Spatiotemporal Variation of Soil Enzyme Activities and Their Dominant Drivers in Salinized Wheat Fields of the Yellow River Delta

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Supplementary Figure S1. Collection of field soil samples.



Supplementary Table S1. Dynamic changes of A-P, AK, SOM and TN contents in 0-80cm soil layer of different salinized wheat fields. (a) Low-salinity (b) Moderate-salinity (c) High-salinity similarly hereinafter. (Different lowercase letters in the figure indicate significant differences among soil layers. This convention applies throughout the subsequent analyses, and the same below).

Growth stage	Soil depth (cm)	A-P(mg/kg)	AK(mg/kg)	SOM(‰)	TN(g/kg)
Before sowing	0-20	57.26±0.67^{a}	68.32±1.13^{a}	12.39±0.60^{a}	0.34±0.01^{a}
	20-40	43.20±2.77^{b}	46.42±1.00^{b}	6.49±0.87^{b}	0.15±0.02^{b}
	40-60	5.74±0.29^{c}	4.91±0.70^{c}	7.01±1.00^{b}	0.15±0.02^{b}
	60-80	3.69±0.26^{c}	2.45±0.13^{c}	8.09±0.50^{b}	0.11±0.02^{b}
Jointing stage	0-20	58.55±4.21^{a}	82.24±3.56^{a}	15.74±0.80^{a}	0.52±0.00^{a}
	20-40	58.28±6.68^{a}	33.31±3.80^{c}	13.94±0.28^{a}	0.46±0.03^{a}
	40-60	8.77±1.00^{b}	14.02±0.90^{d}	13.64±0.38^{a}	0.27±0.02^{b}
	60-80	74.40±8.49^{a}	57.03±3.66^{b}	6.95±1.40^{b}	0.16±0.01^{c}
Flowering stage	0-20	75.03±5.65^{a}	38.13±4.85^{a}	12.78±1.59^{a}	1.21±0.06^{a}
	20-40	52.66±1.74^{b}	15.75±1.01^{b}	4.80±0.75^{b}	0.39±0.03^{c}
	40-60	22.22±3.18^{d}	17.72±1.14^{b}	3.23±0.24^{b}	0.80±0.01^{b}
	60-80	35.81±3.86^{c}	0.00±0.00c	4.70±0.64^{b}	0.47±0.07^{c}
Grouting period	0-20	65.57±2.45^{a}	146.50±0.46^{a}	13.91±0.89^{a}	0.61±0.07^{a}
	20-40	62.56±7.14^{a}	49.92±3.11^{b}	2.14±0.14^{c}	0.49±0.03^{a}
	40-60	11.65±1.84^{b}	29.15±1.38^{c}	3.42±0.76^{c}	0.07±0.01^{b}
	60-80	10.47±0.31^{b}	28.60±4.30^{c}	10.80±0.69^{b}	0.00±0.00^{b}
Maturation stage	0-20	20.38±1.51^{a}	72.73±6.86^{a}	10.90±0.97^{a}	0.39±0.03^{a}
	20-40	5.96±0.08^{c}	18.97±0.34^{c}	5.85±0.12^{b}	0.15±0.01^{b}
	40-60	11.52±0.48^{b}	23.28±3.01^{bc}	6.27±0.64^{b}	0.04±0.02^{b}
	60-80	10.27±1.53^{b}	34.97±0.56^{b}	5.95±0.68^{b}	0.05±0.01^{b}

(a)

Growth stage	Soil depth (cm)	A-P(mg/kg)	AK(mg/kg)	SOM(‰)	TN(g/kg)
Before sowing	0-20	15.96±0.27^{a}	96.04±1.81^{a}	10.70±0.21^{a}	0.54±0.04^{a}
	20-40	13.53±0.87^{b}	73.92±6.97^{b}	6.96±0.14^{b}	0.30±0.02^{b}
	40-60	6.58±0.35^{c}	59.48±3.12^{c}	7.24±0.74^{b}	0.15±0.00^{c}
	60-80	10.45±0.46^{d}	108.45±1.65^{a}	7.40±0.03^{b}	0.21±0.01^{c}
Jointing stage	0-20	36.27±2.33^{a}	322.83±20.71^{a}	11.52±0.22^{a}	0.38±0.02^{a}
	20-40	6.89±0.57^{b}	272.07±17.45^{b}	9.30±0.01^{b}	0.32±0.02^{a}
	40-60	7.92±0.03^{b}	167.22±10.72^{c}	7.00±0.45^{bc}	0.24±0.03^{b}
	60-80	2.38±0.33^{c}	139.35±10.31^{c}	8.47±0.80^{c}	0.17±0.01^{b}
Flowering stage	0-20	55.74±0.21^{a}	135.65±4.01^{a}	9.30±0.32^{a}	0.95±0.00^{a}
	20-40	40.12±2.57^{b}	145.90±6.00^{a}	7.06±1.02^{b}	0.62±0.03^{c}
	40-60	12.25±0.33^{c}	76.08±3.66^{b}	5.07±0.41^{c}	0.72±0.01^{b}
	60-80	16.09±0.78^{c}	51.62±3.31^{c}	6.82±0.22^{bc}	0.56±0.02^{d}
Grouting period	0-20	38.25±3.05^{a}	149.20±2.60^{a}	8.98±0.21^{a}	1.19±0.08^{a}
	20-40	25.30±1.92^{bc}	74.52±4.79^{b}	2.48±0.65^{b}	0.45±0.03^{b}
	40-60	30.07±0.17^{b}	97.96±0.19^{c}	0.98±0.06^{c}	0.03±0.00^{c}
	60-80	19.22±1.23^{c}	112.50±1.39^{d}	1.55±0.10^{bc}	0.04±0.01^{c}
Maturation stage	0-20	25.20±0.61^{a}	96.50±5.66^{a}	8.36±0.21^{a}	0.41±0.03^{a}
	20-40	16.57±0.41^{b}	66.57±2.21^{c}	6.69±0.28^{b}	0.21±0.02^{b}
	40-60	16.51±0.87^{b}	78.21±0.72^{b}	6.65±0.33^{b}	0.20±0.04^{b}
	60-80	15.96±0.31^{b}	70.58±2.95^{bc}	8.98±0.42^{a}	0.26±0.00^{b}

(b)

Growth stage	Soil depth (cm)	A-P(mg/kg)	AK(mg/kg)	SOM(‰)	TN(g/kg)
Before sowing	0-20	51.13±4.01^{a}	94.10±4.04^{a}	12.83±0.28^{b}	0.29±0.03^{ab}
	20-40	34.06±2.21^{b}	50.14±2.48^{b}	12.84±0.82^{b}	0.26±0.02^{ab}
	40-60	17.27±1.56^{c}	60.72±2.88^{b}	13.64±0.66^{b}	0.23±0.00^{b}
	60-80	11.64±0.88^{c}	54.39±4.02^{b}	16.12±0.89^{a}	0.30±0.02^{a}
Jointing stage	0-20	39.92±1.19^{a}	218.61±14.02^{a}	12.97±0.62^{a}	0.16±0.01^{b}
	20-40	29.90±1.92^{b}	90.20±5.80^{b}	8.00±1.98^{b}	0.24±0.03^{a}
	40-60	11.12±0.54^{c}	50.66±3.92^{c}	9.98±0.58^{ab}	0.15±0.01^{b}
	60-80	12.74±0.82^{c}	78.00±5.01^{b}	9.22±0.15^{b}	0.12±0.01^{b}
Flowering stage	0-20	88.72±1.49^{a}	110.33±4.63^{a}	16.03±0.85^{a}	0.22±0.01^{a}
	20-40	22.90±1.92^{b}	106.85±2.17^{a}	13.83±1.97^{a}	0.24±0.01^{a}
	40-60	12.20±0.20^{c}	62.04±5.72^{c}	12.16±0.98^{a}	0.11±0.01^{b}
	60-80	3.00±0.90^{d}	1.29±0.23^{b}	13.29±1.13^{a}	0.11±0.00^{b}
Grouting period	0-20	64.10±1.22^{a}	150.55±4.65^{a}	4.38±1.68^{a}	0.47±0.03^{a}
	20-40	43.61±2.80^{b}	129.80±2.14^{b}	2.15±1.19^{a}	0.36±0.02^{b}
	40-60	29.93±1.92^{c}	78.35±5.03^{d}	1.00±0.32^{a}	0.00±0.00^{c}
	60-80	24.10±1.55^{c}	98.82±6.34^{c}	2.89±1.83^{a}	0.00±0.00^{c}
Maturation stage	0-20	46.40±2.63^{a}	88.73±1.26^{a}	12.75±0.54^{a}	0.25±0.01^{a}
	20-40	27.34±0.10^{b}	65.36±2.54^{b}	7.89±0.38^{b}	0.13±0.01^{b}
	40-60	23.27±0.56^{b}	58.93±4.80^{b}	7.71±0.80^{b}	0.13±0.01^{b}
	60-80	17.41±0.45^{c}	46.01±4.31^{c}	7.54±0.24^{b}	0.26±0.02^{a}

(c)

Supplementary Table S2. Dynamic changes of S-SC, S-AL and S-CL activities in 0-80cm soil layer of different salinized wheat fields.

Growth stage	Soil depth（cm）	S-SC（mg(g·d)）	S-AL（mg(g·d)）	S-CL（mg(g·d)）
Before sowing	0-20	51.36±3.45^{a}	0.66±0.01^{b}	3.64±0.21^{bc}
	20-40	22.46±1.80^{b}	1.00±0.12^{a}	5.02±0.18^{a}
	40-60	2.25±0.12^{c}	0.81±0.05^{ab}	4.07±0.01^{b}
	60-80	0.00±0.00^{c}	0.00±0.00^{c}	3.47±0.15^{c}
Jointing stage	0-20	49.51±1.57^{a}	1.74±0.13^{a}	22.58±1.38^{a}
	20-40	14.45±0.96^{b}	0.79±0.08^{b}	19.70±1.26^{a}
	40-60	7.01±0.31^{c}	0.2±0.02^{c}	4.27±0.60^{b}
	60-80	4.28±0.63^{c}	0.00±0.00^{c}	1.04±0.07^{c}
Flowering stage	0-20	55.86±0.96^{a}	3.08±0.12^{a}	11.53±1.20^{a}
	20-40	15.91±0.36^{b}	0.97±0.04^{b}	8.51±0.55^{b}
	40-60	0.00±0.00^{c}	0.93±0.08^{b}	4.27±0.60^{c}
	60-80	0.00±0.00^{c}	0.95±0.06^{b}	6.64±0.43^{bc}
Grouting period	0-20	69.66±0.63^{a}	1.15±0.04^{a}	39.51±5.39^{a}
	20-40	5.81±0.37^{b}	0.84±0.05^{b}	20.86±0.60^{b}
	40-60	0.00±0.00^{c}	1.19±0.08^{a}	2.81±0.32^{c}
	60-80	0.00±0.00^{c}	0.93±0.08^{b}	0.00±0.00^{c}
Maturation stage	0-20	72.59±6.27^{a}	3.37±0.22^{a}	5.42±0.40^{b}
	20-40	4.17±0.55^{b}	0.61±0.03^{b}	8.23±0.80^{a}
	40-60	1.84±0.02^{b}	0.37±0.02^{b}	5.09±0.00^{b}
	60-80	1.89±0.05^{b}	0.00±0.00^{c}	4.58±0.10^{b}

(a)

Growth stage	Soil depth（cm）	S-SC（mg(g·d)）	S-AL（mg(g·d)）	S-CL（mg(g·d)）
Before sowing	0-20	23.27±1.89^{a}	0.67±0.10^{a}	4.08±0.00^{c}
	20-40	17.23±1.21^{b}	0.58±0.05^{ab}	4.56±0.07^{ab}
	40-60	2.11±0.07^{d}	0.41±0.03^{bc}	4.27±0.10^{bc}
	60-80	8.94±0.57^{c}	0.38±0.02^{c}	4.80±0.21^{a}
Jointing stage	0-20	36.43±2.20^{a}	1.19±0.08^{a}	25.00±1.80^{a}
	20-40	9.19±0.31^{c}	0.66±0.08^{b}	15.67±1.20^{b}
	40-60	13.66±0.88^{b}	0.71±0.05^{b}	10.38±0.67^{c}
	60-80	0.00±0.00^{d}	0.00±0.00^{c}	21.56±1.38^{a}
Flowering stage	0-20	14.45±1.45^{a}	1.52±0.04^{b}	25.56±1.60 ^{a}
	20-40	6.80±0.44^{b}	1.07±0.07^{c}	18.78±1.80^{b}
	40-60	2.87±0.18^{c}	1.79±0.11^{a}	27.16±1.74^{a}
	60-80	8.76±0.56^{d}	0.24±0.02^{d}	15.97±1.03^{b}
Grouting period	0-20	12.13±0.87^{a}	0.95±0.06^{a}	36.40±1.20^{a}
	20-40	6.80±0.44^{b}	0.74±0.05^{b}	22.93±0.60^{b}
	40-60	1.90±0.12^{d}	0.33±0.04^{c}	14.64±0.60^{c}
	60-80	4.83±0.31^{c}	0.12±0.01^{d}	0.00±0.00^{d}
Maturation stage	0-20	6.83±0.31^{a}	1.17±0.08^{a}	3.74±0.00^{b}
	20-40	4.56±0.29^{b}	0.51±0.03^{b}	4.06±0.21^{b}
	40-60	4.11±0.26^{b}	0.34±0.02^{c}	3.90±0.10^{b}
	60-80	1.96±0.13^{c}	0.36±0.02^{c}	4.96±0.10^{a}

(b)

Growth stage	Soil depth（cm）	S-SC（mg(g·d)）	S-AL（mg(g·d)）	S-CL（mg(g·d)）
Before sowing	0-20	31.47±0.13^{a}	2.14±0.14^{a}	3.93±0.10^{a}
	20-40	25.73±2.03^{b}	1.08±0.07^{b}	3.71±0.20^{a}
	40-60	16.39±1.41^{c}	0.84±0.05^{b}	3.92±0.10^{a}
	60-80	17.08±1.00^{c}	0.18±0.01^{c}	3.75±0.01^{a}
Jointing stage	0-20	34.79±1.66^{a}	1.69±0.11^{a}	6.64±0.43^{a}
	20-40	5.82±0.37^{b}	0.73±0.11^{c}	4.27±0.60^{b}
	40-60	0.00±0.00^{c}	1.19±0.08^{b}	2.91±0.19^{c}
	60-80	0.00±0.00^{c}	0.12±0.01^{d}	1.04±0.07^{d}
Flowering stage	0-20	23.90±1.26^{a}	3.24±0.04^{a}	4.27±0.60^{a}
	20-40	2.87±0.18^{b}	0.80±0.08^{b}	3.57±0.19^{bc}
	40-60	0.00±0.00^{c}	0.00±0.00^{c}	2.91±0.19^{b}
	60-80	0.00±0.00^{c}	0.00±0.00^{c}	0.00±0.00^{c}
Grouting period	0-20	19.00±2.20^{a}	1.06±0.08^{a}	15.97±1.03^{a}
	20-40	11.70±0.75^{b}	0.59±0.04^{b}	6.64±0.43^{b}
	40-60	9.74±0.62^{bc}	0.53±0.08^{b}	0.00±0.00^{c}
	60-80	6.03±0.43^{c}	0.15±0.01^{c}	0.00±0.00^{c}
Maturation stage	0-20	35.17±1.44^{a}	1.55±0.16^{a}	3.55±0.10^{a}
	20-40	16.34±0.06^{b}	0.30±0.02^{b}	3.74±0.01^{a}
	40-60	13.37±0.86^{c}	0.43±0.07^{b}	3.71±0.20^{a}
	60-80	8.73±0.12^{d}	0.17±0.01^{b}	3.90±0.10^{a}

(c)

Supplementary Table S3. P-value of correlation analysis results.

	SWC	EC	A-P	AK	SOM	TN	S-SC	S-AL	S-CL
SWC	1								
EC	0.075	1							
A-P	0.097	0.271	1						
AK	0.038	0.022	0.01	1					
S0M	0.004	0.071	0.208	0.026	1				
TN	0.003	0.185	0.005	0.270	0.251	1			
S-SC	0.007	0.000	0.022	0.000	0.002	0.019	1		
S-AL	0.018	0.000	0.244	0.170	0.177	0.005	0.000	1	
S-CL	0.015	0.092	0.013	0.001	0.085	0.039	0.019	0.370	1

(a)

	SWC	EC	A-P	AK	SOM	TN	S-SC	S-AL	S-CL
SWC	1								
EC	0.490	1							
A-P	0.425	0.059	1						
AK	0.495	0.004	0.359	1					
S0M	0.834	0.769	0.765	0.045	1				
TN	0.486	0.452	0.005	0.697	0.109	1			
S-SC	0.540	0.244	0.148	0.005	0.011	0.240	1		
S-AL	0.049	0.826	0.013	0.264	0.260	0.001	0.126	1	
S-CL	0.169	0.065	0.028	0.087	0.564	0.000	0.423	0.016	1

(b)

	SWC	EC	A-P	AK	SOM	TN	S-SC	S-AL	S-CL
SWC	1								
EC	0.518	1							
A-P	0.357	0.000	1						
AK	0.062	0.020	0.025	1					
S0M	0.587	0.609	0.997	0.735	1				
TN	0.790	0.206	0.048	0.361	0.510	1			
S-SC	0.911	0.001	0.002	0.088	0.212	0.095	1		
S-AL	0.229	0.021	0.000	0.092	0.093	0.189	0.001	1	
S-CL	0.503	0.020	0.015	0.025	0.643	0.000	0.108	0.228	1

(c)

Supplementary Table S4. Results of redundancy analysis between soil physical and chemical properties (SWC, EC, A-P, AK, SOM, TN) and enzyme activities (S-SC,S-AL,S-CL) in wheat fields with different degrees of salinization.

Name	Explains%	Contribution%	pseudo-F	P
AK	59.4	67.6	26.3	0.002
EC	18.7	21.2	14.4	0.002
TN	5.9	6.8	5.9	0.012
SOM	2.9	3.3	3.3	0.06
SWC	0.7	0.8	0.8	0.428
A-P	0.3	0.3	0.3	0.722

(a)

Name	Explains%	Contribution%	pseudo-F	P
TN	33.6	48.6	9.1	0.002
AK	19.9	28.8	7.3	0.008
SOM	8.7	12.5	3.7	0.046
SWC	3.7	5.4	1.7	0.204
A-P	2.6	3.7	1.2	0.316
EC	0.7	0.9	0.3	0.766

(b)

Name	Explains%	Contribution%	pseudo-F	P
EC	47.1	67	16	0.002
SOM	13.3	19	5.7	0.02
TN	5	7.1	2.3	0.134
SWC	1.8	2.5	0.8	0.354
A-P	2.4	3.4	1.1	0.276
AK	0.8	1.1	0.3	0.63

(c)