Effects of Chemical Fertilizer Combined with Organic Fertilizer

Subjects: Horticulture
Contributor: Lian Wan

Chemical fertilizer has been excessively used for high yield of citrus around the world, especially in China; meanwhile, it deteriorates the citrus orchard soil environment. To resolve the conflict, the use of organic fertilizer provides a promising solution. This entry is to evaluate the effect of organic fertilizer on citrus yield, growth, soil properties etc. when nutrients of fertilizer of each treatment were equal except CK.

Keywords: soil properties ; yield ; citrus ; organic fertilizer

1. Introduction

Chemical fertilizer has been generally overused around the world. Global chemical fertilizer use has been reported to be about 1.9×10^{11} t, with China ranking first in consumption, accounting for 25% of world usage [1]. Due to great importance of chemical fertilizer to crops in China, the use of chemical fertilizer has continuously expanded from 8.8×10^{9} t in 1978 to 6.0×10^{10} t in 2015 [2]. In addition, China's per hectare application of chemical fertilizer, 393.2 kg/hm^2, is higher than the international environmentally safe use limit of 225 kg/hm^2, and is also about 3.05 times that of the United States and 2.54 times that of the European Union [3][4]. In 2019, China ranked first in citrus production and cultivated area, with about 4.4×10^{8} t and 2.9×10^{7} ha accounting for 27.9% and 29.1% of world production and area [5], respectively. The yields of China's citrus increased further with more fertilizer being applied, especially chemical fertilizer. According to some estimates, excessive application of nitrogen (N), phosphorus (P), and potassium (K) fertilizers were approximately 3.6×10^{6}, 4.3×10^{6}, 3.6×10^{6} t of citrus main production area in China, respectively [6]. What's more, the utilization rate of N, P, and K fertilizer in China is 35–40%, 8–46%, and 35–50%, respectively, far below the level of developed countries [7][8]. It is well known that excessive chemical fertilizer application will adversely affect soil physical and chemical properties, resulting in soil hardness and acidification, which eventually lead to a decline in soil organic matter and fertility [9][10]. In addition, chemical fertilizer also negatively impacts crop quality and causes ecological environment damage, such as water pollution, greenhouse gas emission, and N leaching [11][12]. Moreover, excessive chemical fertilizer application leads to a waste of resources, places a financial burden on farmers, and even reduces the international competitiveness of agricultural products [13][14]. In contrast, organic fertilizer can improve the physical and chemical properties of soil, such as structure, water retention, nutrients, and cation exchange capacity, and promotes positive biological soil properties, enhancing yield and quality and even alleviating the risks of ecological environment deterioration [15][16][17]. Organic fertilizer is a highly abundant resource in China, with approximately 4.0×10^{10} t available; hence the potential for application is enormous [18]. However, compared to the quick nutrient release of chemical fertilizers, organic fertilizers have low nutrient concentrations, and nutrient release is too slow to support crops in a short time [19]. A beneficial approach to overcome this problem is reduction of chemical fertilizers combined with the application of organic fertilizers; this has been shown to better sustain soil fertility compared to applying chemical or organic fertilizers alone [7][15][20].

Several studies have reported that chemical fertilizer combined with organic fertilizer application (CFOF) improves soil conditions and promotes plant growth and even yield in comparison with only chemical fertilizer application. For example, combined application of organic and inorganic fertilizers greatly increases soil organic matter and the total nitrogen content of the soil and improves soil microenvironment in wheat/maize fields [21]. Hazarika et al. [22] found similar results. According to Xiao et al. [19], organic fertilizer combined with compound fertilizer improved soil quality, whereas the utilization of compound fertilizer worsened soil quality and made the soil acidize; this result was similar to that of Song et al. [20] and Pachuau et al. [23]. Qiu et al. [15] reported that chemical fertilizer combined with biofertilizer application significantly promoted root growth, improved the rate of nutrient distribution in citrus, and improved the external and internal qualities of tarocco blood orange; this result was similar to those of previous study of citrus [24][25][26]. According to Pei et al. [7], organic fertilizer is an alternative to chemical fertilizer with no loss in yield and fruit quality for citrus. In addition, apple orchard with organic–inorganic mixed fertilizer promoted soil microbial activity and increased soil organic matter by 16% and crop production by 67% when compared with chemical fertilizer application alone [26] and those results were consistent with research of Lai et al. [27]. Some experiments [28][29][30] also show that application of CFOF improves plant physiological indexes and yield compared with inorganic fertilizers on their own. These studies indicate that CFOF improves soil microbial activity, enhances physical and chemical soil properties, and promotes the absorption and utilization of nutrients, thus facilitating high crop yields. Chemical fertilizer reduction combined with organic fertilizer application meets the requirements for green ecology and is gradually popular in China [7]. Recently, research on reducing chemical fertilizer use and applying organic fertilizer has focused on the effects of reducing N fertilizer on crop yield and quality while rarely measuring changes to soil properties, orchard environment, and plant physiology, especially in citrus systematically, in response to a reduction in chemical fertilizer combined with increased organic fertilizer when equal nutrients of N, P, and K fertilizers are supplied. Due to 'Ponkan' (Citrus reticulata Blanco) being one of the most widely grown varieties of Citrus reticulate, which accounted for 55.3% of the total amount of citrus on cultivated area in China [6], we selected it as our material.

2. Effect of Different Treatments on Soil Properties and Environment

2.1. Soil Physicochemical Properties

Table 1 presents the effect of CFOF on soil physicochemical properties. In the OF + CF and BF + CF treatments, soil porosity, pH, alkali-hydrolyzable N, available P and K, and soil organic matter were significantly ($p \leq 0.05$) higher than that of CF treatments in 2019 and 2020. In addition, soil physicochemical properties of BF + CF were higher than those of OF + CF treatment on the whole, but no significant difference (except available P). These results indicate that CFOF is beneficial to improving soil physicochemical properties, especially when the BF + CF is used.

Table 1. The effect of different treatments on physical and chemical properties.

Year	Treatment	pH Value	Porosity (%)	Organic Matter (g·kg^{-1})	Alkali-Hydrolyzable N (mg·kg^{-1})	Available P (mg·kg^{-1})	Available K (mg·kg^{-1})
2019	CK	5.01 ± 0.06 ab	44.23 ± 0.50 b	20.08 ± 0.41 b	88.82 ± 5.10 c	49.45 ± 2.96 c	188.50 ± 1.45 c
	CF	4.90 ± 0.16 b	44.60 ± 0.61 b	21.13 ± 1.44 b	115.43 ± 6.31 b	51.84 ± 0.72 c	197.96 ± 1.63 b
	OF + CF	5.11 ± 0.12 a	47.82 ± 1.39 a	24.20 ± 1.06 a	129.80 ± 3.33 a	69.12 ± 1.15 a	218.32 ± 4.50 a
	BF + CF	5.18 ± 0.13 a	48.52 ± 0.59 a	23.99 ± 0.72 a	124.54 ± 3.34 a	61.97 ± 4.48 b	221.15 ± 5.01 a
2020	CK	4.97 ± 0.09 b	44.37 ± 1.40 b	19.52 ± 0.81 c	86.36 ± 2.96 c	47.65 ± 3.50 c	177.76 ± 4.71 c
	CF	4.85 ± 0.12 b	44.21 ± 1.60 b	20.80 ± 0.70 b	123.53 ± 8.37 b	54.15 ± 4.54 b	196.51 ± 6.13 b
	OF + CF	5.22 ± 0.10 a	50.95 ± 1.34 a	25.36 ± 0.82 a	136.20 ± 3.45 a	77.33 ± 4.26 a	228.44 ± 7.23 a
	BF + CF	5.20 ± 0.09 a	52.46 ± 0.73 a	25.84 ± 0.43 a	138.48 ± 4.58 a	74.79 ± 4.86 a	230.26 ± 3.69 a

Note: CK: no fertilizer; CF: chemical fertilizer; OF + CF: chemical fertilizer combined with organic fertilizer; BF + CF: chemical fertilizer combined with bioorganic fertilizer. Data are mean ± standard deviation, n = 5. Values in the same row with the same letter(s) are not significantly different per the Duncan analysis at $p \leq 0.05$ between different treatments.

2.2. Soil Microbe Properties

Figure 1 shows the effect of CFOF on soil enzyme activity and the number of cultivable microbes. In each case, soil microbe properties were better in July and lower in April and November. In the OF + CF and BF + CF treatments, soil microbe properties were better than the CK and CF treatments on the whole. In particular, in the OF + CF and BF + CF treatments, soil cultivable bacteria and actinomyces were significantly higher than that of CF in July and November. In addition, when comparing soil cultivable fungus measurements to the CF treatment, OF + CF and BF + CF treatments were significantly higher by 48.1% and 12.4% in July, respectively, while they did not differ significantly in November.

Measurements of urease, sucrase, and acid phosphatase activities in the OF + CF and BF + CF treatments were significantly higher than that of CK and CF in July and November. On the whole, soil microbe properties of BF + CF treatment were better than that of OF + CF. These results showed that CFOF improved soil enzyme activity and the number of cultivable microbes, especially in the BF + CF treatment.

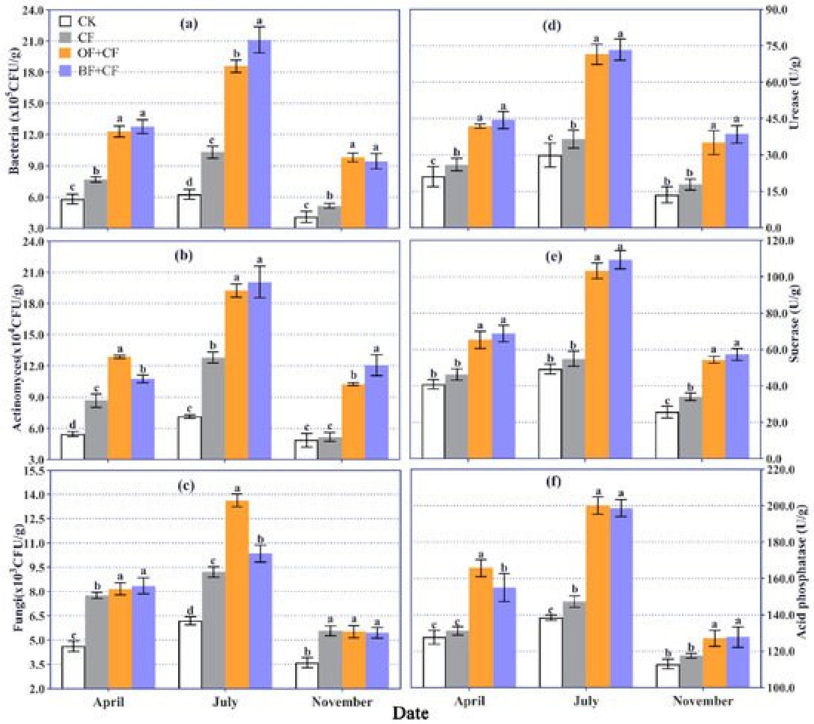

Figure 1. The effect of different treatments on microbial properties of soil, including bacteria (**a**), actinomycetes (**b**), fungi (**c**), urease (**d**), sucrase (**e**), acid phosphatase (**f**). CK: no fertilizer; CF: chemical fertilizer; OF + CF: chemical fertilizer combined with organic fertilizer; BF + CF: chemical fertilizer combined with bioorganic fertilizer. The bars were means ± standard error; the column with different letters indicated significant difference at $p \leq 0.05$.

2.3. Soil Environment

Figure 2 shows the effect of CFOF on CO2 emission flux and $NO3^{-}$-N in soil. As seen in **Figure 2**a, CO2 emission flux in OF + CF and BF + CF treatments was higher than that observed under the CK and CF treatments. A rapid growth trend from February to July, with a peak in July, and then and a downward trend were observed. CO2 emission flux was significantly higher in the OF + CF and BF + CF treatments than in the CF treatment by 57.7% and 60.7%, respectively, in July, and significantly higher in the BF + CF treatment than in the OF + CF and CF treatments by 32.6% and 15.6%, respectively. On the whole, CO2 emission flux was also higher in the BF + CF treatment than that of OF + CF. As illustrated in **Figure 2**b, $NO3^{-}$-N from different soil layers was significantly higher in the CF, OF + CF and BF + CF treatments than that of CK. The 0–20 cm soil layer, when compared between the CF, BF + CF treatments had $NO3^{-}$-N that was significantly lower by 19.7% in 2019, while the OF + CF and BF + CF treatments were also significantly lower by 21.2% and 25.7%, respectively, in 2020. In the 20–40 cm soil layer, compared with the CF treatment, $NO3^{-}$-N was significantly lower by 16.6% in the BF + CF treatment in 2019, while OF + CF and BF + CF treatments also had significantly lower $NO3^{-}$-N by 21.9% and 25.9%, respectively, in 2020. In the 40–60 cm soil layer, compared with the CF treatment, $NO3^{-}$-N in the OF + CF and BF + CF treatments was also significantly lower by 26.0% and 19.9%, respectively, in 2019, while significantly lower by 33.9% and 46.2%, respectively, in 2020. Additionally, $NO3^{-}$-N in the 40–60 cm soil layer of the CF treatment was larger than that of any other soil layer, while $NO3^{-}$-N in the 20–40 cm soil layer of the OF + CF and BF + CF treatments was larger than that of any other soil layer. Furthermore, $NO3^{-}$-N from each soil layer of the BF + CF treatment was lower than that of those measured from the OF + CF treatment on the whole. Therefore, CFOF is beneficial for slowing down the accumulation and migration of $NO3^{-}$-N in the soil while promoting CO2 emission flux to some degree, especially in the BF + CF treatment.

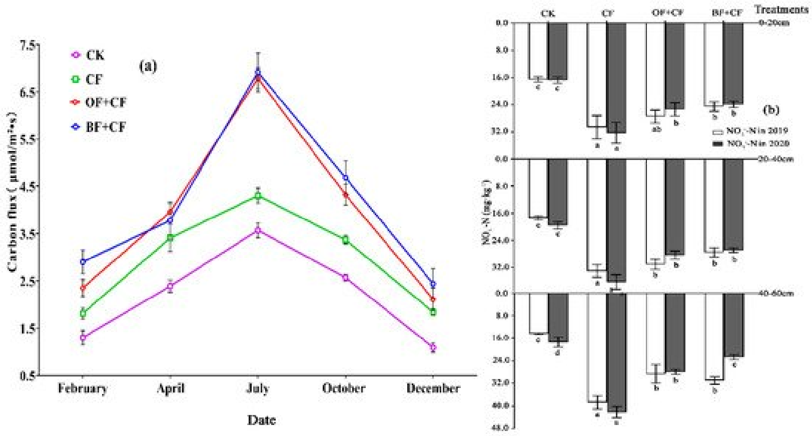

Figure 2. The effect of different treatments on environments of soil, including carbon flux (**a**), NO3-N (**b**).CK: no fertilizer; CF: chemical fertilizer; OF + CF: chemical fertilizer combined with organic fertilizer; BF + CF: chemical fertilizer combined with bioorganic fertilizer. The bars were means ± standard error; the column with different letters indicated significant difference at $p \leq 0.05$.

3. Effect of Different Treatments on Growth Physiology

3.1. Plant Growth

Table 2 presents the effect of CFOF on plant growth index. In comparison with leaf area, thickness of a hundred leaves, dry matter of a hundred leaves of CK and CF, all that of CFOF was promoted in 2019, especially BF + CF significantly. In the OF + CF and BF + CF treatments, twig length was longer than that observed in the CK and CF treatments in 2019. In addition, the plant growth index in 2019 was similar to that of 2020. The plant growth index observed in the BF + CF treatment was higher than that of OF + CF treatment on the whole. These results show that CFOF is beneficial for promoting plant growth, especially the BF + CF treatment.

Table 2. The effect of different treatments on plant growth.

Year	Treatment	Area of Leaf (cm^2)	Thickness of Hundred Leaves (mm)	Dry Matter of Hundred Leaves (g)	Length of Twigs (cm)
2019	CK	17.53 ± 0.77 c	26.74 ± 0.38 c	15.63 ± 0.52 c	6.98 ± 0.54 b
	CF	18.59 ± 1.06 bc	27.02 ± 0.35 bc	17.03 ± 0.19 b	7.60 ± 0.86 ab
	OF + CF	19.71 ± 1.05 ab	27.85 ± 0.69 b	17.75 ± 0.69 ab	7.96 ± 0.92 ab
	BF + CF	20.78 ± 1.42 a	28.88 ± 0.74 a	18.06 ± 0.78 a	8.50 ± 0.83 a
2020	CK	17.38 ± 0.86 c	26.00 ± 0.33 c	14.86 ± 0.62 c	6.80 ± 0.30 b
	CF	18.76 ± 0.33 b	27.73 ± 0.32 b	16.52 ± 0.56 b	7.95 ± 0.10 a
	OF + CF	20.30 ± 0.56 a	28.50 ± 0.62 a	17.36 ± 0.35 a	8.13 ± 0.39 a
	BF + CF	20.34 ± 0.90 a	28.62 ± 0.42 a	17.95 ± 0.44 a	8.38 ± 0.56 a

Note: CK: no fertilizer; CF: chemical fertilizer; OF + CF: chemical fertilizer combined with organic fertilizer; BF + CF: chemical fertilizer combined with bioorganic fertilizer. Data are mean ± standard deviation, n = 5. Values in the same row with the same letter(s) are not significantly different per the Duncan analysis at $p \leq 0.05$ between different treatments.

3.2. Nutrient Elements

Table 3 presents the effect of CFOF on leaf nutrient physiology and twigs. The results showed that N, P, and K contents of leaves and twigs were higher in the OF + CF and BF + CF treatments than that of CK and CF treatments, in general. Moreover, N content of leaves in the OF + CF and BF + CF treatments was significantly higher than that observed in the CK treatment by 4.8% and 5.4%, respectively, in 2019, and by 6.2% and 6.3%, respectively, in 2020. Compared with the CK treatment, leaf K content in the OF + CF and BF + CF treatments was significantly higher by 12.6% and 16.6%, respectively, in 2019, and by 27.9% and 29.5%, respectively, in 2020. N, P, and K contents of twigs measured under the

OF + CF and BF + CF treatments were significantly higher than that observed in the CK treatment in 2019 and 2020.Moreover, leaf K content in the BF + CF treatment was significantly higher than that observed in the CF treatment by 7.3% and 7.4% in 2019 and 2020. Furthermore, the nutrient content of leaves and twigs from the BF + CF treatment was higher than that of the OF + CF treatment; however, no significant difference was observed.

Table 3. The effect of different treatments on nutrients of leave and twigs.

Year	Treatment	Leave			Twigs		
		N ($g \cdot kg^{-1}$)	P ($g \cdot kg^{-1}$)	K ($g \cdot kg^{-1}$)	N ($g \cdot kg^{-1}$)	P ($g \cdot kg^{-1}$)	K ($g \cdot kg^{-1}$)
2019	CK	27.95 ± 0.66 b	1.34 ± 0.16 a	13.10 ± 0.51 c	11.17 ± 0.25 b	0.81 ± 0.06 b	8.17 ± 0.40 a
	CF	29.15 ± 0.55 a	1.40 ± 0.05 a	14.23 ± 0.46 b	11.70 ± 0.37 ab	0.92 ± 0.07 a	8.46 ± 0.15 a
	OF + CF	29.30 ± 0.15 a	1.43 ± 0.04 a	14.75 ± 0.52 ab	11.85 ± 0.40 a	0.95 ± 0.08 a	8.49 ± 0.32 a
	BF + CF	29.47 ± 0.74 a	1.46 ± 0.02 a	15.27 ± 0.56 a	11.97 ± 0.60 a	0.97 ± 0.04 a	8.63 ± 0.37 a
2020	CK	27.89 ± 0.53 b	1.36 ± 0.30 a	12.38 ± 1.05 c	11.22 ± 0.40 b	0.78 ± 0.06 b	8.20 ± 0.73 b
	CF	29.40 ± 0.89 a	1.43 ± 0.07 a	14.93 ± 0.52 b	12.57 ± 0.36 a	0.88 ± 0.05 a	8.98 ± 0.23 a
	OF + CF	29.62 ± 0.16 a	1.41 ± 0.07 a	15.83 ± 0.14 ab	12.11 ± 0.13 a	0.93 ± 0.06 a	9.01 ± 0.16 a
	BF + CF	29.66 ± 0.87 a	1.45 ± 0.09 a	16.03 ± 0.64 a	12.53 ± 0.71 a	0.95 ± 0.05 a	8.92 ± 0.18 a

Note: CK: no fertilizer; CF: chemical fertilizer; OF + CF: chemical fertilizer combined with organic fertilizer; BF + CF: chemical fertilizer combined with bioorganic fertilizer. Data are mean ± standard deviation, n = 5. Values in the same row with the same letter(s) are not significantly different per the Duncan analysis at $p \le 0.05$ between different treatments.

Table 4 presents the effect of CFOF on nutrient physiology of fruits and roots. The nutrient content of fruits and roots grown under the OF + CF and BF + CF treatments was higher than that observed for the CK and CF treatments in 2019 and 2020. In 2019, compared with the CF treatment, nutrient content of fruits was significantly higher in the OF + CF and BF + CF treatments, while the nutrient content of roots grown under the BF + CF treatment was also significantly higher. In 2020, N and P contents of fruits were significantly higher in the OF + CF and BF + CF treatments than that observed in the CF treatment, and P and K contents of roots grown in the BF + CF treatment were significantly higher than that seen in the CF treatment by 16.7% and 8.9%, respectively. In addition, nutrient content of fruits and roots in the BF + CF treatment was higher than that seen in the OF + CF treatment; however, no statistically significant difference was observed. Therefore, CFOF is beneficial in promoting the absorption of nutrients in the citrus organ, especially the BF + CF treatment.

Table 4. The effect of different treatments on nutrients of fruits and roots.

Year	Treatment	Fruits			Roots		
		N ($g \cdot kg^{-1}$)	P ($g \cdot kg^{-1}$)	K ($g \cdot kg^{-1}$)	N ($g \cdot kg^{-1}$)	P ($g \cdot kg^{-1}$)	K ($g \cdot kg^{-1}$)
2019	CK	19.17 ± 0.23 d	1.26 ± 0.05 c	11.23 ± 0.41 b	10.82 ± 0.11 b	0.36 ± 0.02 c	8.56 ± 0.39 b
	CF	19.70 ± 0.48 c	1.37 ± 0.07 b	11.71 ± 0.13 b	11.03 ± 0.44 b	0.38 ± 0.03 bc	8.62 ± 0.67 b
	OF + CF	20.77 ± 0.14 b	1.45 ± 0.02 a	12.57 ± 0.34 a	11.46 ± 0.46 ab	0.41 ± 0.01 ab	8.87 ± 0.39 b
	BF + CF	21.87 ± 0.31 a	1.48 ± 0.04 a	12.73 ± 0.48 a	11.83 ± 0.56 a	0.43 ± 0.04 a	9.72 ± 0.45 a
2020	CK	19.23 ± 0.23 d	1.29 ± 0.05 c	11.20 ± 0.56 b	10.84 ± 1.07 a	0.33 ± 0.03 c	8.46 ± 0.32 c
	CF	20.19 ± 6.19 c	1.44 ± 0.05 b	11.91 ± 0.08 ab	11.10 ± 0.91 a	0.36 ± 0.04 bc	8.86 ± 0.45 bc
	OF + CF	20.94 ± 5.94 b	1.51 ± 0.02 a	12.13 ± 0.23 a	12.14 ± 1.13 a	0.39 ± 0.02 ab	9.21 ± 0.33 ab
	BF + CF	22.03 ± 1.03 a	1.53 ± 0.01 a	12.35 ± 0.78 a	12.11 ± 0.17 a	0.42 ± 0.01 a	9.65 ± 0.42 a

Note: CK: no fertilizer; CF: chemical fertilizer; OF + CF: chemical fertilizer combined with organic fertilizer; BF + CF: chemical fertilizer combined with bioorganic fertilizer. Data are mean ± standard deviation, n = 5. Values in the same row with the same letter (s) are not significantly different per the Duncan analysis at p ≤ 0.05 between different treatments.

References

1. National Bureau of Statistics of the People's Republic of China. International Statistical Yearbook; China Statistics Press: Beijing, China, 2020. (In Chinese)
2. National Bureau of Statistics of the People's Republic of China. China Statistical Yearbook; China Statistics Press: Beijing, China, 2020. (In Chinese)
3. IBRD. International Bank for Reconstruction and Development. Indicator. 2021. Available online: https://data.worldbank.org/indicator/AG.CON.FERT.ZS?view=chart (accessed on 27 September 2021).
4. Yang, Y.; He, Y.; Li, Z. Social capital and the use of organic fertilizer: An empirical analysis of Hubei Province in China. Environ. Sci. Pollut. Res. 2020, 27, 1–12.
5. FAOSTAT. Food and Agriculture Organization of the United Nations. Production Module. 2021. Available online: http://www.fao.org/faostat/zh/#data/QCL (accessed on 27 September 2021).
6. Liang, S.S. Studies on NPK Fertilization Status and the Potential of Reducing Application Rate in Major Citrus Planting Regions of China. Master's Thesis, Huazhong Agricultural University, Wuhan, China, 2017. (In Chinese).
7. Pei, Y.; Wu, Y.P.; Zhang, W.; Jiang, Y.B.; Sun, F.L.; Cheng, Y.F. The impacts of substituting organic fertilizers for chemical fertilizer on fruit, leaf and soil in citrus orchard. Soils Fertil. Sci. China 2021, 4, 88–95. (In Chinese)
8. Chen, Y.; Hu, S.; Guo, Z.; Cui, T.; Zhang, L.; Lu, C.; Yu, Y.; Luo, Z.; Fu, H.; Jin, Y. Effect of balanced nutrient fertilizer: A case study in Pinggu District, Beijing, China. Sci. Total. Environ. 2021, 754, 142069.
9. Gu, B.; Ju, X.; Chang, J.; Ge, Y.; Vitousek, P.M. Integrated reactive nitrogen budgets and future trends in China. Proc. Natl. Acad. Sci. USA 2015, 112, 8792–8797.
10. Lv, F.; Song, J.; Giltrap, D.; Feng, Y.; Yang, X.; Zhang, S. Crop yield and N2O emission affected by long-term organic manure substitution fertilizer under winter wheat-summer maize cropping system. Sci. Total. Environ. 2020, 732, 139321.
11. Liu, Z.; Wang, S.; Xue, B.; Li, R.; Geng, Y.; Yang, T.; Li, Y.; Dong, H.; Luo, Z.; Tao, W. Emergy-based indicators of the environmental impacts and driving forces of non-point source pollution from crop production in China. Ecol. Indic. 2021, 121, 107023.
12. Yang, G.; Tang, H.; Nie, Y.; Zhang, X. Responses of cotton growth, yield, and biomass to nitrogen split application ratio. Eur. J. Agron. 2011, 35, 164–170.
13. Wu, H.; Ge, Y. Excessive application of fertilizer, agricultural non-point source pollution, and farmers' policy choice. Sustainability 2019, 11, 1165.
14. Fang, P.; Abler, D.; Lin, G.; Sher, A.; Quan, Q. Substituting organic fertilizer for chemical fertilizer: Evidence from apple growers in China. Land 2021, 10, 858.
15. Qiu, F.; Liu, W.; Chen, L.; Wang, Y.; Ma, Y.; Lyu, Q.; Yi, S.; Xie, R.; Zheng, Y. Bacillus subtilis biofertilizer application reduces chemical fertilization and improves fruit quality in fertigated Tarocco blood orange groves. Sci. Hortic. 2021, 281, 110004.
16. Chang, K.H.; Wu, R.Y.; Chuang, K.C.; Hsieh, T.F.; Chung, R.S. Effects of chemical and organic fertilizers on the growth, flower quality and nutrient uptake of Anthurium andreanum, cultivated for cut flower production. Sci. Hortic. 2010, 125, 434–441.
17. Tejada, M.; Gonzalez, J.L. Effects of the application of a compost originating from crushed cotton gin residues on wheat yield under dryland conditions. Eur. J. Agron. 2003, 19, 357–368.
18. Niu, X.S.; Ju, X.T. Organic fertilizer resources and utilization in China. J. Plant Nutr. Fertil. 2017, 23, 1462–1479. (In Chinese)
19. Xiao, L.; Sun, Q.; Yuan, H.; Lian, B. A practical soil management to improve soil quality by applying mineral organic fertilizer. Acta Geochim. 2017, 36, 198–204.
20. Song, H.; Wang, J.; Zhang, K.; Zhang, M.; Hui, R.; Sui, T.; Yang, L.; Du, W.; Dong, Z. A 4-year field measurement of N2O emissions from a maize-wheat rotation system as influenced by partial organic substitution for synthetic fertilizer. J. Environ. Manag. 2020, 263, 110384.

21. Yang, Q.; Zheng, F.; Jia, X.; Liu, P.; Dong, S.; Zhang, J.; Zhao, B. The combined application of organic and inorganic fertilizers increases soil organic matter and improves soil microenvironment in wheat-maize field. J. Soils Sediments 2020, 20, 2395–2404.

22. Hazarika, T.K.; Aheibam, B. Soil nutrient status, yield and quality of lemon (Citrus limon Burm.) cv. 'Assam lemon' as influenced by bio-fertilizers, organics and inorganic fertilizers. J. Plant Nutr. 2019, 42, 853–863.

23. Pachuau, R.; Singh, B.; Lalnunpuia, J.; Mawii, L. Effect of organic manures on growth, yield and quality of assam lemon . Int. J. Curr. Microbiol. Appl. Sci. 2019, 8, 1009–1019.

24. Huang, X.; Muneer, M.A.; Li, J.; Hou, W.; Ma, C.; Jiao, J.; Cai, Y.; Chen, X.; Wu, L.; Zheng, C. Integrated nutrient management significantly improves Pomelo (Citrus grandis) root growth and nutrients uptake under acidic soil of southern China. Agronomy 2021, 11, 1231.

25. Li, R.; Chang, Y.; Hu, T.; Jiang, X.; Liang, G.; Lu, Z.; Yi, Y.; Guo, Q. Effects of different fertilization treatments on soil, leaf nutrient and fruit quality of citrus Grandis var. Longanyou. World J. Eng. Technol. 2017, 5, 1–14.

26. Ghosh, A.; Dey, K.; Bhowmick, N.; Medda, P.S.; Ghosh, S.K. Impact of different pruning severity and nutrient management on growth and yield of lemon cv. Assam lemon (Citrus Limon Burm.). Int. J. Plant Res. 2016, 29, 25.

27. Lai, D.; Kuang, S.Z.; Xiao, W.Q.; Liu, C.H.; He, H.; Shao, X.H. Effects of organic-inorganic mixed fertilizers substituting chemical fertilizer on Citrus reticulata Tankan Fruit yield, quality and soil nutrients. Guangdong Agric. Sci. 2021, 48, 23–29. (In Chinese)

28. Hameed, A.; Fatma, S.; Wattoo, J.I.; Yaseen, M.; Ahmad, S. Accumulative effects of humic acid and multinutrient foliar fertilizers on the vegetative and reproductive attributes of citrus (Citrus reticulata cv. kinnow mandarin). J. Plant Nutr. 2018, 41, 2495–2506.

29. Elhassan, A.A.M.; El-Tilib, A.M.A.; Ibrahim, H.S.; Hashim, A.A.; Awadelkarim, A.H. Response of foster grapefruit (Citrus paradisi Macf.) to organic and inorganic fertilization in central Sudan. Ann. Agric. Sci. 2011, 56, 37–41.

30. Lee, J. Effect of application methods of organic fertilizer on growth, soil chemical properties and microbial densities in organic bulb onion production. Sci. Hortic. 2010, 124, 299–305.