

Effects of Organic Fertilizer Type and Application Rate on Soil–Microbe Interactions, Yield, and Quality of Greenhouse Tomato

Supplementary Materials

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Table S1. Photosynthetic gas exchange parameters of greenhouse tomatoes under different fertilization treatments

Treatment	Pn (mmol·m ⁻² s ⁻¹)			gs (mol·m ⁻² s ⁻¹)			Tr (mmol·m ⁻² s ⁻¹)		
	Flowering stage	Fruit expansion stage	Harvest stage	Flowering stage	Fruit expansion stage	Harvest stage	Flowering stage	Fruit expansion stage	Harvest stage
Control	27.0±0.7 4f	25.2±1 .29e	15.6±0 .64f	0.30±0. 03i	0.34±0 .006e	0.25±0 .03e	15.4±0. 1h	10.1±0.0 e	12.9±0.0 2ef
BCF1	30.2±0.8 2de	25.5±0 .20e	16.6±0 .20de	0.35±0. 02efgh	0.39±0 .02cd	0.29±0 .02c	16.7±0. 1efg	12.0±1.5 d	13.1±0.6 ef
BCF2	31.9±0.6 1bc	29.5±1 .16bc	17.6±0 .28bc	0.37±0. 01defg	0.42±0 .006bc	0.29±0 .01cd	17.4±0. 6cde	13.1±0.7 bc	13.2±0.0 de
BCF3	32.3±0.2 1bc	29.9±1 .47bc	17.9±0 .73bc	0.38±0. 006cd	0.44±0 .02b	0.30±0 .01bc	17.7±0. 1cd	13.2±0.6 abc	13.5±0.0 bc
BCF4	33.3±0.2 6c	30.7±0 .82b	18.4±0 .41b	0.42±0. 02b	0.49±0 .02a	0.32±0 .01ab	18.9±0. 6a	14.3±1.0 a	13.6±0.0 ab
BMF1	27.3±0.3 1f	25.9±2 .24e	16.0±1 .11ef	0.32±0. 02hi	0.39±0 .01d	0.27±0 .02de	16.0±0. 6gh	11.6±0.0 d	12.9±0.0 ef
BMF2	27.5±2.7 0f	26.7±0 .46de	15.7±0 .10f	0.34±0. 02fgh	0.40±0 .01cd	0.28±0 .006cd	16.7±0. 1efg	12.6±0.6 cd	13.2±0.0 de
BMF3	29.5±0.3 2e	29.2±0 .37bc	17.6±0 .18bc	0.37±0. 02defg	0.44±0 .03b	0.29±0 .02c	17.7±0. 02cd	13.2±0.6 abc	13.4±0.0 bcd
BMF4	32.0±0.8 9bc	30.0±0 .32b	18.0±0 .16bc	0.41±0. 006bc	0.48±0 .006a	0.30±0 .01bc	17.9±1. 1bc	13.9±0.6 ab	13.5±0.2 bc
BOF	31.5±0.3	28.3±0	17.2±0	0.34±0.	0.40±0	0.30±0	17.0±0.	12.7±0.8	13.4±0.0

1	2cd	.66cd	.36cd	01fgh	.01cd	.02bc	6def	cd	bcd
BOF	31.9±0.6	29.2±0	17.8±0	0.36±0.	0.43±0	0.30±0	17.7±0.	13.2±0.6	13.4±0.0
2	2bc	.58bc	.58bc	04defg	.02b	.02bc	1cd	abc	bcd
BOF	32.8±0.5	30.2±0	18.1±0	0.38±0.	0.47±0	0.31±0	18.6±0.	13.3±0.7	13.6±0.0
3	4bc	.06b	.04b	01cd	.04a	.01ab	0ab	abc	ab
BOF	34.9±1.6	32.8±1	19.4±0	0.45±0.	0.51±0	0.33±0	19.2±0.	14.1±0.5	13.8±0.1
4	3a	.56a	.78a	04a	.01a	.006a	6a	ab	a

Note: Different superscript letters indicate significant differences among treatments (one-way ANOVA, Tukey's HSD, $P < 0.05$); the same letter indicates no significant difference. Abbreviations. Pn, net photosynthetic rate ($\mu\text{mol CO}_2\cdot\text{m}^{-2}\cdot\text{s}^{-1}$); gs, stomatal conductance ($\text{mol H}_2\text{O}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$); Tr, transpiration rate ($\text{mmol H}_2\text{O}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$); OM, organic matter; TN, total nitrogen; AP, available phosphorus (Olsen-P); AK, available potassium; EC, electrical conductivity; DAP, days after planting. Treatment codes. Control, no fertilization; BCF1–BCF4, bone calcium organic fertilizer at 7500, 15000, 30000, 45000 $\text{kg}\cdot\text{ha}^{-1}$; BMF1–BMF4, bone mud organic fertilizer at 7500, 15000, 30000, 45000 $\text{kg}\cdot\text{ha}^{-1}$; BOF1–BOF4, bio-organic fertilizer at 7500, 15000, 30000, 45000 $\text{kg}\cdot\text{ha}^{-1}$.

Table S2. Tomato yield and quality analysis

Note: Different superscript letters indicate significant differences among treatments (one-way ANOVA,

Treatment	Single-plant yield (kg)	Yield $\text{kg}\cdot\text{ha}^{-1}$	Soluble solids content (SSC °Brix)
Control	2.0±0.1h	34496 ± 1056e	5.2±0.2e
BCF1	2.2±0.0g	37840 ± 704cde	6.4±0.1d
BCF2	2.6±0.1d	45760 ± 2112abcd	6.6±0.1cd
BCF3	2.7±0.1c	47908 ± 1936abc	6.6±0.1cd
BCF4	2.7±0.1c	48048 ± 2364abc	7.1±0.5a
BMF1	2.0±0.2h	35728 ± 2640de	6.5±0.5cd
BMF2	2.3±0.2f	40702 ± 3072bcde	6.4±0.2d
BMF3	2.3±0.4f	40832 ± 3216bcde	6.6±0.2cd
BMF4	2.8±0.2b	49984 ± 2640ab	7.0±0.2ab
BOF1	2.2±0.1g	39248 ± 1760cde	6.5±0.3cd
BOF2	2.5±0.2e	44704 ± 3696abcde	6.4±0.1d
BOF3	2.6±0.3d	45584 ± 4104abcd	6.8±0.2bc
BOF4	3.0±0.3a	52096 ± 4928a	7.2±0.3a

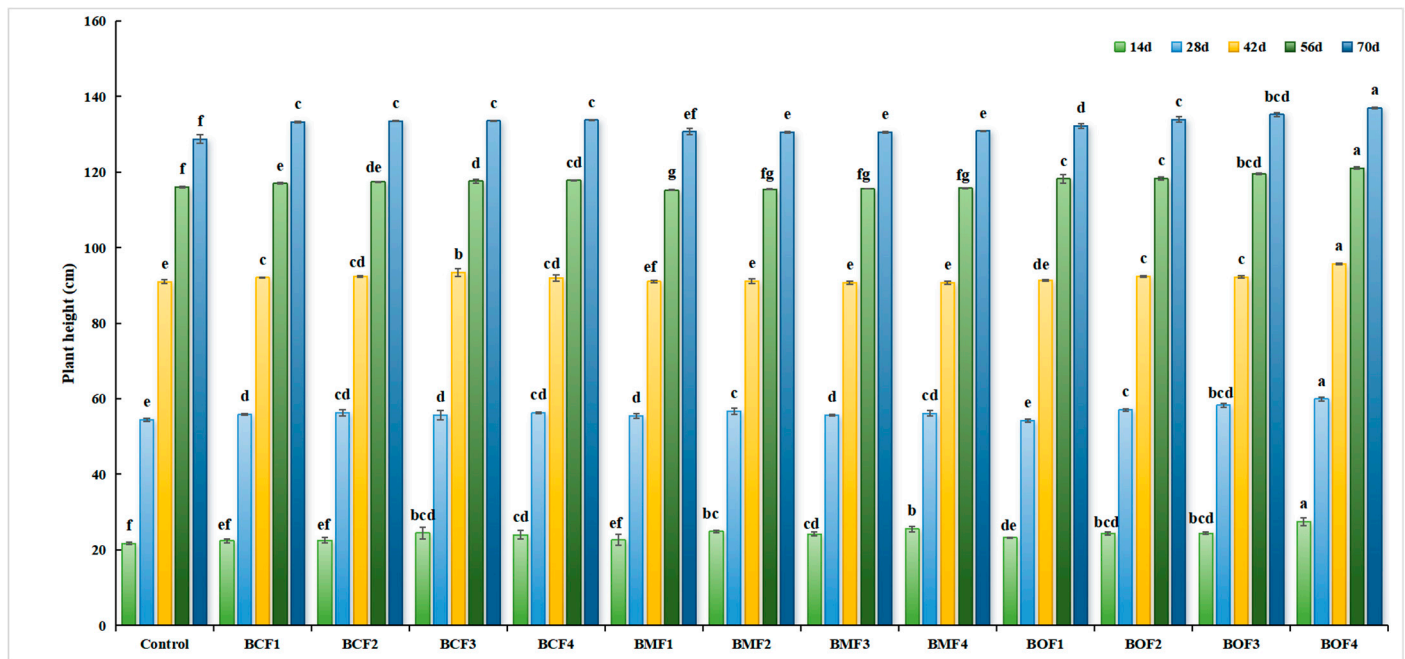
Tukey's HSD, $P < 0.05$); the same letter indicates no significant difference. Abbreviations and treatment codes are as in Table S1.

Table S3. Soil moisture content (%) under different fertilization treatments

Treatme nt	28d	42d	56d	70d	84d	98d
Control	27.4±1.3c	34.5±0.4b	41.9±0.6c	31.7±0.4bc	26.2±1.1b	25.6±0.4d
BCF1	27.0±1.3c	32.8±1.7bcd	40.9±1.6cde	31.7±0.8bc	26.7±1.0b	27.4±1.1bcd

BCF2	31.0±0.4ab	40.0±0.2a	46.4±1.3b	37.8±0.1a	32.8±1.3a	33.5±2.0a
BCF3	26.9±0.3c	32.6±0.5bcd	41.1±1.0cd	32.6±1.6bc	25.7±0.7bc	26.3±1.1bcd
BCF4	24.3±0.7d	31.3±1.8cd	41.8±0.9c	32.8±0.9b	23.5±1.4bc	27.3±1.1bcd
BMF1	23.2±0.4de	31.1±2.4d	40.1±2.2de	31.1±1.8bc	23.4±0.8bc	26.9±0.9bcd
BMF2	22.9±2.1de	32.8±1.4bcd	39.4±1.1e	31.9±0.8bc	27.0±4.7b	28.0±1.0bc
BMF3	32.1±1.8a	40.6±1.0a	47.2±0.6ab	38.2±1.1a	31.5±1.2a	32.6±1.6a
BMF4	26.9±0.2c	32.7±0.5bcd	40.8±0.4cde	32.2±0.8bc	26.2±1.7b	26.8±1.0bcd
BOF1	29.5±0.1b	39.5±0.7a	48.1±0.5a	30.9±1.2bc	32.6±0.5a	33.3±2.1a
BOF2	26.5±0.6c	32.1±0.6cd	40.3±1.1cde	31.5±1.8bc	25.4±1.1bc	27.0±2.4bcd
BOF3	19.5±1.6f	31.0±1.1d	41.8±0.6c	32.4±2.2bc	26.0±1.4b	25.9±0.5cd
BOF4	21.5±1.9e	33.1±1.8bc	41.4±0.7cd	30.8±0.6cd	22.2±5.6c	28.2±0.6b

Note: Abbreviations and treatment codes are as in Table S1.



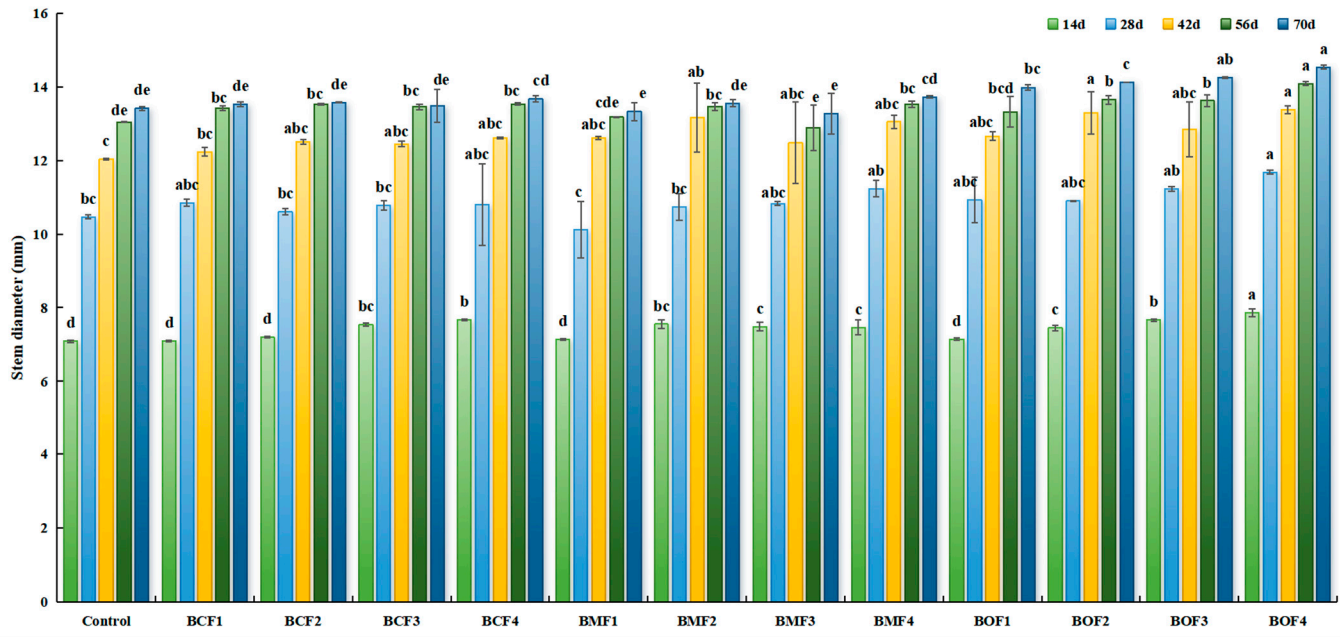


Figure S1. Tomato plant height and stem diameter under different fertilization treatments. (a) Tomato plant height under different fertilization treatments. (b) Tomato stem diameter under different fertilization treatments.

Table S4. Soil pH and fertility indices at the microbiological sampling time (70 DAP) under different fertilization treatments.

Treatment	pH	Organic matter content (g/kg)	Total nitrogen content (mg/kg)	Available phosphorus content (mg/kg)	Available potassium content (mg/kg)
Control	7.2±0.3a	21.7±0.9h	0.17±0.008f	135.7±0.5h	225.0±0.6l
BCF1	6.8±0.1bc	26.6±2.2f	0.17±0.006f	143.7±0.6fg	249.1±0.7j
BCF2	6.6±0.0bcd	26.9±1.3e	0.20±0.002e	145.6±0.7e	262.0±0.8h
BCF3	6.4±0.0de	28.3±1.5c	0.23±0.006d	149.8±0.4c	275.9±0.9d
BCF4	6.1±0.0f	29.2±1.5b	0.28±0.008b	152.1±0.2b	285.6±1.0b
BMF1	6.9±0.1b	25.5±1.5g	0.17±0.007f	133.9±1.3i	247.4±0.2k
BMF2	6.7±0.0bc	27.7±4.8de	0.20±0.009e	143.3±0.6g	263.6±0.6g
BMF3	6.5±0.1de	27.5±2.9de	0.23±0.004d	146.5±0.3de	268.4±1.1f
BMF4	6.3±0.1ef	28.5±1.1c	0.25±0.013c	150.8±0.6c	279.5±1.4c
BOF1	6.7±0.0bc	26.4±3.7f	0.18±0.004f	144.4±1.1f	252.1±0.6i
BOF2	6.6±0.1bcd	27.2±5.2e	0.22±0.006d	146.9±0.8d	270.4±0.9e
BOF3	6.3±0.0ef	29.0±2.7b	0.25±0.005c	150.5±0.3c	279.2±0.2c
BOF4	6.0±0.0f	30.9±1.3a	0.31±0.006a	155.0±0.9a	287.7±1.2a

Note: Abbreviations and treatment codes follow Table S1. pH denotes the measure of soil acidity/alkalinity (dimensionless).

Table S5. Overview of raw sequencing reads, quality control, and effective data.

Samp le	RawP E	Comb ined	Quali fied	Nochi me	Base(nt)	Avgl en(nt)	GC (%)	Q20 (%)	Q30 (%)	Effectiv e (%)
Contr ol	13721 5	13641 2	1361 73	12703 3	321643 24	253.2	56.1	99.5	98.1	92.6
Contr ol	13298 5	13226 8	1320 45	12317 5	311903 82	253.2	56	99.4	97.7	92.6
Contr ol	13590 9	13515 6	1349 17	12539 7	317520 58	253.2	55.7	99.4	97.9	92.3
BCF1	11564 5	11501 1	1148 24	10658 7	269868 61	253.2	55.7	99.5	98.0	92.2
BCF1	13478 8	13401 3	1338 27	12419 2	314453 49	253.2	56.0	99.6	98.2	92.1
BCF1	13604 4	13538 0	1352 22	12516 4	316944 31	253.2	56.0	99.5	98.0	92.0
BCF2	13709 8	13639 6	1361 31	12769 0	323309 54	253.2	55.8	99.4	97.9	93.1
BCF2	13824 7	13745 8	1371 74	12826 7	324761 11	253.2	55.7	99.4	97.7	92.8
BCF2	13424 0	13352 5	1332 30	12398 4	313902 24	253.2	55.6	99.4	97.7	92.4
BCF3	13691 8	13616 9	1358 85	12659 7	320570 77	253.2	56.3	99.4	97.8	92.5
BCF3	13368 1	13291 3	1326 40	12362 8	313019 05	253.2	56.1	99.3	97.6	92.5
BCF3	14454 2	14374 2	1434 18	13473 7	341207 18	253.2	56.0	99.4	97.8	93.2
BCF4	12353 0	12291 8	1226 70	11506 6	291362 91	253.2	55.9	99.4	97.8	93.2
BCF4	13275 8	13199 3	1317 24	12285 9	311122 22	253.2	56.3	99.5	98.0	92.5
BCF4	96266	95765	9559 8	90857	230102 99	253.3	56.2	99.4	97.8	94.4
BMF 1	12409 7	12339 2	1230 97	11600 9	293741 74	253.2	56.2	99.4	97.8	93.5
BMF 1	13608 4	13523 4	1349 90	12601 6	319088 87	253.2	56.2	99.5	98.1	92.6
BMF 1	13613 6	13541 9	1351 43	12663 1	320674 87	253.2	55.9	99.5	98.0	93.0
BMF 2	13669 4	13581 5	1355 51	12614 8	319441 02	253.2	56.3	99.5	98.1	92.3
BMF 2	13523 6	13445 0	1341 61	12459 2	315527 57	253.3	56.3	99.4	97.7	92.1

BMF	13298	13216	1319	12226	309656	253.3	56.0	99.4	97.9	91.9
2	7	7	01	7	17					
BMF	13243	13175	1314	12202	309035	253.3	56.1	99.4	97.9	92.1
3	9	2	91	6	55					
BMF	13597	13497	1347	12580	318641	253.3	56.4	99.5	98.1	92.52
3	8	7	13	2	68					
BMF	11143	11089	1107	10338	261814	253.3	56.2	99.5	97.9	92.8
3	9	9	42	1	27					
BMF	13559	13484	1345	12534	317379	253.2	56.0	99.4	97.8	92.4
4	3	1	48	6	96					
BMF	13206	13106	1308	12152	307718	253.2	56.2	99.6	98.1	92.0
4	8	0	22	0	82					
BMF	13244	13171	1314	12193	308711	253.2	55.6	99.4	97.9	92.1
4	1	0	51	1	06					
BOF1	13394	13323	1329	12371	313254	253.2	56.3	99.4	97.9	92.4
	7	9	46	8	49					
BOF1	13245	13170	1314	12423	314640	253.3	56.4	99.5	97.9	93.8
	5	7	43	2	31					
BOF1	13240	13161	1313	12187	308640	253.2	56.0	99.4	97.9	92.1
	3	9	62	8	59					
BOF2	11284	11226	1120	10405	263471	253.2	55.9	99.5	98.0	92.2
	7	0	05	5	23					
BOF2	13434	13355	1332	12436	314938	253.2	56.2	99.5	98.1	92.6
	2	7	84	5	28					
BOF2	94051	93622	9344	88020	222915	253.3	56.0	99.5	98.0	93.6
			2		75					
BOF3	13341	13267	1323	12443	315107	253.2	55.9	99.4	97.9	93.3
	0	0	55	7	67					
BOF3	13852	13723	1369	13025	329908	253.3	55.9	99.5	98.0	94.0
	8	8	82	4	69					
BOF3	13548	13474	1344	12548	317821	253.3	56.0	99.4	97.9	92.6
	9	7	85	4	33					
BOF4	91719	91243	9107	83869	212393	253.2	55.7	99.4	97.9	91.4
			4		17					
BOF4	13185	13115	1308	12145	307471	253.2	55.1	99.4	97.7	92.1
	3	3	69	8	64					
BOF4	13784	13723	1369	12772	323395	253.2	55.5	99.4	97.9	92.7
	9	7	94	5	18					

Table S6. Topological parameter calculation

Treat ment	Den sity	Diam eter	Average_ Degree	Clustering_C oefficient	Modul arity	Avg_Path_ Length	Node_ Count	Edge_ Count
Contro l	0.04 9	2	12.1	1	0.86	2	249	1503
BCF1	0.04 9	2	12.0	1	0.85	2	246	1473
BCF2	0.06 1	2	16.3	1	0.80	2	271	2214
BCF3	0.04 4	2	11.4	1	0.91	2	258	1468
BCF4	0.04 6	2	11.2	1	0.917	2	247	1388
BMF1	0.06 1	2	17.5	1	0.75	2	287	2512
BMF2	0.04 4	2	11.4	1	0.91	2	262	1493
BMF3	0.04 0	2	9.8	1	0.92	2	248	1214
BMF4	0.05 1	2	13.4	1	0.88	2	265	1773
BOF1	0.04 5	2	12.0	1	0.92	2	269	1615
BOF2	0.04 5	2	10.9	1	0.92	2	243	1325
BOF3	0.04 6	2	13.2	1	0.90	2	288	1896
BOF4	0.04 7	2	12.1	1	0.88	2	258	1556

Note: Abbreviations and treatment codes are as in Table S1.