration of		Duration of germination in hours				
$CaCl_2$ M	NaCl M	24	48	72	96	120
0	0	0.0	19.2	98.4	98.4	100.0
0	0.2	0.0	0.0	1.6	10.4	18.4
0.1	0.2	0.0	2.4	6.4*	14.4	23.0**
0.2	0.2	0.0	0.8	5.6	9.6	20.0
0.3	0.2	0.0	0.8	4.0	8.0	13.6
0.1	0	0.0	16.0	94.4	97.6	98.4
0.2	0	0.0	15.2*	93.6*	96.0	96.0
0.3	0	0.0	14.4**	92.0**	98.4	98.4
LSD at 5% level		0.0	3.5	4.3	4.1	6.3
1% level		0.0	4.7	5.8	5.5	8.5

Figures show percentage.

* Significant at 5% level.

** Significant at 1% level.

Table : 4. Effect of $CaCl_2$ on growth of seedlings of paddy under the influence of NaCl.

Concentration of		Length	
$CaCl_2$ M	NaCl M	Root mm	Shoot mm
0	0	40.20	37.60
0	0.2	3.44	4.40
0.1	0.2	6.80	5.57
0.2	0.2	5.80	5.28
0.3	0.2	4.96	4.24
0.1	0	41.92	38.60
0.2	0	39.32	37.20
0.3	0	37.40	29.20**
LSD at			
5% level		7.46	4.27
1% level		10.06	5.76

** Significant at 0.01 level.

tions tried (Table 5). Succinic acid at 5 mg/l showed the maximum stimulation of germination under saline condition.

The growth of root system was slightly enhanced by 5, 10 and 25 mg/l succinic acid (Table 6). Growth of shoot system was not much affected by succinic acid. The growth of root system under the influence of salt was enhanced by 5, 10 and 25 mg/l succinic acid. Succinic acid at 5, 20 and 25 mg/l concentrations improved the growth of shoot system under saline condition.

Proline

Treatment of seeds with proline did not result in any significant increase in the rate of emergence or final percentage germination of seeds (Table 7). However, the germination of seeds under the influence of 0.2 M NaCl was significantly enhanced by proline tried at all concentrations. Treatment of seeds with proline failed to bring about any marked increase in growth of root or shoot system (Table 8). However, proline increased the growth of root system especially under the influence of salt. A maximum stimulation of growth of root system under saline condition was brought about by 0.02% proline.

Table : 5. Effect of succinic acid on germination of seeds of paddy under the influence of salt.

Concentration of		Duration of germination in hours				
Succinic acid mg/l	NaCl M	24	48	72	96	120
0	0	0.0	19.2	94.4	96.0	96.0
0	0.2	0.0	0.0	1.6	17.6	22.4
5	0.2	0.0	0.0	7.2*	52.0**	60.0**
10	0.2	0.0	0.0	4.0	40.0**	43.2**
20	0.2	0.0	0.0	4.0	41.6**	48.8**
25	0.2	0.0	0.0	6.4	45.6**	55.2**
5	0	0.0	24.0	97.6	99.2	99.2
10	0.	0.0	21.6	98.4	98.4	98.4
20	0	0.0	16.8	96.0	98.4	99.2
25	0	0.0	16.0	93.6	97.6	97.6
LSD at 5% level		0.0	6.3	5.1	10.1	9.8
1% level		0.0	8.4	6.8	13.6	13.2

Figures show percentage.

* Significant at 5% level.

** Significant at 1% level.

Table : 6. Effect of succinic acid on growth of seedlings of paddy under the influence of NaCl.

Concentration of		Length	
Succinic acid mg/l	NaCl M	Root mm	Shoot mm
0	0	45.64	31.28
0	0.2	3.60	4.76
5	0.2	5.88	6.64
10	0.2	6.64	4.08
20	0.2	4.54	5.16
25	0.2	6.36	7.68
5	0	53.56	31.28
10	0	53.08	32.28
20	0	43.00	31.92
25	0	48.36	32.60
LSD at	5% level	7.95	3.16
	1% level	10.67	4.25

Table : 7. Effect of proline on germination of seeds of paddy under the influence of NaCl.

Concentration of		Duration of germination in hours				
Proline %	NaCl M	24	48	72	96	120
0	0	0.0	19.2	93.6	94.4	95.2
0	0.2	0.0	0.0	6.4	18.0	21.6
0.01	0.2	0.0	0.0	8.0	22.4	58.4**
0.02	0.2	0.0	0.0	13.6	30.4**	65.6**
0.03	0.2	0.0	0.0	10.4	28.0**	64.0**
0.04	0.2	0.0	0.0	4.0	19.2	63.6**
0.01	0	0.0	18.4	96.0	97.6	97.6
0.02	0	0.0	19.2	96.8	99.2	99.2
0.03	0	0.0	17.6	94.4	98.4	99.2
0.04	0	0.0	17.6	92.8	96.8	98.4
LSD at 5% level		0.0	6.1	7.3	6.2	8.8
1% level		0.0	8.3	9.8	8.6	11.8

Figures show percentage.

** Significant at 1% level.

Table : 8. Effect of proline on growth of seedlings of paddy under the influence of NaCl.

Concentration of		Length	
Proline %	NaCl M	Root mm	Shoot mm
0	0	50.44	30.12
0	0.2	4.08	5.08
0.01	0.2	6.32	5.28
0.02	0.2	6.80	5.68
0.03	0.2	5.80	5.44
0.04	0.2	5.36	4.24
0.01	0	52.24	30.76
0.02	0	52.76	30.88
0.03	0	50.96	30.52
0.04	0	49.44	30.48
LSD at	5% level	4.94	2.07
	1% level	6.63	2.78

Polyethylene glycol (PEG MW 6,000)

Soaking of seeds in PEG solution (-12.5 bars) for different durations did not show any appreciable increase in the final percentage of germination of seeds (Table 9). However, the rate of emergence of seeds at the end of 48 hours of germination was significantly reduced by soaking of seeds in PEG for 4 hours, whereas, the same was significantly enhanced by 24 and 48 hours of soaking. Pre-treatment of seeds with PEG for 12, 24 and 48 hours significantly increased the final percentage of germination under saline condition. The maximum stimulation of germination was observed when the seeds were soaked in PEG for a period of 24 hours.

Treatment of seeds with PEG for 4, 12 and 48 hours resulted in a significant increase in the growth of root system (Table 10). However, in the case of shoot system, significant increase in growth was observed when seeds were treated with PEG for a period of 24 hours only. In general, treatment of seeds with PEG has been found to enhance the growth of root and shoot systems of seedlings under saline condition. A trend towards increase in growth of root and shoot systems under saline condition was also observed with increase in the duration of soaking of seeds

Table : 9. Effect of polyethylene glycol (PEG, 6000) on germination of seeds of paddy under the influence of NaCl.

Duration of soaking in PEG (Hr)	NaCl M	Duration of germination in hours				
		24	48	72	96	120
C o n t r o l		0.0	50.4	95.2	96.8	96.8
0	0.2	0.0	0.0	2.4	5.6	18.4
4	0.2	0.0	0.0	0.0	4.8	16.8
12	0.2	0.0	0.0	1.6	10.4	45.6**
24	0.2	0.0	0.0	1.6	5.6	55.2**
48	0.2	0.0	0.0	1.6	5.6	29.6**
4	0.0	0.0	27.2**	96.0	98.4	98.4
12	0.0	0.0	44.8	98.4	99.2	99.2
24	0.0	0.0	79.2**	98.4	98.4	99.2
48	0.0	0.0	85.6**	95.2	96.0	96.8
LSD at 5% level		0.0	7.8	3.8	7.1	7.3
1% level		0.0	10.5	5.1	9.6	9.7

Figures show percentage.

** Significant at 1% level.

Table : 10. Effect of Polyethylene glycol (PEG, 6000) on growth of seedlings of paddy under the influence of NaCl.

Duration of soaking in PEG (Hr)	NaCl M	Length	
		Root mm	Shoot mm
C o n t r o l		58.16	37.84
0	0.2	3.24	4.20
4	0.2	4.00	4.40
12	0.2	6.40	6.40
24	0.2	10.24*	7.80**
48	0.2	9.12	7.28*
4	0	72.00**	37.84
12	0	72.16**	38.04
24	0	55.72	41.60*
48	0	72.80**	40.60
LSD at 5% level		6.74	2.91
1% level		9.04	3.90

* Significant at 5% level.

** Significant at 1% level.

in PEG from 4 to 24 hours. But this trend was not observed when the duration of soaking was increased from 24 to 48 hours. A significant increase in the growth of root system under saline condition was observed when the seeds were given a soaking treatment with PEG for a period of 24 hours. However, soaking of seeds in PEG for 24 and 48 hours resulted in a significant increase in the growth of shoot system under the influence of salt.

Kinetin

Treatment of seeds with kinetin did not show any marked effect on the rate of emergence or on the final percentage of germination of seeds. However, the rate of emergence as well as the final percentage of germination under saline condition were significantly enhanced by kinetin tried at all concentrations (Table 11). Kinetin at a concentration of 20 mg/l brought about the maximum percentage of germination (50%) of seeds under the influence of 0.2 M NaCl.

A trend towards decrease in growth of root system was observed with increase in the concentration of kinetin except at a concentration of 5 mg/l (Table 12). Treatment of seeds with kinetin slightly reduced the growth of shoot system except at a concentration of 20 mg/l. Kinetin

Table : 11. Effect of kinetin on germination of seeds of paddy under the influence of NaCl.

Concentration of		Duration of germination in hours				
Kinetin mg/l	NaCl M	24	48	72	96	120
0	0	0.0	20.8	91.2	93.6	94.4
0	0.2	0.0	0.0	3.2	6.4	18.4
2.5	0.2	0.0	0.0	5.6	16.0*	31.2**
5	0.2	0.0	0.0	6.4	21.6**	34.4**
10	0.2	0.0	0.0	7.2	15.2*	26.4**
15	0.2	0.0	0.0	4.0	18.2**	40.0**
20	0.2	0.0	0.0	7.2	26.4**	50.4**
2.5	0	0.0	16.8	90.4	95.2	95.2
5	0	0.0	18.4	91.2	96.0	96.0
10	0	0.0	21.6	91.2	94.4	96.0
15	0	0.0	20.8	93.6	96.0	96.0
20	0	0.0	20.0	92.0	96.0	96.8
LSD at 5% level		0.0	4.7	5.4	7.5	5.7
1% level		0.0	6.2	7.1	10.1	7.6

Figures show percentage

* Significant at 5% level.

** Significant at 1% level.

Table : 12. Effect of kinetin on growth of seedlings of paddy under the influence of NaCl.

Concentration of		Growth	
Kinetin mg/l	NaCl M	Root mm	Shoot mm
0	0	51.96	36.16
0	0.2	3.60	4.44
2.5	0.2	7.92	6.00
5	0.2	6.24	10.44**
10	0.2	6.40	8.48*
15	0.2	8.20	5.96
20	0.2	8.08	13.08**
2.5	0	50.08	35.56
5	0	55.24	34.08
10	0	47.88	34.04
15	0	46.00	33.20
20	0	40.60	36.60
LSD at	5% level	9.59	3.44
	1% level	12.82	4.60

* Significant at 5% level.

** Significant at 1% level.

failed to bring about any significant increase in the growth of root system under saline condition. However, the growth of shoot system under the influence of salt was significantly enhanced by kinetin at 5, 10 and 20 mg/l concentrations. Kinetin at a concentration of 20 mg/l brought about a maximum stimulation of shoot system under saline condition.

GA_3

GA_3 tried at all concentrations brought about a significant increase in the rate of emergence of seeds at the end of 48 hours of germination (Table 13). However, the final percentage of germination of seeds was not much affected by GA_3. GA_3 resulted in a marked increase in the rate of emergence (except 20 mg/l) and the final percentage of germination of seeds under saline condition. GA_3 at 10 and 15 mg/l concentrations brought about a maximum stimulation of germination of seeds under the influence of salt. As compared to the control (salt alone) a four-fold increase in the final percentage germination of seeds was observed under the influence of 10 and 15 mg/l GA_3.

The growth of root system was slightly improved by GA_3. However, there was no significant increase in the growth of

Table : 13. Effect of GA_3 on germination of seeds of paddy under the influence of NaCl.

Concentration of		Duration of germination in hours				
GA_3 mg/l	NaCl M	24	48	72	96	120
C o n t r o l		0.0	32.0	94.4	97.6	97.6
0	0.2	0.0	0.0	7.2	16.0	22.4
5	0.2	0.0	6.4*	33.6**	68.0**	84.8**
10	0.2	0.0	7.2**	35.2**	69.6**	88.0**
15	0.2	0.0	8.0**	30.4**	69.6**	88.0**
20	0.2	0.0	2.4	19.2**	57.6**	83.2**
5	0	0.0	68.0**	98.4	100.0	100.0
10	0	0.0	71.2**	98.4	98.4	99.2
15	0	0.0	66.4**	95.2	98.4	99.2
20	0	0.0	58.4**	95.2	95.2	97.6
LSD at 5% level		0.0	5.3	7.6	5.5	4.2
1% level		0.0	7.2	10.2	7.4	5.7

Figures show percentage

* Significant at 5% level.

** Significant at 1% level.

root system as a result of the treatment of seeds with GA_3 (Table 14). As compared to the growth of root system, the shoot system exhibited stimulation of growth especially under 10 and 15 mg/l GA_3. The stimulatory effect of GA_3 was more pronounced in the growth of root and shoot systems under saline condition as compared to the control. GA_3 at 5, 10 and 15 mg/l concentrations significantly increased the growth of root system under saline condition. GA_3 tried at all concentrations brought about a significant increase in the growth of shoot system under the influence of salt. The maximum stimulation of growth of shoot system was affected by 10 mg/l GA_3. Since the maximum stimulation of germination of seeds and growth of seedlings under saline condition are brought about by GA_3 (10 mg/l), further studies were carried out employing GA_3 (10 mg/l) with a view to finding out the mechanisms by which GA_3 stimulates the germination of seeds and growth of seedlings under saline condition.

Changes in the dry weight of endosperms during germination

The endosperm of the resting seed showed a dry weight of 17.67 mg and it decreased steadily as germination progressed (Table 15). At the end of 120 hours of germination, more than 35.5% of the initial dry weight got lost. Under

Table:14. Effect of GA_3 on growth of seedlings of paddy under the influence of NaCl.

Concentration of		Length	
GA_3 mg/l	NaCl M	Root mm	Shoot mm
C o n t r o l		32.00	37.72
0	0.2	3.96	5.00
5	0.2	10.76*	13.12**
10	0.2	10.04*	13.60**
15	0.2	9.92*	13.12**
20	0.2	9.40	12.04**
5	0	36.56	39.16
10	0	37.84	40.36*
15	0	34.64	41.52*
20	0	33.92	39.92
LSD at	5% level	5.96	2.51
	1% level	8.00	3.36

* Significant at 5% level

** Significant at 1% level

Table : 15. Effect of GA_3 on dry weight[a] of endosperms of paddy during germination under the influence of NaCl.

Concentration of		Duration of germination in hours					
GA_3 10 mg/l	NaCl M	0	24	48	72	96	120
C o n t r o l		17.67	17.17	16.17	15.30	14.07	11.39
0	0.2	17.67	17.67	17.45	16.58	16.04	15.78
10	0.2	17.67	17.67	16.58**	15.86**	15.00**	14.67**
10	0	17.67	17.17	15.50**	15.30	13.12**	9.95**
LSD at 5% level		0.06	0.32	0.37	0.19	0.56	0.43
1% level		0.09	0.49	0.56	0.29	0.85	0.65

[a] mg dry weight/endosperm

** Significant at 1% level.

the influence of salt, the endosperm of the seed showed only a loss of 11% of its initial dry weight. However, treatment of seeds with GA_3 brought about a greater loss (17%) in the dry weight of endosperm under the influence of salt as compared to its control (salt alone). Treatment of seeds with GA_3 alone resulted in a rapid loss in dry weight of endosperm during germination. By the end of 120 hours of germination more than 43% of the initial dry weight of endosperm was found lost.

Changes in the chemical composition of endosperm of paddy during germination

Starch

The endosperm of the dry seed showed a starch content of 15.08 mg and it accounted for 85% of its initial dry weight (Fig. 1). During germination of seed the starch content of endosperm showed a steady decrease and by the end of 120 hours of germination more than 59% of its initial level got depleted. The maximum rate of depletion of starch was observed during 24 to 48 hours of germination. However, in presence of salt the depletion of starch declined sharply and only a reduction of 29% of the initial level was observed at the end of 120 hours of germination.

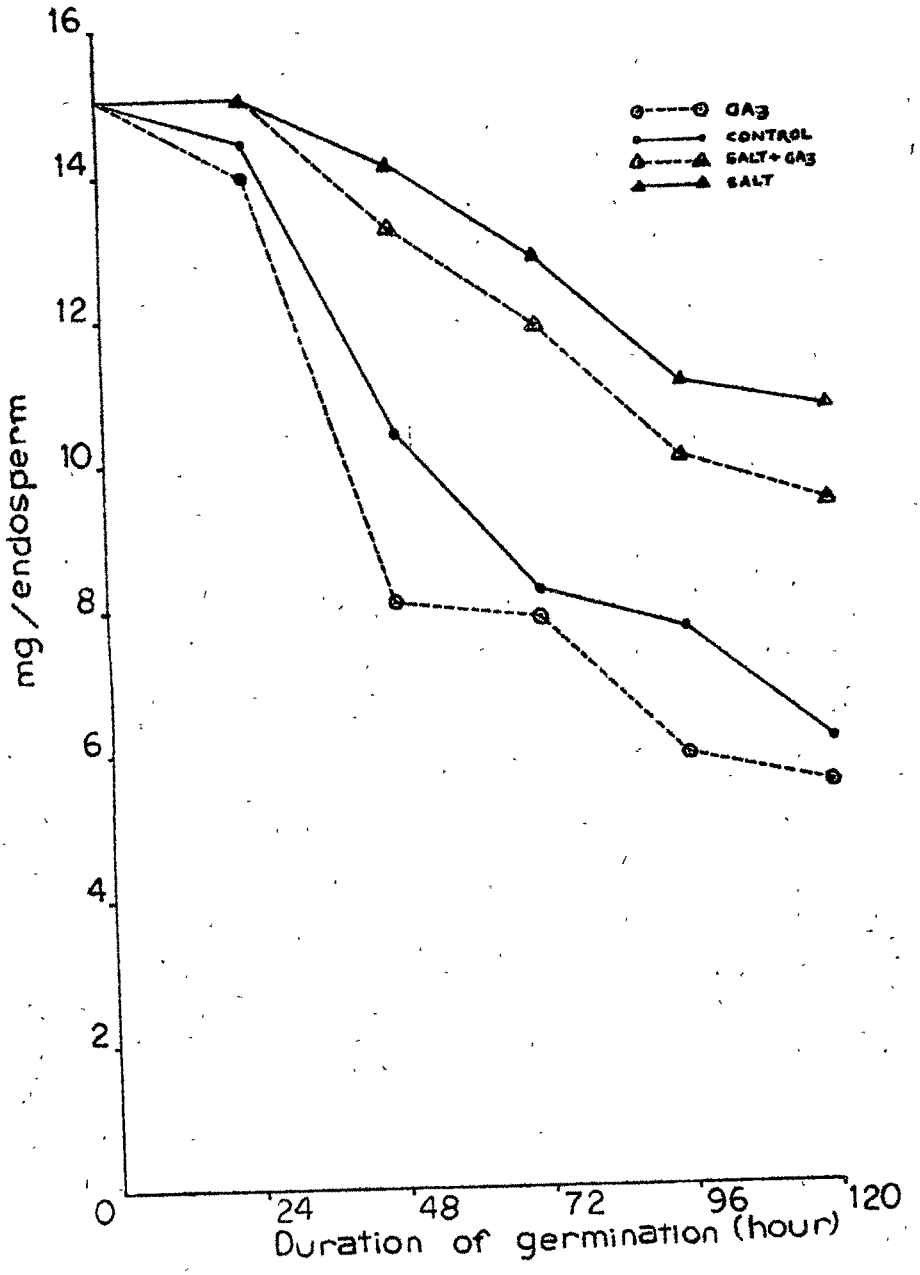


FIG. 1. CHANGES IN THE STARCH CONTENT OF ENDOSPERM OF PADDY DURING GERMINATION.

Treatment of seeds with GA_3 enhanced the depletion of starch during germination of seeds under the influence of salt. At the end of 120 hours of germination 37.6% of starch was found depleted. Treatment of seeds with GA_3 alone resulted in a rapid depletion of starch during germination of seeds and at the end of 120 hours of germination 63% of the initial level of starch got depleted.

Total soluble sugars

It has been observed that the endosperm of the resting seed contains 163.6 µgs of soluble sugars (Fig. 2). During germination, the level of soluble sugars did not show any appreciable increase upto 48 hours. From 48 hours onwards the level of the soluble sugars exhibited a steep rise and at the end of 120 hours, it exhibited a 9-fold increase. In presence of salt the sugar level did not rise much and at the end of 120 hours, it increased only to 260.4 µgs. Endosperms of seeds treated with GA_3 showed double the amount of sugars under the influence of salt, as compared to its control (salt alone). The endosperm of seeds treated with GA_3 showed 14-fold increase in the initial level of sugars at the end of 120 hours.

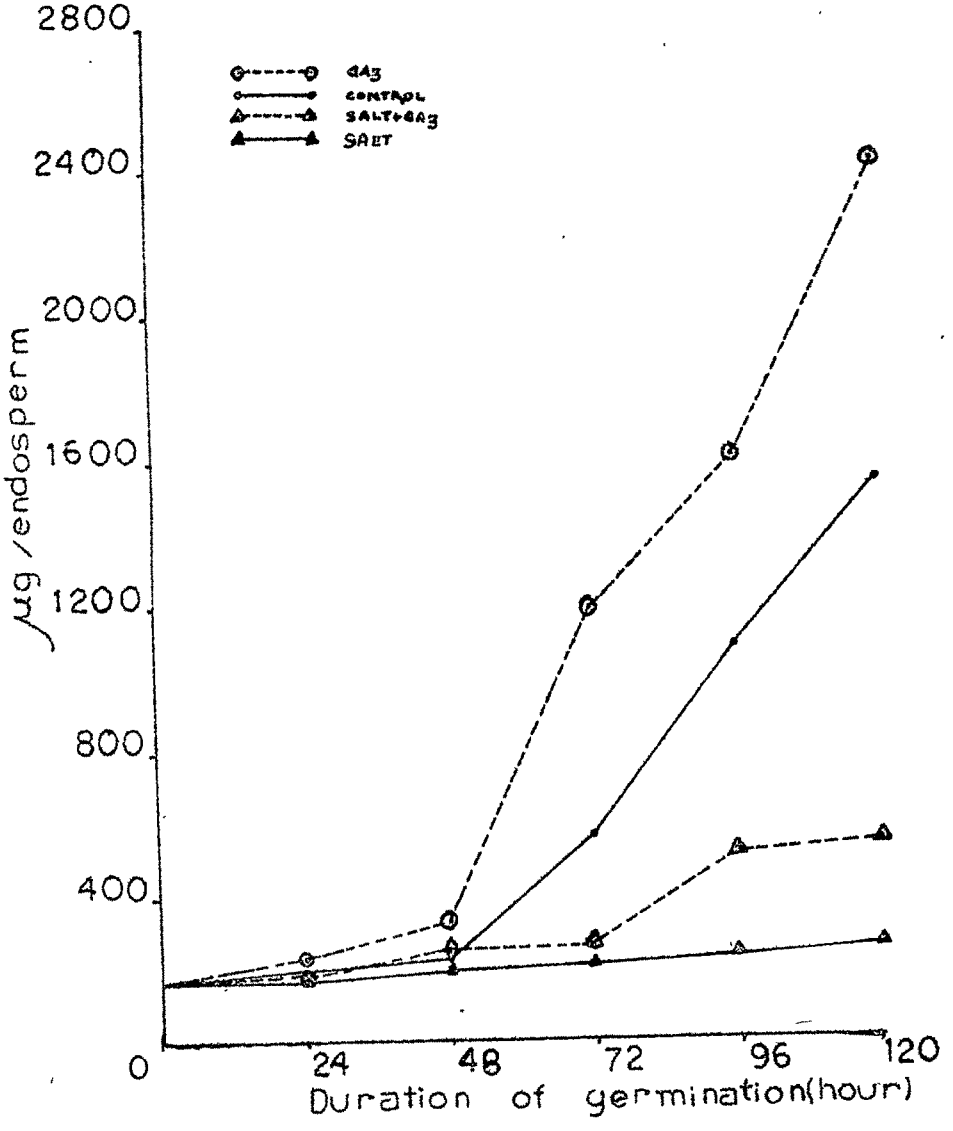


FIG. 2. CHANGES IN THE TOTAL SOLUBLE SUGAR CONTENT OF ENDOSPERM OF PADDY DURING GERMINATION.

Reducing sugars

Endosperm of resting seed contained a very low quantity (17.45 µgs) of reducing sugars (Fig. 3). The level of reducing sugars increased steadily during germination and registered a 24.6-fold increase at the end of 120 hours. The endosperm of seed germinated in 0.2 M NaCl, showed only 5-fold increase in the level of reducing sugars at the end of 120 hours. Whereas, the endosperm of seed treated with GA_3 and germinated under saline condition, showed an increase of more than 8-fold as compared to the initial level by the end of 120 hours of germination. The endosperm of seed treated with GA_3 showed 38-fold increase in its content of reducing sugars by the end of 120 hours as compared to their initial level.

Total proteins

It has been observed that the endosperm of dry seed contains 1.39 mgs protein and it accounted for 7.9% of its dry weight (Fig. 4). During germination, the protein content decreased steadily and reached to half the initial level at the end of 120 hours. The maximum rate of depletion of protein was observed during 0 to 24 hours of germination. In presence of salt the depletion of protein was slow and a

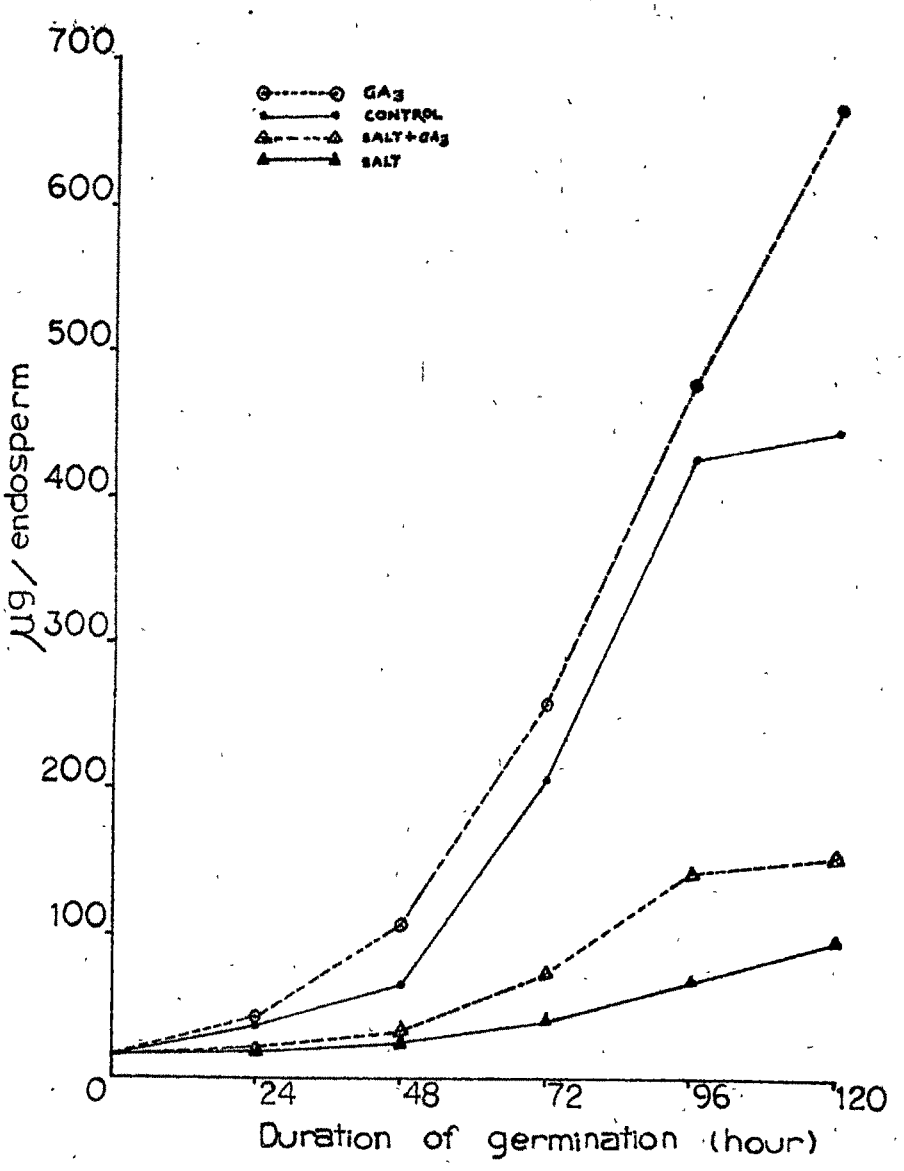


FIG. 3. CHANGES IN THE CONTENT OF REDUCING SUGARS OF ENDOSPERM OF PADDY DURING GERMINATION.

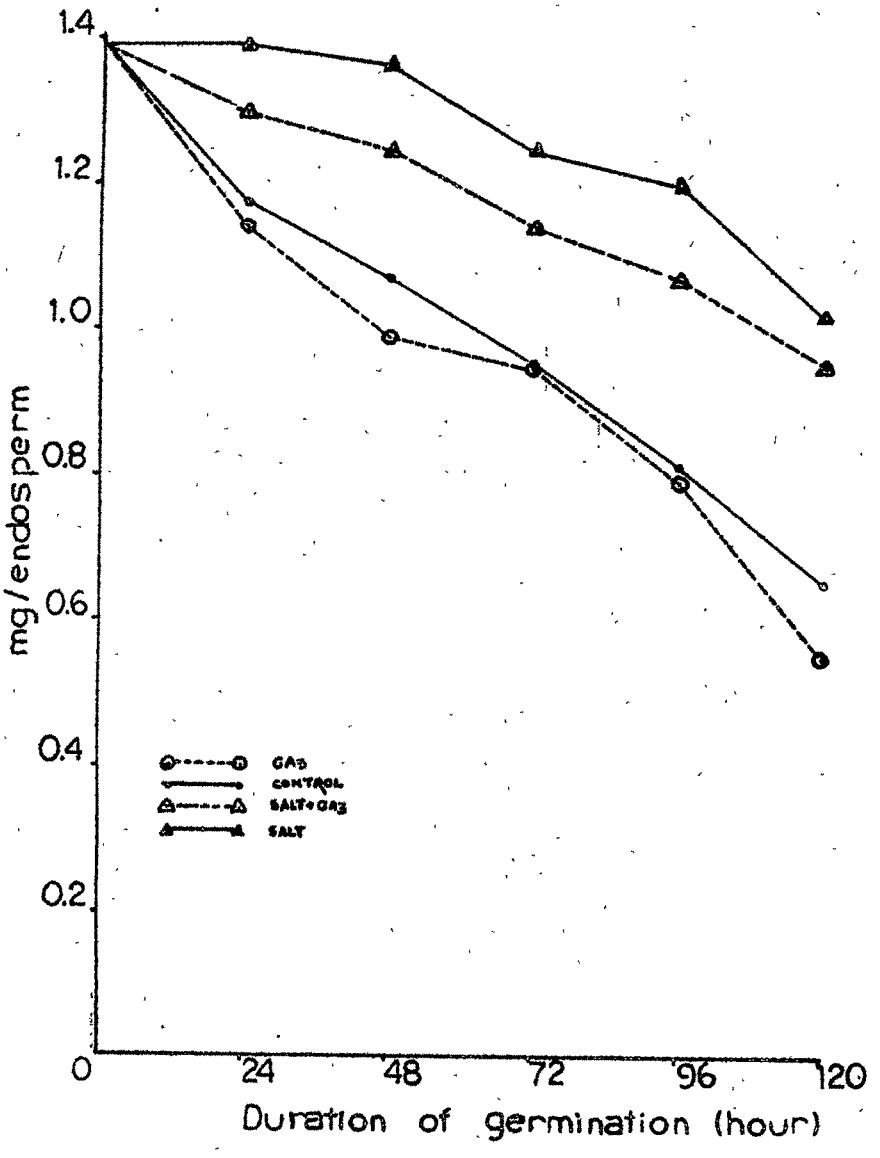


FIG. 4. CHANGES IN THE TOTAL PROTEIN CONTENT OF ENDOSPERM OF PADDY DURING GERMINATION.

reduction of 26.6% of its initial level was observed at the end of 120 hours of germination. Treatment of seeds with GA_3 enhanced the rate of depletion of protein under the influence of salt and at the end of 120 hours, 31.6% of the initial protein content got depleted. Treatment of seeds with GA_3 alone lead to a rapid depletion of protein during germination of seeds. By the end of 120 hours of germination 50% of the initial protein content was depleted under the influence of GA_3.

Total nitrogen

The endosperm of the dry seed contained 134.27 µgs of nitrogen (Fig. 5). During germination, the nitrogen content decreased gradually and by the end of 120 hours of germination about 50% of the initial nitrogen level was depleted. A very slow rate of depletion of nitrogen was observed during germination of seeds under saline condition and at the end of 120 hours, only 13.5% of the initial level got depleted. However, when the seeds were pretreated with GA_3 and germinated in presence of salt, 22% of the initial level of nitrogen got depleted by the end of 120 hours of germination. A rapid depletion of total nitrogen was observed during germination of seeds under the influence of GA_3 alone and about 59% of the initial content of total

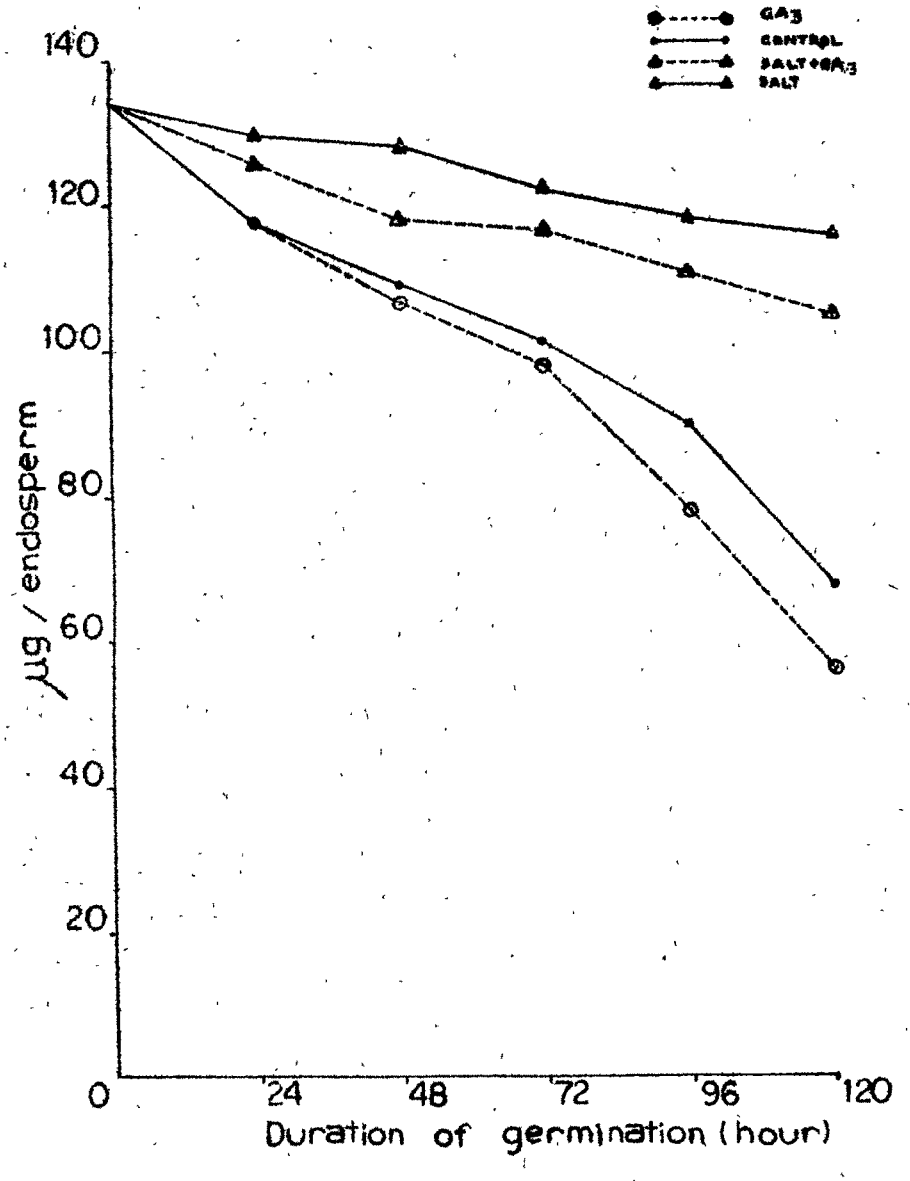


FIG. 5. CHANGES IN THE TOTAL NITROGEN CONTENT OF ENDOSPERM OF PADDY DURING GERMINATION.

nitrogen was found depleted by the end of 120 hours of germination.

Phytin

The endosperm of the resting seed contained 35.69 µgs of phytin (Fig. 6). During germination its level decreased steadily and at the end of 120 hours, 67.8% of its initial level got depleted. During germination of seeds under the influence of salt, the phytin content showed a very slow rate of depletion and by the end of 120 hours of germination only 28% of the initial level got depleted. Treatment of seeds with GA_3 slightly enhanced the rate of depletion of phytin during germination under saline condition and at the end of 120 hours, 49% of the initial level was found depleted. As compared to the pure control, treatment of seeds with GA_3 resulted in an enhanced rate of depletion of phytin and at the end of 120 hours of germination 74% of initial level of phytin was found depleted.

Inorganic phosphorus (iP)

The endosperm of dry seed showed a very low content of inorganic phosphorus (6.0 µgs) (Fig. 7). During germination its level increased during 24 and 96 hours. A maximum increase was observed at the end of 96 hours of germination. The changes

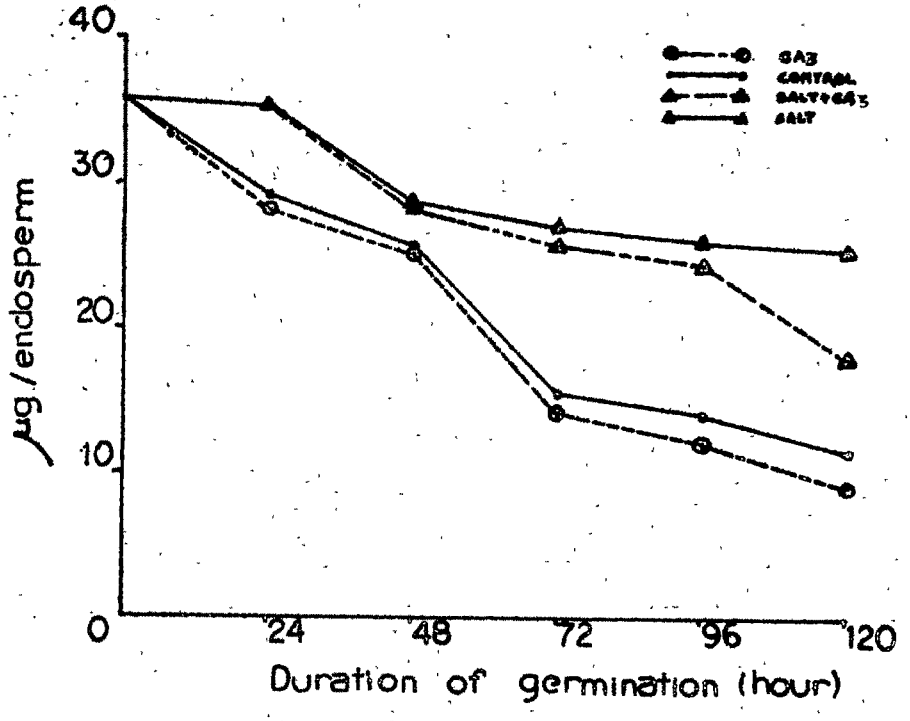


FIG. 6. CHANGES IN THE PHYTIN CONTENT OF ENDOSPERM OF PADDY DURING GERMINATION.

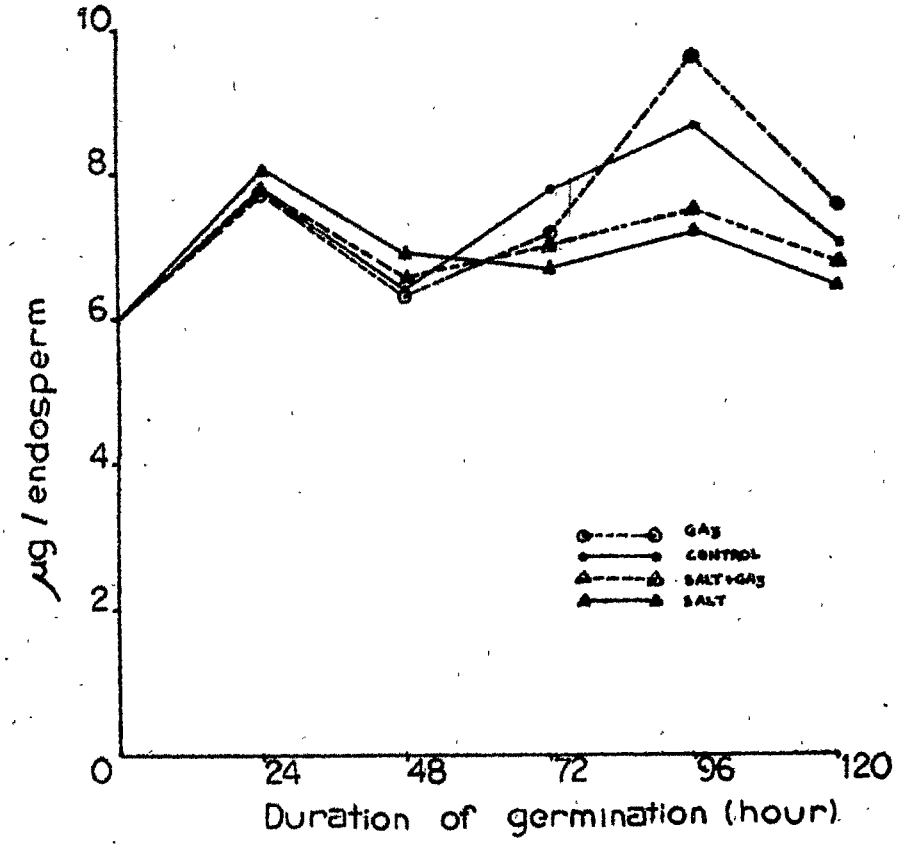


FIG. 7. CHANGES IN THE INORGANIC PHOSPHORUS CONTENT OF ENDOSPERM OF PADDY DURING GERMINATION.

in the level of inorganic phosphorus followed the same pattern as that of control during germination of seeds under all other treatments. However, a higher level of inorganic phosphorus was observed under the influence of GA_3 as compared to those of controls.

Action spectra of enzymes during germination

Amylases

A very low amylolytic activity has been observed in the endosperms of resting seeds (Fig. 8). It increased steadily as germination progressed and showed a 215-fold increase in its activity by the end of 120 hours of germination. During germination of seeds under the influence of salt only a slight increase in the activity of amylase could be observed. The highest activity observed under the influence of salt at the end of 120 hours of germination was only 10% of the maximum activity observed in the control. However, the treatment of seeds with GA_3 enhanced the activity of amylase during germination under the influence of salt. Treatment of seeds with GA_3 brought about 3.5 fold increase in the activity of amylase as compared to the control (salt alone) at the end of 120 hours of germination. The activity of amylase was only slightly stimulated by GA_3

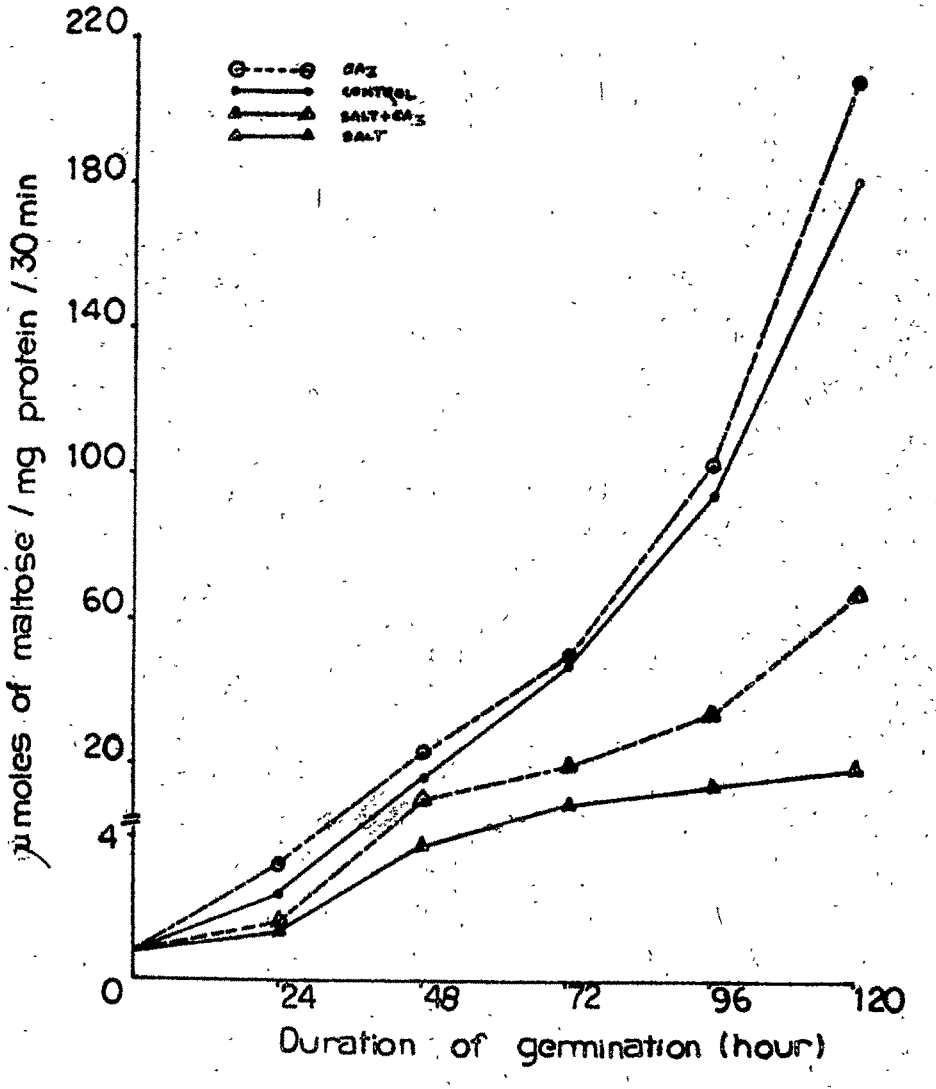


FIG. 8. TOTAL AMYLOLYTIC ACTIVITY DURING GERMINATION OF PADDY.

as compared to that of control.

The activity of α-amylase was not detected in the endosperms of resting seeds. However, the activity appeared at the end of 24 hours of germination and increased slightly till the end of 96 hours (Fig. 9). From 96 hours onwards the activity registered a sharp rise. During germination of seeds under the influence of salt, only a very low activity of α-amylase could be detected. Treatment of seeds with GA_3 stimulated the activity of amylase under the influence of salt especially during 96 and 120 hours of germination markedly. A slightly higher activity of amylase was observed during the germination of GA_3 treated seeds as compared to that of the control.

The endosperms of dry seeds exhibited a very low activity of β-amylase (Fig. 10). The activity remained almost constant till the end of 24 hours of germination and registered a steady increase thereafter. At the end of the duration studied, the endosperms of seeds showed a 131-fold increase in their activity as compared to their initial level. A low rate of increase in the activity of β-amylase was observed in the endosperms of seeds during germination under the influence of salt and only a 14-fold increase in its activity could be observed at the end of 120 hours as

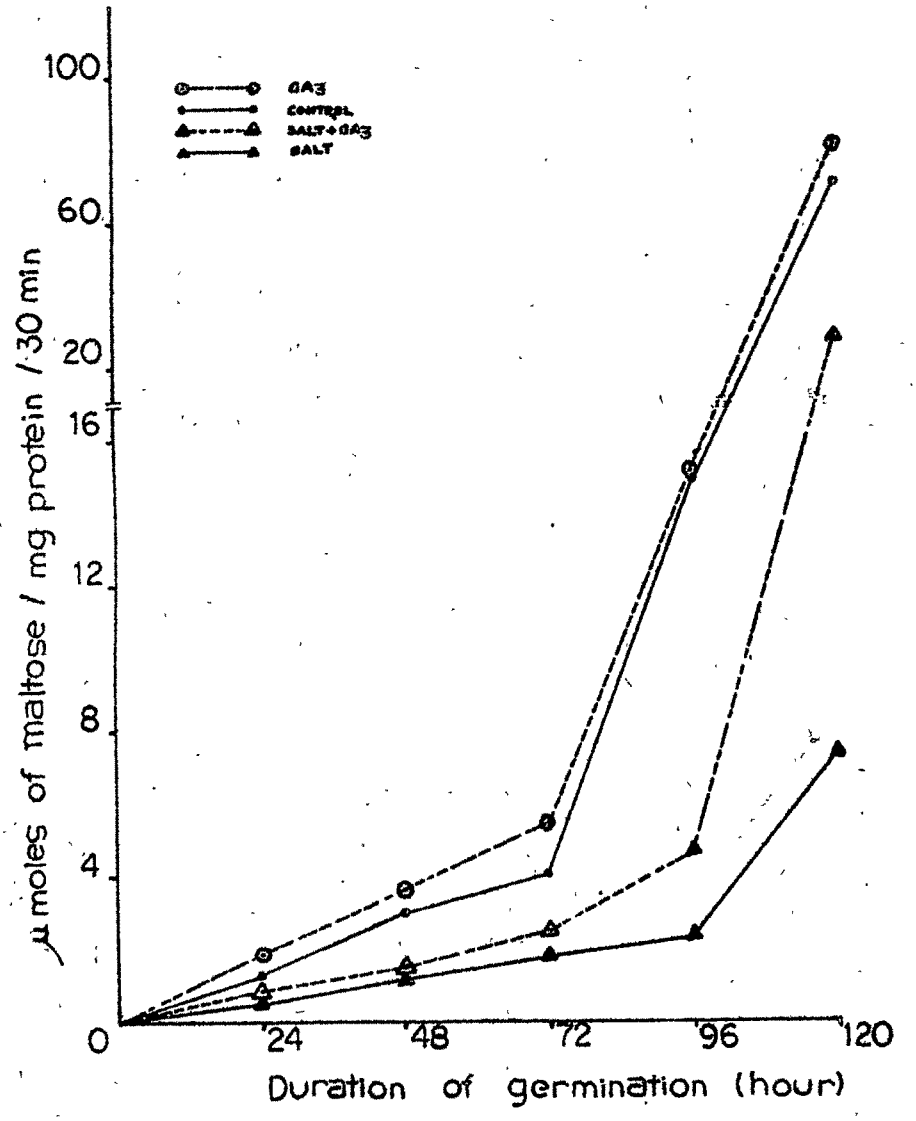


FIG. 9. ACTIVITY OF α - AMYLASE DURING GERMINATION OF PADDY.

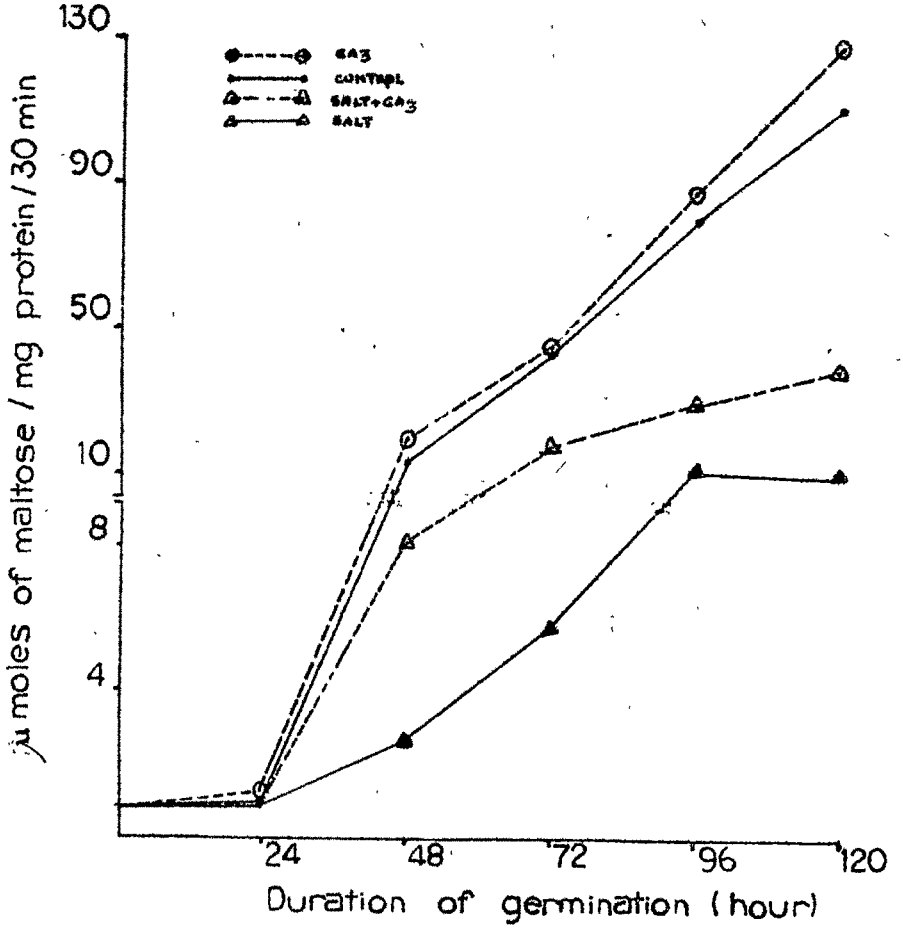


FIG. 10. ACTIVITY OF β-AMYLASE DURING GERMINATION OF PADDY.

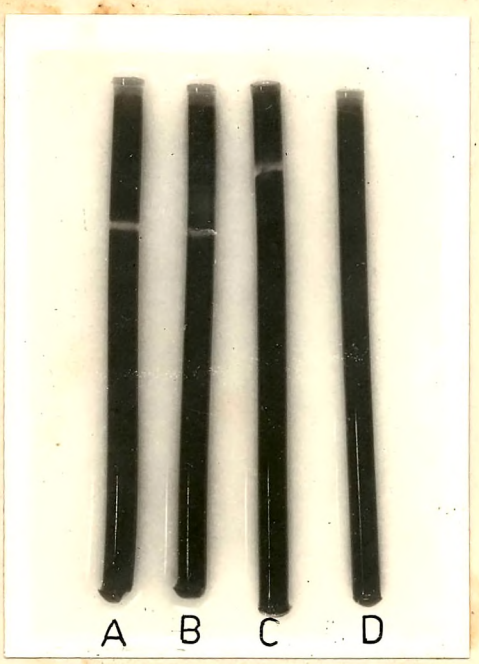
compared to its initial level. Treatment of seeds with GA_3 stimulated the activity of β-amylase during germination under the influence of salt considerably and at the end of 120 hours a 2.4 fold increase in its activity was observed as compared to that of a control (salt alone). Under the influence of GA_3, a slightly enhanced activity of β-amylase was observed during germination of seeds except at the end of 72 hours.

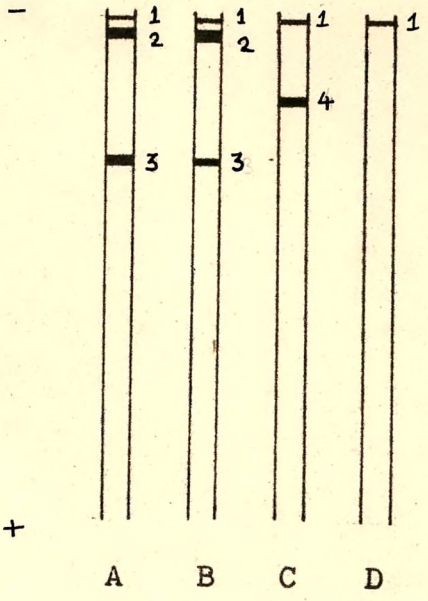
Isozyme pattern of amylases

α-amylase

The crude extract of the endosperms of dry seeds when applied to electrophoresis did not show any band of α-amylase. At the end of 24 hours of germination 3 bands (Nos. 1, 2 and 3) appeared (Plate I). The crude extract of α-amylase of salt treated seeds showed the presence of band No. 1 only. However, when the seeds were treated with GA_3 and kept for germination in the saline medium, development of a new band (No. 4) of α-amylase could be observed. At the end of 48 hours of germination, bands - No. 2 and 3 disappeared and band No. 5 appeared (Plate II). The isozymes of α-amylase of seeds germinated under the influence of salt alone showed the presence of a new band (No. 4). At the end of 72 hours of germination, the isozymes

ISOZYME PATTERN OF α-AMYLASE DURING GERMINATION





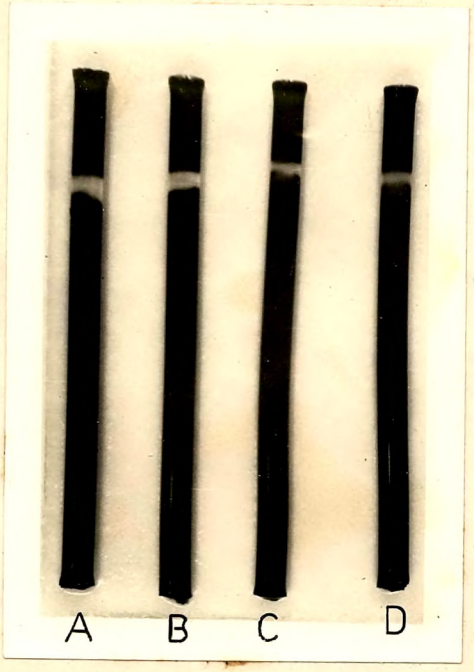
A GA_3

B CONTROL

C SALT + GA_3

D SALT

PLATE I - 24 Hour



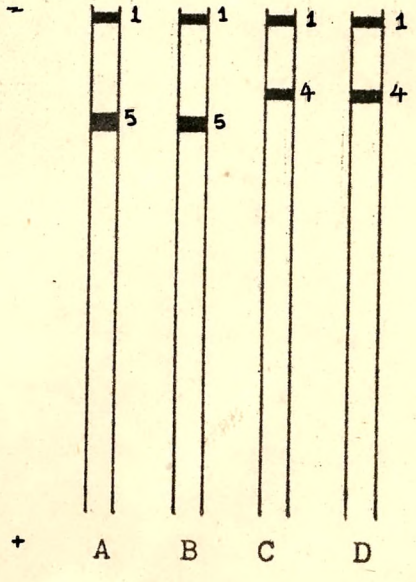


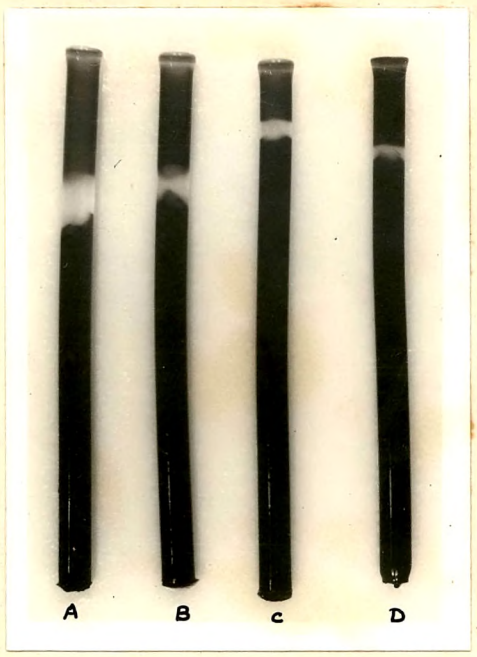
PLATE II - 48 Hour

of α-amylase of seeds under all treatments showed the same pattern as observed at the end of 48 hours (Plate III). At the end of 96 hours of germination, 3 bands (Nos. 1, 2 and 5) were observed. Band 3 was also detected on the gels except the salt treated one (Plate IV). At the end of 120 hours of germination, band 6 appeared on the gel (Plate V). Over and above the 3 bands (1, 2 and 6) observed in the case of control, GA_3 treated seeds showed the presence of an additional band - No. 7. Seeds under the influence of salt alone showed the bands - No. 1, 2 and 4. As in the case of GA_3 treated seeds, band No. 7 was located in the seeds treated with salt plus GA_3 also.

β-amylase

The crude extract from the endosperms of dry seeds of paddy showed 2 bands - No. 1 and 2 (Plate VI). At the end of 24 hours of germination, band 2 disappeared and 3 appeared on the gels of all the treatments (Plate VII). The extract of GA_3 treated seeds showed appearance of additional bands - No. 4 and 5. At the end of 48 hours of germination, the control, GA_3 alone and salt plus GA_3 treated seeds exhibited 3 bands viz. 1, 2 and 4, whereas, the seeds treated with salt alone showed the bands - 1, 3 and 4 (Plate VIII). At the end of 72 hours of germination bands - No. 3 and 6 were detected on the gels of all the treatments (Plate IX). Band No. 1

ISOZYME PATTERN OF α-AMYLASE DURING GERMINATION



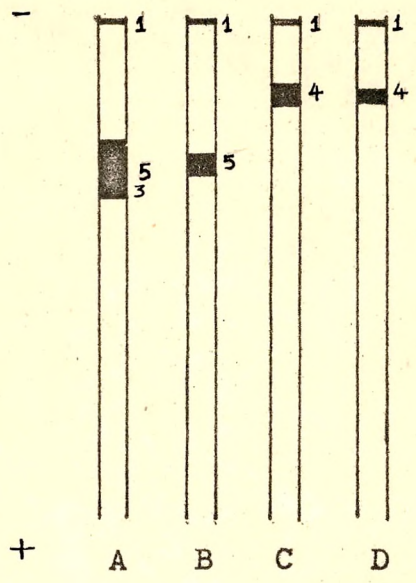


PLATE III - 72 Hour

A GA_3

B CONTROL

C SALT + GA_3

D SALT

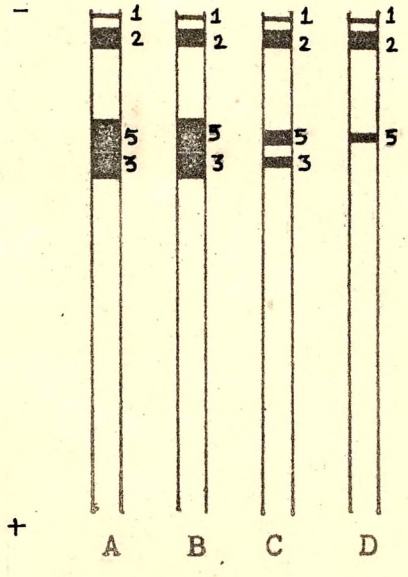
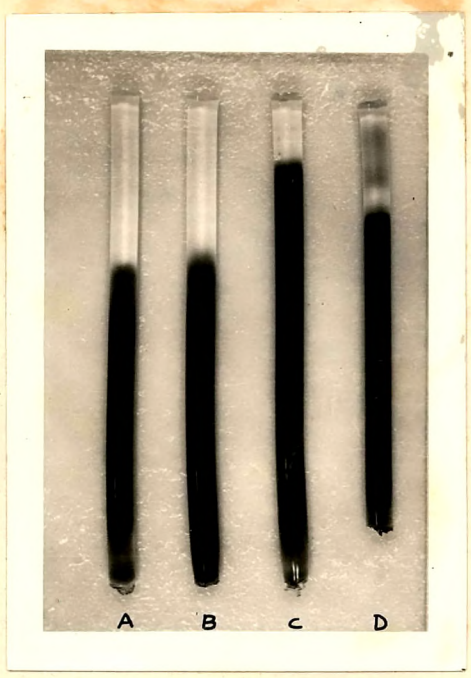


PLATE IV - 96 Hour



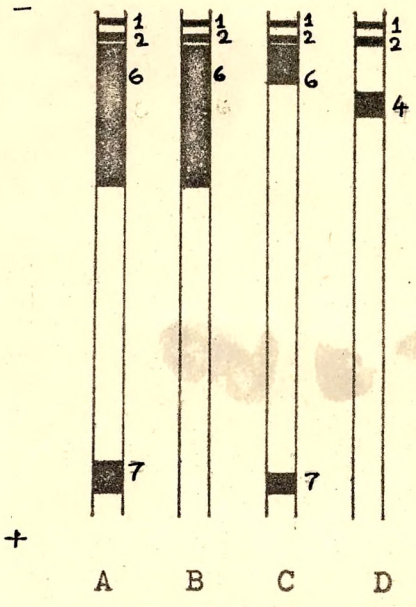


PLATE V - 120 Hour

A GA_3

B CONTROL

C SALT + GA_3

D SALT

ISOZYME PATTERN OF α-AMYLASE DURING GERMINATION.

ISOZYME PATTERN OF β-AMYLASE DURING GERMINATION

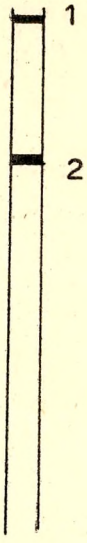


PLATE VI - 0 Hour

A GA_3

B CONTROL

C SALT + GA_3

D SALT

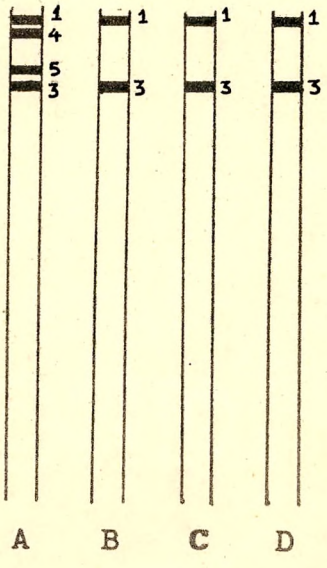
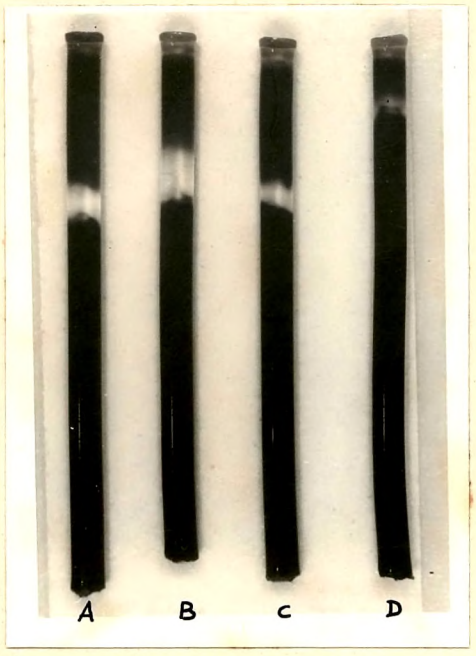


PLATE VII - 24 Hour

ISOZYME PATTERN OF β-AMYLASE DURING GERMINATION



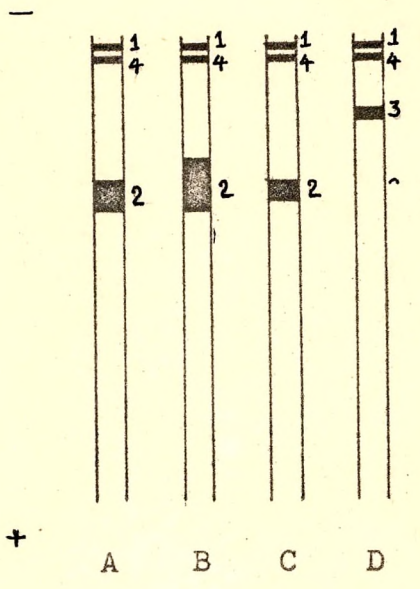


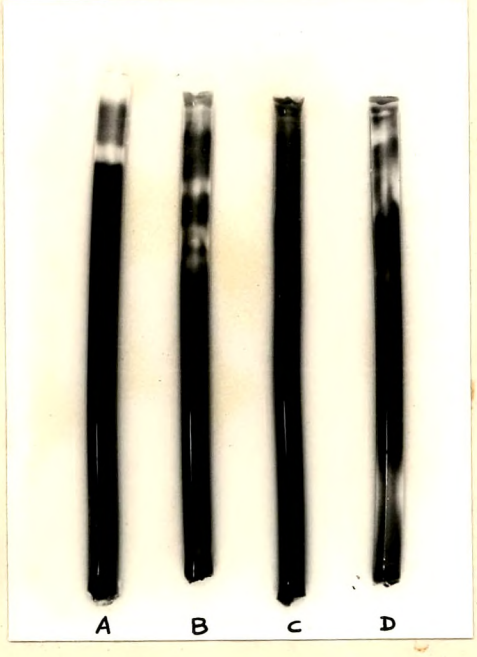
PLATE VIII - 48 Hour

A GA_3

B CONTROL

C SALT + GA_3

D SALT



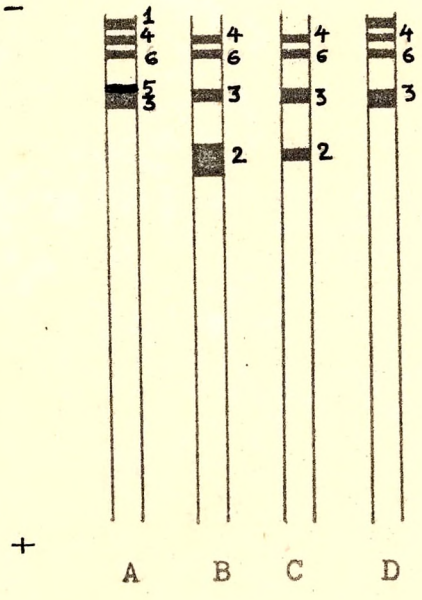


PLATE IX - 72 Hour

disappeared and 2 appeared on the gels of control and salt plus GA_3 treated seeds. Band No. 5 was observed on the gel of GA_3 treated seeds. At the end of 96 hours of germination, band No. 4 disappeared from the gels of all the treatments (Plate X). Band No. 7 was detected on the gels of control, GA_3 alone and salt plus GA_3 treated seeds. Band No. 2 was observed on the gels of control and GA_3 treated seeds, whereas, an additional band No. 8 was observed only on the gel of GA_3 treated seeds. The pattern of salt treated seeds remained unchanged during 96 hours of germination. At the end of 120 hours of germination band No. 9 was detected in all the treatments (Plate XI). Band No. 10 was present in control and GA_3 treated seeds, whereas, band 11 was present in salt and salt plus GA_3 treated seeds.

Maltase

The endosperms of resting seeds showed a very low activity of maltase and it increased gradually till the end of 72 hours of germination (Fig. 11). From 72 hours onwards the activity rose sharply reaching the maximum activity at the end of 96 hours of germination and remained almost constant thereafter. The maltase showed a very low activity during germination of seeds under the influence of salt as compared to that of the control. The action

ISOZYME PATTERN OF β- AMYLASE DURING GERMINATION

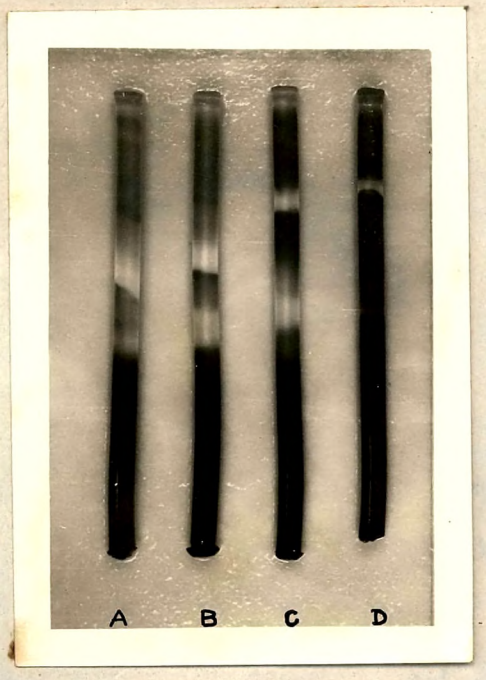
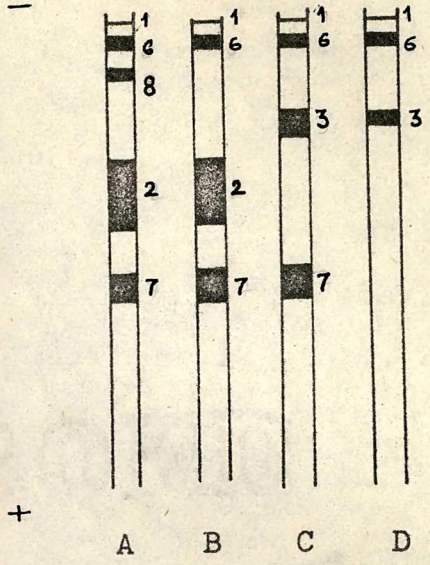


PLATE - X - 96 Hour



A GA_3

B CONTROL

C SALT + GA_3

D SALT

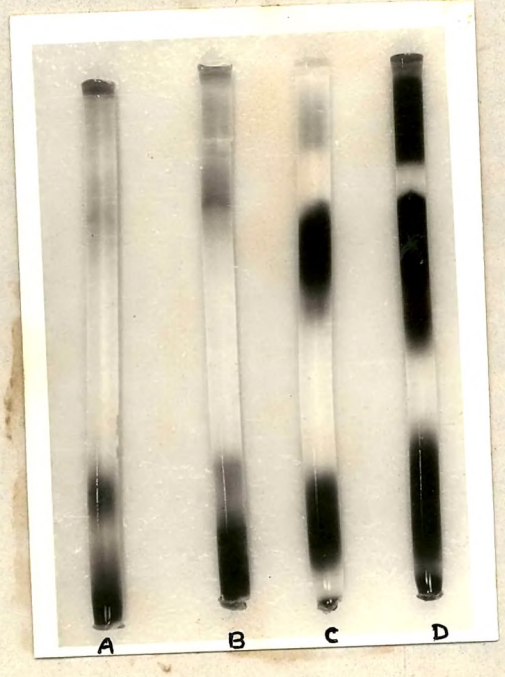
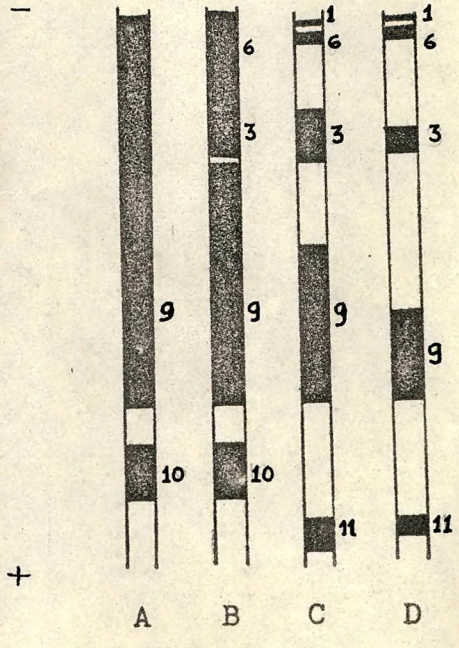


PLATE XI - 120 Hour



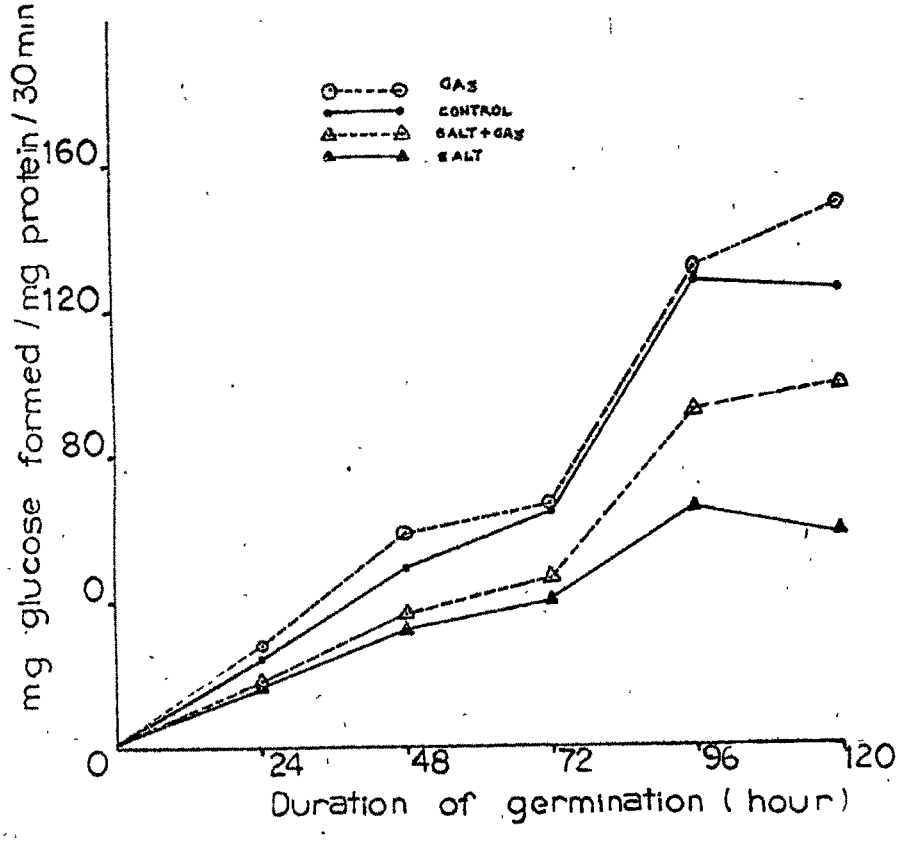


FIG. 11. ACTIVITY OF MALTASE DURING GERMINATION OF PADDY.

spectrum of maltase during germination of seeds under the influence of salt also followed almost the same pattern as that of control except for the fact that a fall in the activity was observed at the end of 120 hours. Treatment of seeds with GA_3 enhanced the activity of the enzyme during germination of seeds under saline condition as compared to its control (salt alone). Under the influence of GA_3 alone slightly enhanced activity of maltase was observed during germination of seeds.

Invertase

The endosperm of the resting seed showed a very low activity of invertase (Fig. 12). The activity rose up sharply and registered the peak at the end of 48 hours of germination and declined till the end of 72 hours. From 72 hours of germination onwards the enzyme activity showed a further rise. During germination of seeds under all other treatments the said pattern of enzyme activity was observed. A very low activity of enzyme was observed during the germination of seeds under saline condition. Treatment of seeds with GA_3 highly stimulated the activity of the enzyme under saline condition. However, under normal conditions of germination of seeds, GA_3 brought about only a slight stimulation of the enzyme activity.

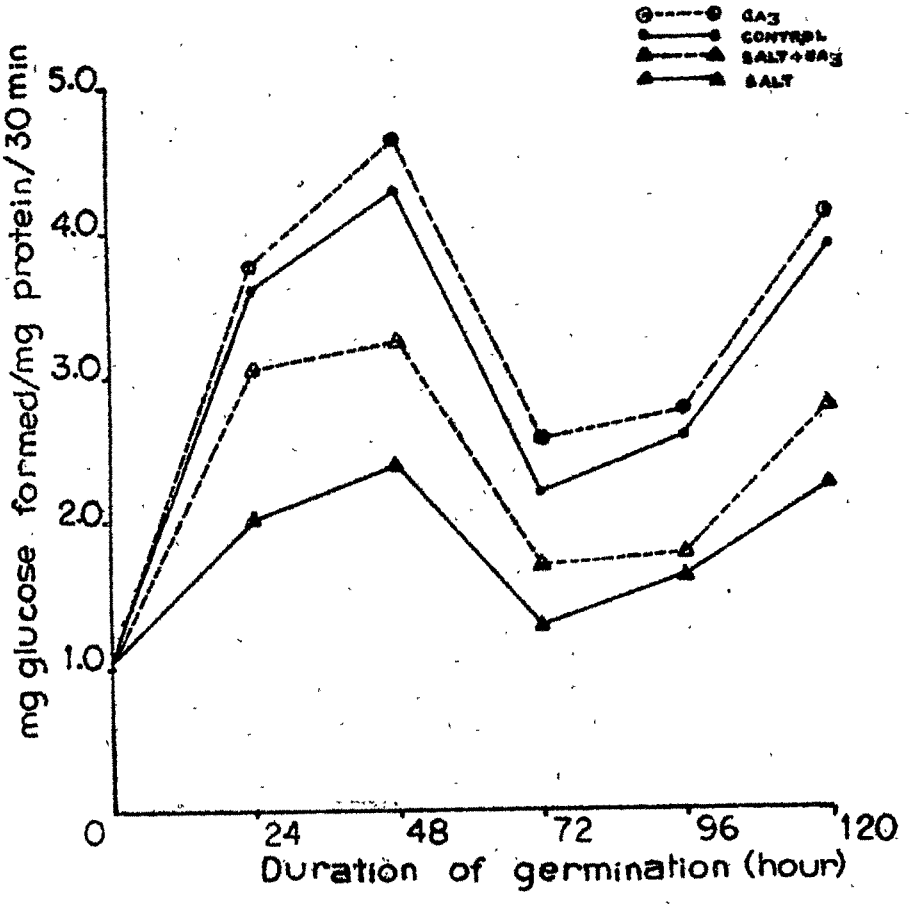


FIG. 12. ACTIVITY OF INVERTASE DURING GERMINATION OF PADDY.

Protease

A low activity of protease was detected in the endosperm of the resting seed (Fig. 13). It increased steadily during 48 hours of germination and remained almost constant till the end of 96 hours and showed a further rise thereafter. Protease showed only a very low activity during germination of seeds under saline condition. However, GA_3 treated seeds showed a highly stimulated protease activity during germination under the influence of salt. Treatment of seeds with GA_3 alone highly enhanced the activity of protease during germination. The maximum stimulation of enzyme activity by GA_3 was observed at the end of 24 hours of germination.

Phytase

Activity of phytase was not detected in the endosperms of dry seeds (Fig. 14). The activity appeared after a lag phase of 24 hours and registered a steady increase as germination progressed. During germination of seeds under the influence of salt a very low activity of phytase was observed and the maximum activity observed at the end of 120 hours was only one third of that of control. Treatment of seeds with GA_3 highly stimulated the activity of phytase during germination of seeds under saline condition. The

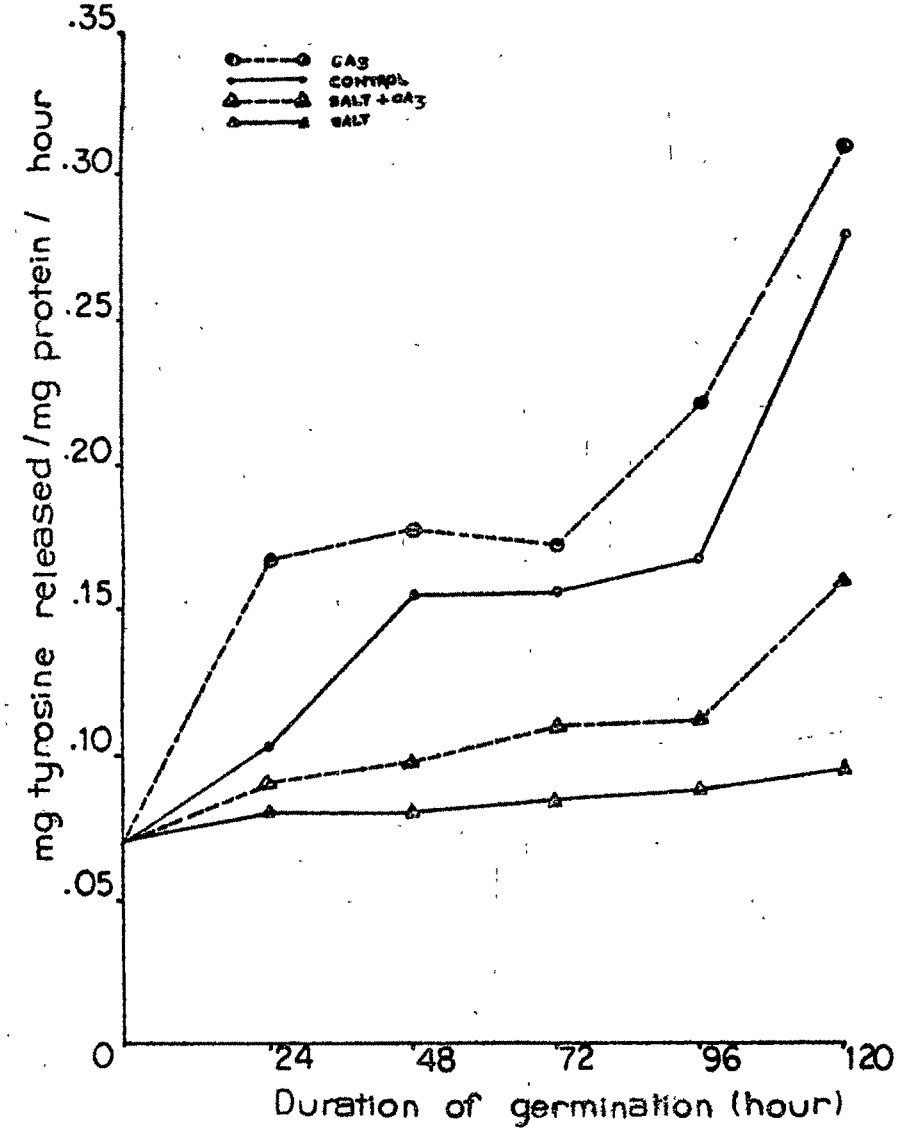


FIG. 13. ACTIVITY OF PROTEASE DURING GERMINATION OF PADDY.

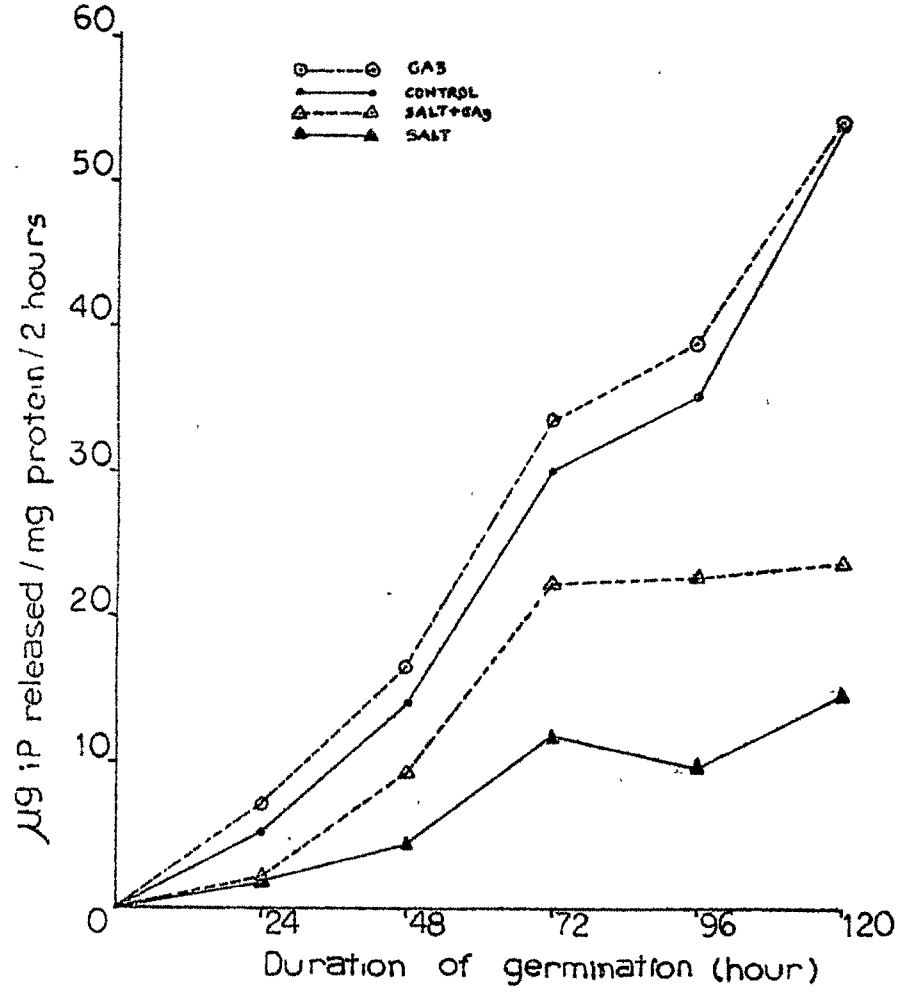


FIG. 14. ACTIVITY OF PHYTASE DURING GERMINATION OF PADDY.

maximum stimulation of phytase activity by GA_3 was observed at the end of 96 hours of germination of seeds under the influence of salt. A slightly higher activity of phytase was observed during germination of seeds under the influence of GA_3 as compared to that of control.

ATPase

Low activity of ATPase was detected in the endosperms of resting seeds (Table 15). The activity increased sharply registering the peak activity at the end of 24 and 96 hours of germination. During germination of seeds under the influence of salt a very low activity of ATPase was observed except at the end of 24 hours of germination. The activity observed at the end of 24 hours of germination was higher than that of the control. The activity of the enzyme during germination of seeds under the influence of salt was stimulated by GA_3 only from 48 hours onwards. During germination of GA_3 treated seeds the ATPase activity increased gradually and registered its peak at the end of 96 hours and declined thereafter.

Changes in oxygen uptake

The dry seeds of paddy showed a very low rate of

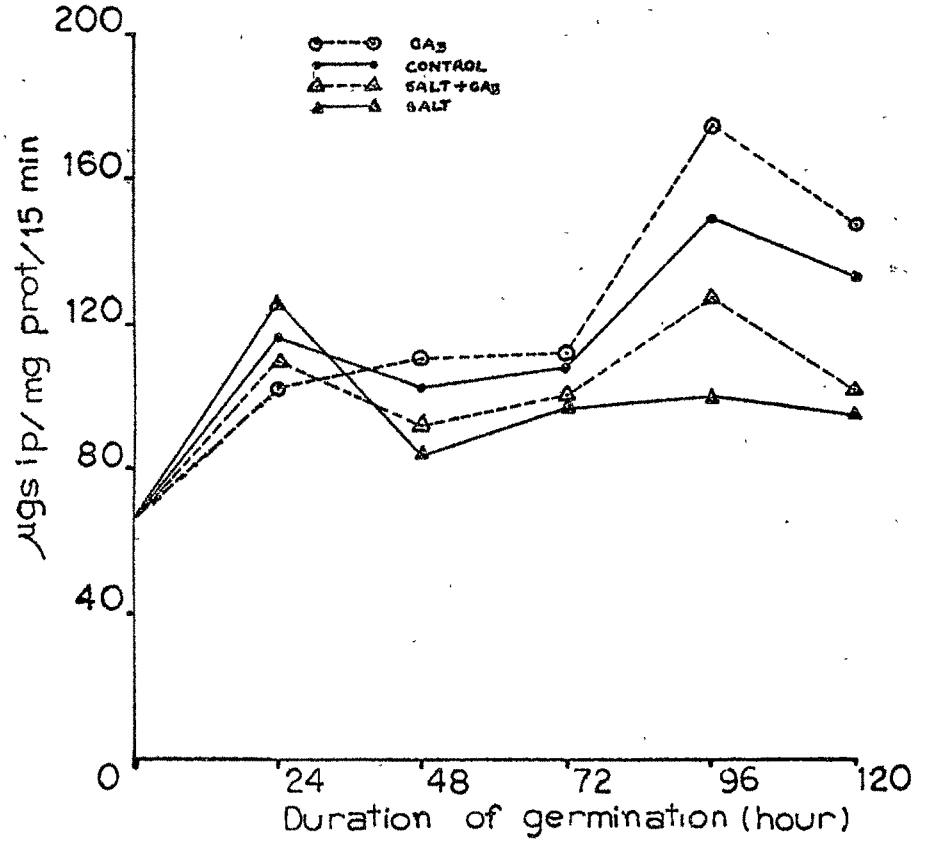


FIG. 15. ACTIVITY OF ATPase DURING GERMINATION OF PADDY.

respiration (Fig. 16). After a lag phase of 24 hours, the rate of respiration increased sharply till the end of 72 hours and it showed a slight increase thereafter. Under the influence of salt a slightly higher rate of respiration was observed till the end of 24 hours of germination as compared to that of control. However, this trend was not observed during subsequent stages of germination. The rate remained almost constant till the end of 48 hours of germination and it increased steadily registering the peak at 96 hours and declined thereafter. In general, a marked reduction in the rate of respiration was observed during germination of seeds under the influence of salt. Under the influence of salt, GA_3 treated seeds showed a lower rate of respiration till the end of 48 hours of germination as compared to their control (salt alone). However, these seeds showed a marked increase in their respiration from 48 hours onwards. A slight increase in the rate of respiration was observed during the germination of seeds under the influence of GA_3 as compared to the control.

Pyruvic dehydrogenase

The activity of pyruvic dehydrogenase was detected in the endosperms of resting seeds (Fig. 17). During germination, the activity increased steadily registering the peak at the end of 48 hours and declined thereafter. During germination

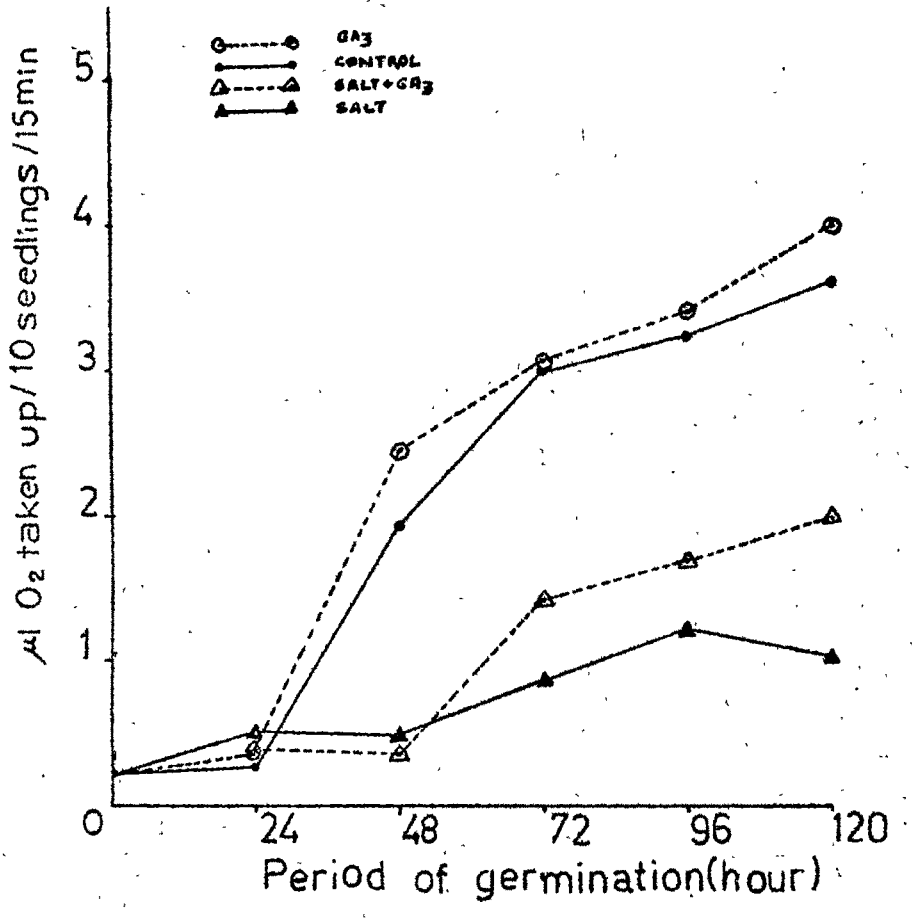


FIG. 16. CHANGES IN THE RATE OF OXYGEN UPTAKE DURING GERMINATION OF PADDY.

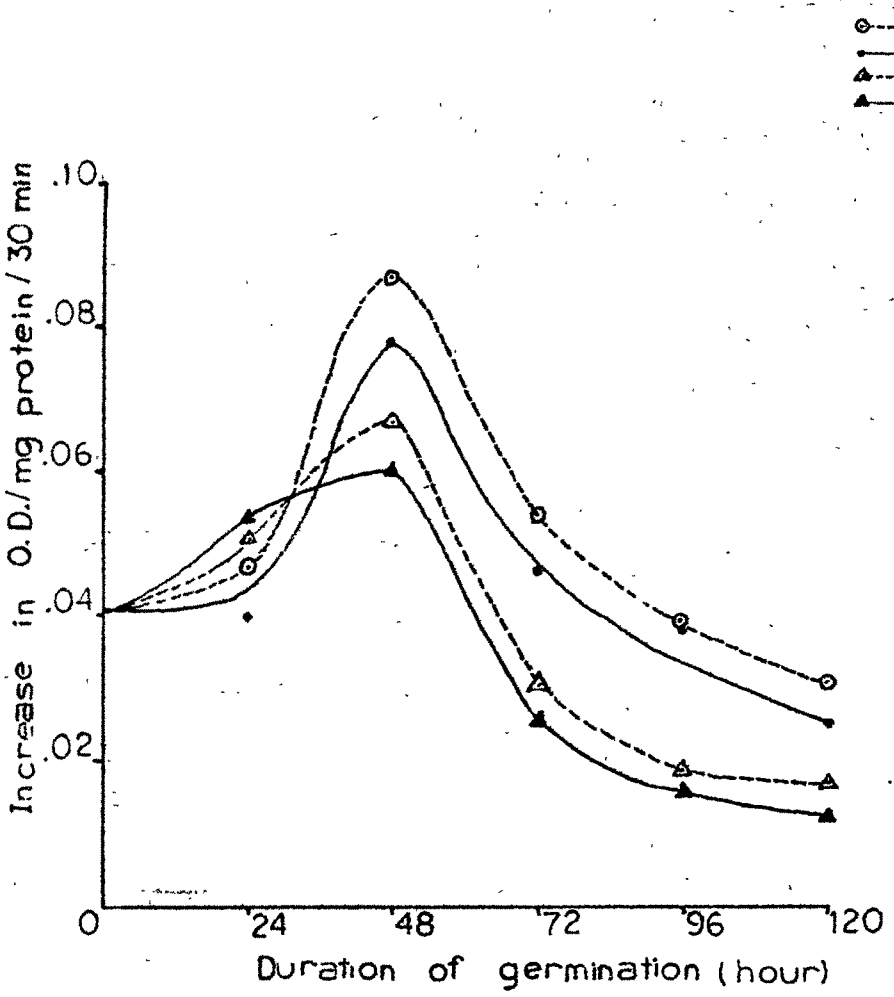


FIG. 17. ACTIVITY OF PYRUVIC DEHYDROGENASE DURING GERMINATION OF PADDY.

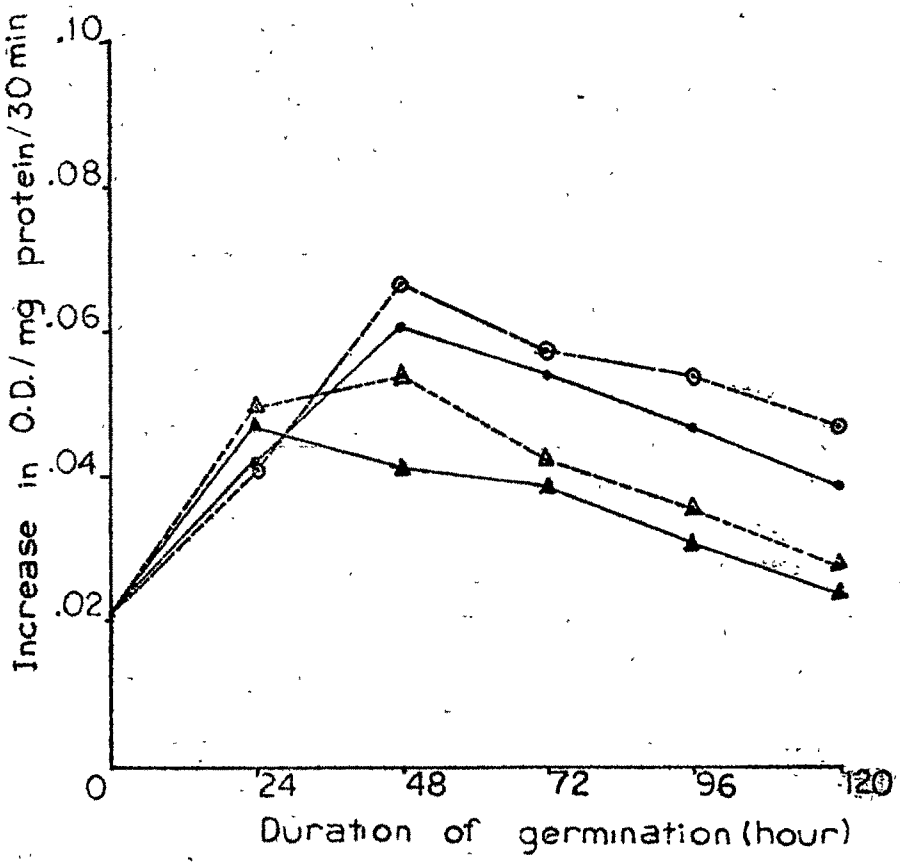


FIG. 18. ACTIVITY OF α-KETOGLUTARIC DEHYDROGENASE DURING GERMINATION OF PADDY.

of seeds under influence of salt a very low activity of the enzyme was observed (except at 24 hours) as compared to that of control. However, the enzyme activity followed the same pattern as that of control. Treatment of seeds with GA_3 brought about an increase in the enzyme activity during their germination under the influence of salt from 36 hours. A higher activity of pyruvic dehydrogenase was seen during germination of seeds under the influence of GA_3 as compared to that of control.

α-Ketoglutaric dehydrodenase

The endosperms of the resting seeds exhibited a low activity of α-ketoglutaric dehydrogenase (Fig. 18). It increased markedly upto 48 hours of germination and exhibited a gradual decrease thereafter. Under saline condition the enzyme activity markedly increased upto 24 hours of germination and declined gradually thereafter. The enzyme activity under the influence of salt was much lower as compared to that of the control except during the initial stage of germination. Treatment of seeds with GA_3 enhanced the activity of the enzyme during their germination under saline condition as compared to the control (salt alone). During germination of seeds under the influence of GA_3 a slightly higher activity of α-ketoglutaric dehydrogenase was observed as compared to that of the control.

Succinic dehydrogenase (SDH)

The endosperm of resting seed exhibited a higher activity of SDH as compared to that of pyruvic and α-ketoglutaric dehydrogenases (Fig. 19). During germination, the activity increased steadily and registered its peak at the end of 24 hours and declined sharply till the end of 96 hours and showed a slight increase thereafter. Under all other treatments (except GA_3) the enzyme activity followed the same pattern as that of the control. During germination of seeds under the influence of salt a very high activity of SDH was observed till the end of 72 hours as compared to that of the control. The activity at the end of 96 and 120 hours of germination was much lower than that of the control. The treatment of seeds with GA_3 failed to stimulate the activity of the enzyme during their germination under the influence of salt except during the later stages of germination. However, treatment of seeds with GA_3 alone enhanced the activity of the enzyme during germination of seeds as compared to that of their control.

Glucose-6-phosphate dehydrogenase (G-6-PDH)

The activity of G-6-PDH was detected in the endosperms of dry seeds and it increased steadily during germination registering a peak at the end of 48 hours and declined

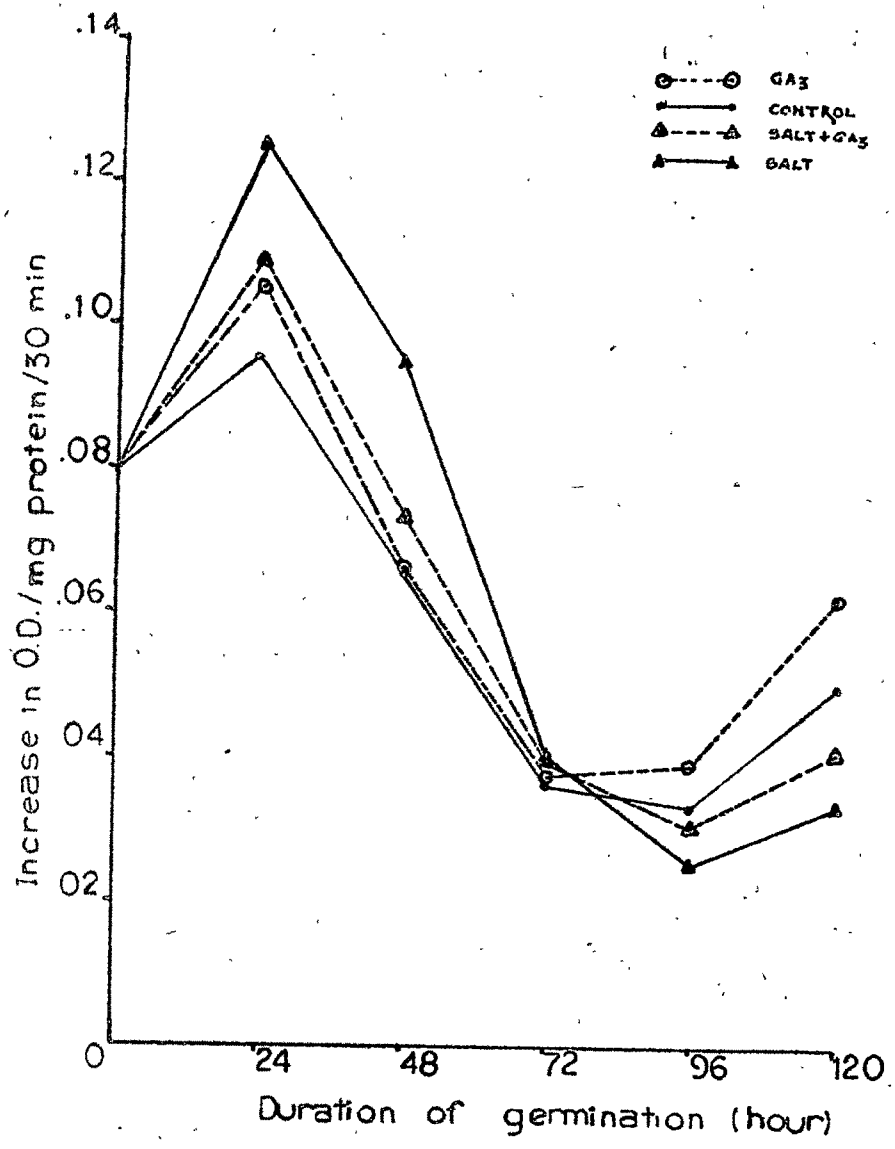


FIG.19.ACTIVITY OF SUCCINIC DEHYDRO-GENASE DURING GERMINATION OF PADDY.

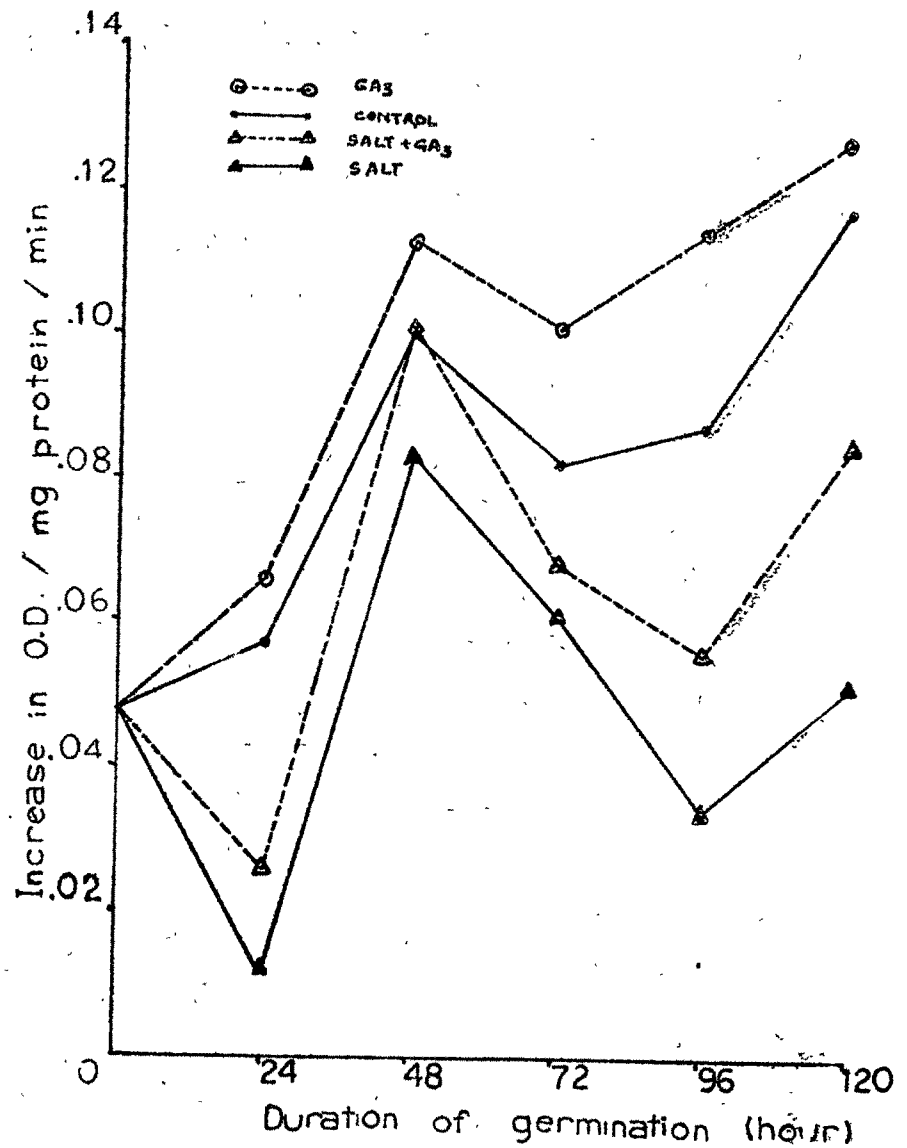


FIG.20. ACTIVITY OF GLUCOSE-6-PHOSPHATE DEHYDROGENASE DURING GERMINATION OF PADDY.

thereafter (Fig. 20). Under the influence of salt, the activity declined sharply during the initial stage (till the end of 24 hours) of germination. During 24 and 48 hours of germination the activity showed a sharp increase registering the peak at the end of 48 hours and declined till the end of 96 hours. From 96 hours onwards the activity increased slightly. The activity of G-6-PDH under the influence of salt was less than that of the control. GA_3 treated seeds also showed the same pattern of the enzyme activity during their germination under the influence of salt but showed a higher activity as compared to that of the control (salt alone). During germination of seeds under the influence of GA_3, a higher activity of G-6-PDH was observed as compared to the control.

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