Table S1. Fertilization situation in first experiment

Code	Treatment	Mineral fertilizer			Bio-organic fertilizer			
		N $kg \cdot ha^{-1}$	P_2O_5 $kg \cdot ha^{-1}$	K_2O $kg \cdot ha^{-1}$	No.1 $kg \cdot ha^{-1}$	Seek $kg \cdot ha^{-1}$	Jiajiapei $kg \cdot ha^{-1}$	Fulvic Acid $kg \cdot ha^{-1}$
CK	no fertilizer	—	—	—	—	—	—	—
T1	conventional fertilizer	193.2	135	135	—	—	—	—
T2	-N20%	154.5	135	135	—	—	—	—
N1	-N20%+NO.1	132	97.5	130	750	—	—	—
N2	-N20%+NO.1	109.5	60	125	1500	—	—	—
N3	-N20%+NO.1	64.5	22.5	120	3000	—	—	—
S1	-N20%+Seek	132	97.5	130	—	750	—	—
S2	-N20%+Seek	109.5	60	125	—	1500	—	—
S3	-N20%+Seek	64.5	22.5	120	—	3000	—	—
J1	-N20%+Jiajiapei	147.3	127.8	131.4	—	—	360	—
J2	-N20%+Jiajiapei	140.1	120.6	127.8	—	—	720	—
J3	-N20%+Jiajiapei	125.7	112.8	124.2	—	—	1440	—
F1	N20%+Fulvic acid	138	112.5	127.5	—	—	—	750
F2	-N20%+Fulvic acid	108	90	120	—	—	—	1500
F3	-N20%+Fulvic acid	84	67.5	112.5	—	—	—	3000
T3	-N30%	135.2	135	135	—	—	—	—
n1	-N30%+NO.1	112.7	97.5	130	750	—	—	—
n2	-N30%+NO.1	90.2	60	125	1500	—	—	—
n3	-N30%+NO.1	45.2	22.5	120	3000	—	—	—
s1	-N30%+Seek	123	97.5	130	—	750	—	—
s2	-N30%+Seek	94.5	60	125	—	1500	—	—
s3	-N30%+Seek	66	22.5	120	—	3000	—	—
j1	-N30%+Jiajiapei	128	127.8	131.4	—		360	—
j2	-N30%+Jiajiapei	120.8	120.6	127.8	—	—	720	—
j3	-N30%+Jiajiapei	113.6	112.8	124.2	—	—	1440	—
f1	-N30%+Fulvic acid	123	112.5	127.5	—	—	—	750
f2	-N30%+Fulvic acid	94.5	90	120	—	—	—	1500
f3	-N30%+Fulvic acid	66	67.5	112.5	—	—	—	3000

Table S2. Information of primers used in this study

	Primers	Primer sequence (5'- 3')	Target gene	Target subfragment	Subfragment length (bp)	PCR reaction condition
Bacteria	FW-F515	GTGCCAGC(A/C)GCCGCGGTAA	16S	V4	291	an initial denaturation at 95 °C for 3 minutes, followed by 27 cycles of 30 s at 95 °C, annealing for 30 s at 55 °C and elongation for 45 s at 72 °C, the last step being extension at 72 °C for 10 minutes.
	REV-R806	GGACTAC(G/A/C)(G/C)GGGTATCTAAT				
Fungi	FW-F817	TTAGCATGGAATAAT(A/G)(A/G)AATAGGA	18S	V5-V7	379	an initial denaturation at 95 °C for 3 minutes, followed by 35 cycles of 30 s at 95 °C, annealing for 30 s at 55 °C and elongation for 45 s at 72 °C, the last step being extension at 72 °C for 10 minutes
	REV-R1196	TCTGGACCTGGTGAGTTTCC				

Table S3. Effect of nitrogen reduction by 20% combined with bio-organic fertilizer on five elements in soil of cabbage

Treatments	P μg·g^{-1}	K μg·g^{-1}	Ca μg·g^{-1}	Zn μg·g^{-1}
CK	17.49±0.48b	56.58±1.59b	40.07±1.65c	0.28±0.01b
T1	19.65±0.48ab	61.35±1.06ab	47.17±1.41abc	0.34±0.01ab
T2	20.42±1.02a	62.81±3.10ab	46.14±4.57abc	0.31±0.08ab
N1	19.87±0.33a	61.86±1.22ab	46.38±1.37abc	0.27±0.01b
N2	20.61±0.29a	67.76±2.31a	51.84±1.05a	0.34±0.02ab
N3	19.70±0.46ab	65.92±0.70a	45.44±0.88abc	0.28±0.04b
S1	19.79±0.41a	65.17±3.31ab	46.71±1.61abc	0.44±0.10a
S2	19.34±0.46ab	67.57±0.65a	41.07±0.65c	0.27±0.01b
S3	17.99±0.58b	67.08±0.39a	44.72±1.66abc	0.27±0.01b
J1	20.35±0.45a	61.59±1.08ab	45.95±0.25abc	0.33±0.02ab
J2	20.28±0.66a	58.78±2.59b	48.61±1.21ab	0.31±0.01ab
J3	19.18±0.20ab	60.90±3.40ab	42.73±0.85bc	0.25±0.02b

Table S4. Effects of different fertilization with nitrogen reduced 20% treatments on photosynthetic characteristics of cabbage

Treatments	P_n μmol·m^{-2}·s^{-1}	G_s mmol·m^{-2}·s^{-1}	C_i μmol·mol^{-1}	T_r mmol·m^{-2}·s^{-1}
CK	15.27±0.45e	0.28±0.05c	197.28±9.40cd	3.44±0.16c
T1	18.79±0.64cd	0.46±0.02ab	223.72±7.41ab	4.57±0.16ab
T2	15.80±0.11e	0.29±0.0c	193.85±067d	3.33±0.03c
N1	21.28±0.65bc	0.45±10.07ab	216.27±5.63bc	5.14±0.32a
N2	21.99±0.81bc	0.40±0.03ab	210.32±2.01bc	4.57±0.10ab
N3	17.51±0.86de	0.47±0.03a	220.65±3.51ab	3.37±0.12c
S1	19.57±0.58bcd	0.50±0.03a	235.03±3.57a	4.59±0.13ab
S2	20.81±0.67bc	0.44±0.05ab	216.78±5.06bc	4.97±0.25a
S3	18.26±0.66cd	0.30±0.01c	196.79±1.81cd	3.78±0.13c
J1	20.55±0.92bc	0.34±0.03bc	202.09±2.47cd	3.76±0.36c
J2	23.51±0.33a	0.47±0.01a	216.56±0.99bc	5.20±0.10a
J3	20.32±1.18bc	0.30±0.05c	211.72±2.00bc	3.97±0.45bc

Table S5. Effects of different fertilization with nitrogen reduced 20% treatments on growth of cabbage

Treatments	Plant height (cm)	Leaf length (cm)	Leaf width (cm)	Crown length (cm)	Crown width (cm)
CK	19.17±0.17d	21.33±1.45bc	14.33±0.42c	29.83±0.54c	26.67±1.05 c
T1	21.33±0.61abc	24.00±0.73a	18.33±0.42a	33.83±0.70a	31.83±0.65a
T3	22.67±0.71ab	22.00±0.45bc	18.50±0.67a	32.67±0.21ab	30.33±1.23ab
N1	23.25±0.63ab	25.40±0.51a	17.80±0.20ab	34.00±0.37a	32.00±0.32a
N2	22.50±1.06ab	23.83±1.19abc	18.00±0.37ab	34.17±0.60a	30.67±1.69ab
N3	22.50±0.43ab	22.00±0.58bc	17.33±0.33ab	31.83±0.70abc	29.83±0.70ab
S1	22.00±0.52abc	23.00±0.63bc	17.33±0.49ab	33.50±0.50ab	30.50±0.56ab
S2	23.17±1.22ab	23.33±1.05abc	18.00±0.52ab	33.83±1.70a	32.33±1.65a
S3	21.00±0.26bcd	21.17±0.48c	17.33±0.42ab	32.50±1.31ab	30.33±0.92ab
J1	23.50±1.26a	23.17±1.08abc	17.83±0.48ab	32.83±0.95ab	30.50±1.12ab
J2	22.17±0.17abc	23.00±0.37abc	18.00±0.26ab	33.67±0.61a	31.00±0.77ab
J3	20.00±0.30cd	21.50±0.67bc	16.67±0.33b	31.67±0.76abc	28.50±0.43b
F1	21.67±0.76abc	23.00±0.63abc	17.33±0.49ab	33.00±0.82ab	30.33±0.67ab
F2	20.00±0.45cd	21.17±0.54c	16.67±0.33b	30.83±0.40ab	28.50±0.34b
F3	21.83±0.40abc	23.00±0.77abc	17.33±0.33ab	33.00±0.82bc	30.17±0.48ab

Table S6. Effects of different fertilization with nitrogen reduced 30% treatments on growth of cabbage

Treatments	Plant height (cm)	Leaf length (cm)	Leaf width (cm)	Crown length (cm)	Crown width (cm)
CK	19.17±0.17d	21.33±1.45c	14.33±0.42c	29.83±0.54d	26.67±1.05c
T1	21.33±abc	24.00±0.73a	18.33±0.42a	33.83±0.70abcd	31.83±0.65a
T3	20.83±abcd	21.00±0.77c	16.67±0.33b	30.83±0.70bcd	29.83±0.75ab
n1	20.17±bcd	21.83±0.70b	16.83±0.40a	31.33±0.49abcd	28.50±0.43bc
n2	20.33±bcd	22.00±0.52c	17.67±0.56a	31.83±0.40abcd	29.17±0.31abc
n3	20.67±abcd	21.67±0.61b	17.00±0.58a	31.17±0.48bcde	28.00±0.63bc
s1	22.33±a	24.50±0.99a	17.17±0.48a	32.83±1.01abcd	29.33±1.45abc
s2	21.83±abc	22.00±0.58b	17.33±0.92a	32.67±0.95abcd	29.50±1.18abc
s3	21.33±abc	22.33±0.71a	17.17±0.31a	33.67±1.28abcd	29.33±0.88abc
j1	21.67±abc	22.00±0.58b	17.17±0.48a	31.67±0.88abcd	29.83±0.31ab
j2	20.00±bcd	21.83±0.65b	17.00±0.37a	30.17±1.14cd	28.67±0.61bc
j3	20.50±abcd	21.67±0.42b	17.00±0.37a	32.33±0.67abcd	29.50±0.43abc
f1	22.33±a	22.33±0.33a	16.83±0.48a	31.33±0.49abcd	28.83±0.40abc
f2	20.33±bcd	22.00±0.77b	17.00±0.37a	31.83±0.40abcd	27.33±2.08bc
f3	19.67±cd	21.50±0.50b	16.50±0.43a	31.83±0.60abcd	29.17±0.79abc

Table S7. Effects of bio-organic fertilizer with nitrogen reduction on soil element content of non-heading Chinese cabbage

Treatments	P $\mu g \cdot g^{-1}$	K $\mu g \cdot g^{-1}$	Ca $\mu g \cdot g^{-1}$	Zn $\mu g \cdot g^{-1}$
CK	20.03±0.26a	61.39±3.14ab	46.99±0.31a	0.48±0.04a
T1	19.40±0.48ab	65.42±3.73a	45.73±1.59ab	0.56±0.1a
T2	19.88±0.23a	64.95±1.18a	45.74±0.65ab	0.42±0.02abc
N2	21.71±0.27a	58.49±1.03ab	47.83±1.17a	0.43±0.01ab
S2	18.47±0.50b	61.88±1.69ab	42.83±1b	0.31±0.02bc
J2	18.94±0.32ab	56.43±1.97b	43.35±1.51b	0.27±0.03c

Table S8. Effects of bio-organic fertilizer with nitrogen reduction on element content of the plant

Treatments	P $\mu g \cdot g^{-1}$	K $\mu g \cdot g^{-1}$	Ca $\mu g \cdot g^{-1}$	Zn $\mu g \cdot g^{-1}$
CK	38.20±0.43a	213.98±1.58d	64.18±1.41e	0.09±0.01cd
T1	32.17±0.26b	247.61±7.09c	80.25±1.61b	0.17±0.04 b
T2	31.10±0.58b	279.71±5.66b	79.27±1.70b	0.10±0.01bcd
N2	27.06±0.36c	309.90±9.13a	69.28±0.69d	0.28±0.03a
S2	33.80±0.32b	296.61±13.46ab	73.84±0.94c	0.15±0.03bc
J2	28.08±0.25c	282.58±10.75b	92.14±1.72a	0.10±0.01bcd

Table S9. Effect of different fertilizer treatments on bacterial, fungi, protist *Alpha* diversity indexes of soil

	Treatment	Sobs	Shannon	Simpson	Ace
Bacterial	CK	1832.67±300.01a	6.15±0.56a	0.006±0.001b	2490.69±321.41a
	T1	1667.67±280.20a	5.93±0.44ab	0.008±ab	2312.25±400.21a
	T2	1619.33±160.54a	5.74±0.65ab	0.012±0.001a	2283.51±254.87a
	N2	1790.67±80.20a	6.05±0.24b	0.007±0.001ab	2458.22±250.10a
	S2	1745.00±298.01a	5.98±0.57ab	0.007±0.001ab	2422.26±150.21a
Fungi	CK	470.67±45.21a	6.15±0.48a	0.07±0.01b	565.12±80.98a
	T1	475.67±23.86a	5.93±0.54a	0.08±0.01ab	551.89±67.21a
	T2	379.33±30.21a	5.74±0.41a	0.15±0.02a	528.23±54.03a
	N2	444.33±32.04a	6.05±0.21a	0.08±0.01ab	514.56±41.02a
	S2	460.00±18.54a	5.98±0.24a	0.10±0.01ab	550.17±42.54a

Table S10. Effects of bio-organic fertilizer with nitrogen reduction on photosynthetic characteristics of the cabbage

Treatments	*P*n ($\mu mol \cdot m^{-2} \cdot s^{-1}$)	*G*s ($mmol \cdot m^{-2} \cdot s^{-1}$)	*C*i ($\mu mol \cdot mol^{-1}$)	*T*r ($mmol \cdot m^{-2} \cdot s^{-1}$)
CK	21.25±0.60bc	0.40±0.04b	270.67±7.51c	5.62±0.31b
T1	22.86±1.46ab	0.54±0.06b	285.07±7.48ab	6.32±0.24b
T2	22.14±28bc	0.48±0.03b	283.80±7.81ab	6.41±0.27b
N2	25.32±0.73a	0.73±0.07a	293.50±5.62a	7.51±0.24a
S2	23.58±0.69ab	0.54±0.05b	280.78±6.63abc	5.97±0.24b
J2	20.00±0.32d	0.43±0.03b	288.85±6.54ab	6.13±0.23b

Table S11. Effects of bio-organic fertilizer with nitrogen reduction on growth of the cabbage

Treatments	Plant height (cm)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)	Petiole width (cm)
CK	12.05±0.21d	11.18±0.22c	3.90±0.29b	7.15±0.89ab	2.13±0.18b
T1	14.50±0.35bc	14.23±0.59a	5.10±0.04a	7.88±0.52b	2.68±0.06 a
T2	14.05±0.31c	12.88±0.68b	4.33±0.23b	7.83±0.40b	2.50±0.07a
N2	15.93±0.11a	14.83±0.50a	5.53±0.05a	8.98±0.42a	2.85±0.13a
S2	15.48±0.23a	14.28±0.43a	5.15±0.11a	8.85±0.28a	2.80±0.13a
J2	14.78±0.18b	13.20±0.50b	4.33±0.17b	8.20±0.97ab	2.58±0.14a

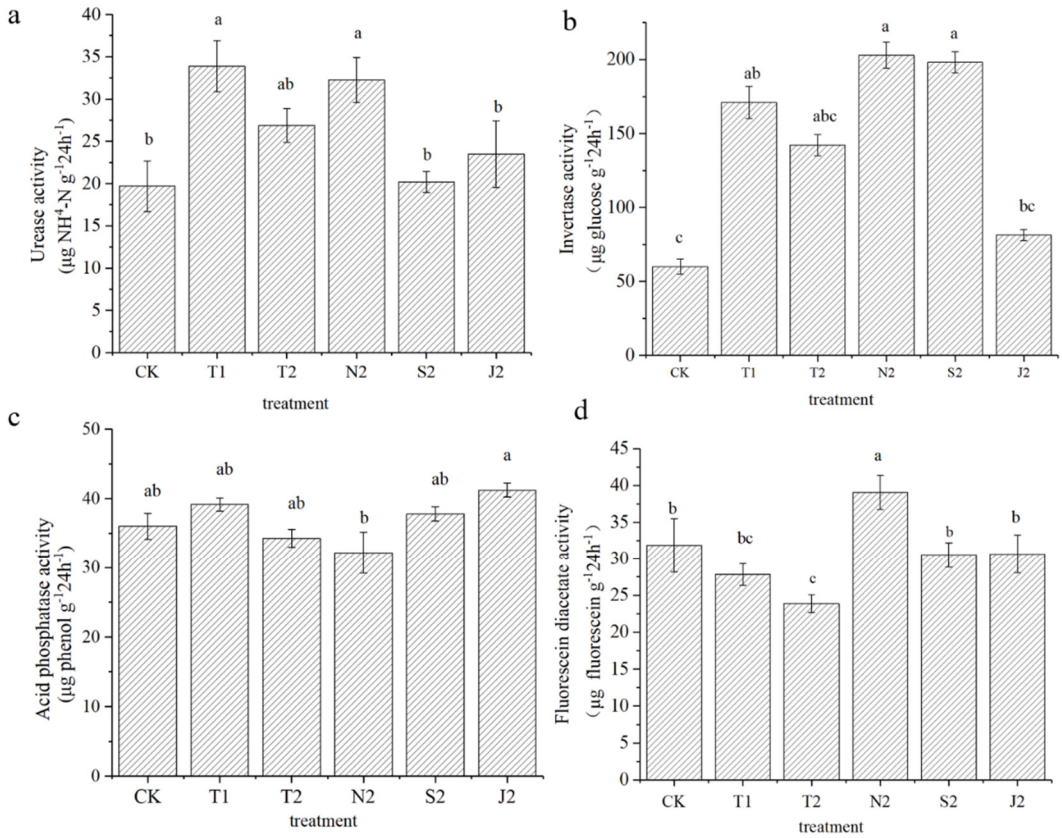

Figure S1 Soil-enzyme activities at the root soil of cabbage under different fertilization treatments, (**a**) Urease activity; (**b**) Invertase activity; (**c**) Acid phosphatase activity; (**d**) Fluorescein diacetate activity.

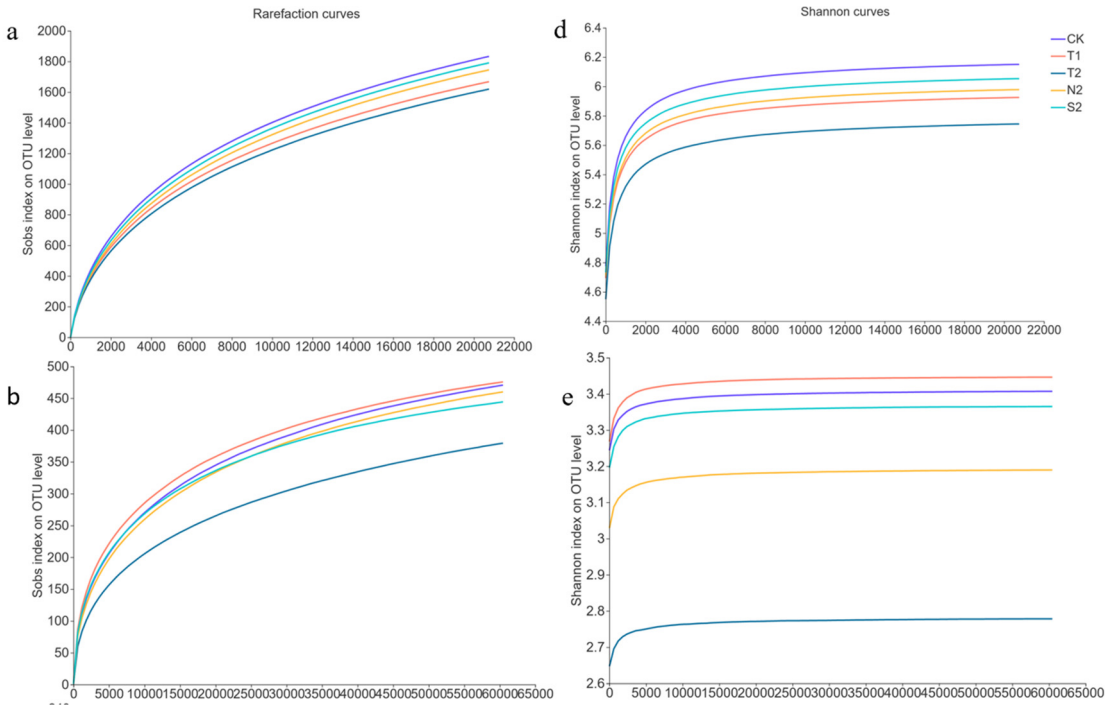

Figure S2 Dilution curve of (**a, d**) bacteria, (**b, e**) fungi species abundance *Alpha* diversity index of soil samples

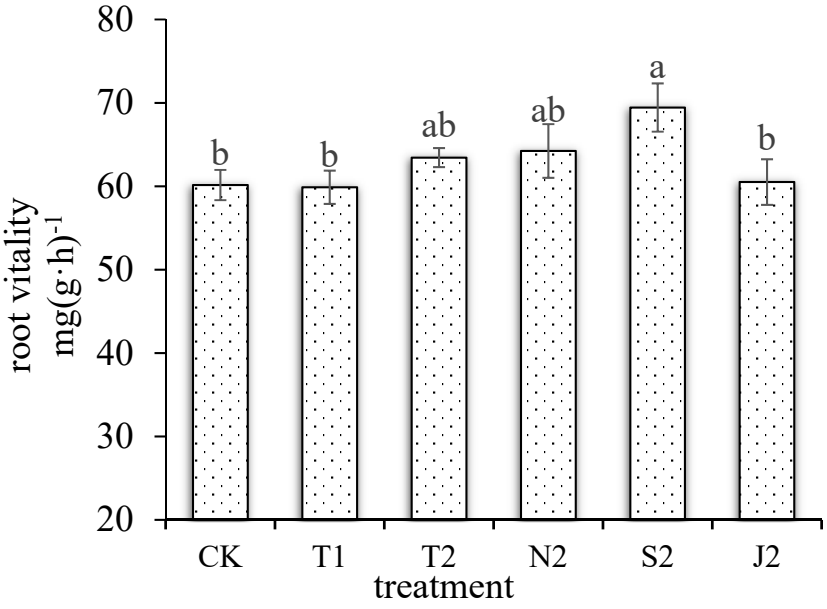

Figure S3 Effects of bio-organic fertilizer with nitrogen reduction on root vitality

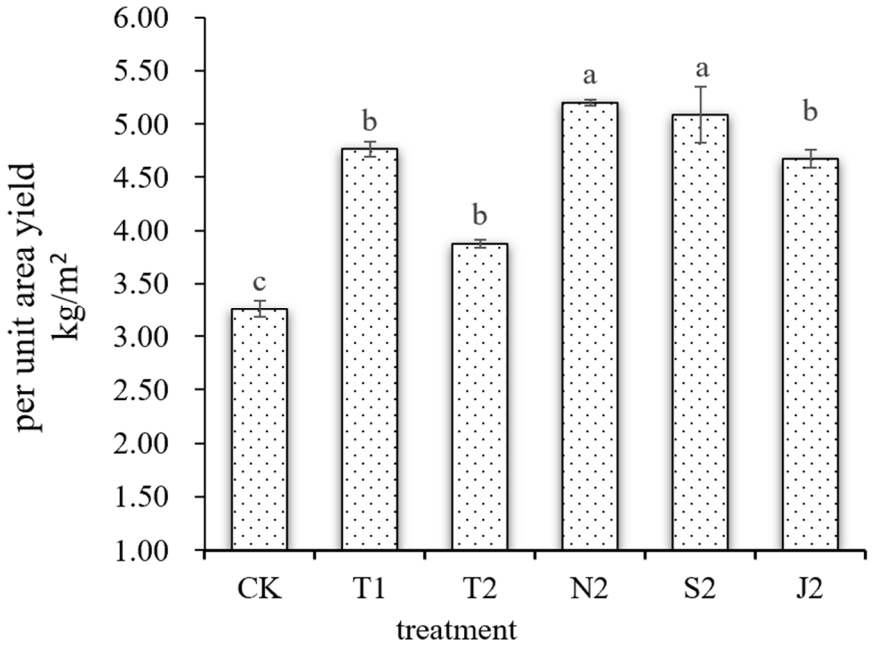

Figure S4 Effects of bio-organic fertilizer with nitrogen reduction on yield of non-heading Chinese cabbage

Figure S5 Field growth status of non-nodular Chinese cabbage