Effects of Film Mulching and Irrigation on Biomass of Leaves, Roots and Tubers and Soil Nutrient Characteristics of Cyperus esculentus L.

Ya Ding (dingya@stu.xju.edu.cn)
Xinjiang University https://orcid.org/0000-0001-8969-9441
Zhihao Zhang
Li Li
Fanjiang Zeng

Research Article

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Abstract

Aims To study the effect of drip irrigation mulching and the most suitable irrigation system for *Cyperus esculentus L.*, and to provide a reference for the construction of a cultivation model for water-saving and high yield management of Cyperus esculentus.

Methods To study the effects of irrigation and mulching control on the nutrients and biomass of Cyperus esculentus, a combination of field and indoor experiments analyzed the film mulching (FM) and no film mulching (NFM) treatments and different irrigation treatments, CK (control, the common local irrigation of 5316.45 m3·ha^{-2}), T1 (3431.40 m3·ha^{-2}) and T2 (4133.85 m3·ha^{-2}), and the correlation between soil and plant nutrient content and biomass.

Results The result showed that contents of soil organ carbon (SOC), soil total nitrogen (STN), and soil total phosphorus (STP) dropped layer by layer with soil depth increased, and film mulching reduced SOC, STN, and STP contents, and reaching maximum under the T2NFM treatment. T2NFM treatment significantly increased leaf total phosphorus (LTP) and root total nitrogen (RTN). The aboveground and underground biomass reached maximum under the T2FM treatment, followed by higher biomass under FM than the NFM treatment. According to correlation analysis that the biomass of Cyperus esculentus, soil and plant nutrient contents, and yield could be improved by changing the water and fertilizer supply.

Conclusion In conclusion, the region's soils are generally nitrogen-limited, therefore supplemental nitrogen fertilization is recommended for agricultural production. In addition, the irrigation of 4133.85 m^{3}·ha^{-2} under the mulching condition not only improved yield but also saved water resources.

Introduction

Soil moisture is a major environmental component that limits plant growth and yield, especially in the northwest arid zone, where an arid climate, poor soils, and severe water scarcity (Yue et al., 2016) have constrained efficient and sustainable agricultural development, and severely damaged to the ecosystem. Mulching is a generally utilized agricultural strategy that can improve soil structure, moisture, and temperature conditions, promote microbial development, reproduction, and activity, increase the activity of soil enzymes, and accelerate soil mineralization processes (W. Zhang et al., 2022; X. Zhang et al., 2019) which have a significant impact on material change and supplement cycle processes and affect the supplementation and stoichiometry of soil (Liu et al., 2018). Therefore, the combination of irrigation and mulching techniques can promote healthy crop growth while achieving the goals of water conservation and high yield.

The ability of a plant to survive depends on its ability to survive in the soil throughout its life cycle. The basic components of soil supplements, C, N, and P are essential for plant development (Zeng et al., 2017), and soil microbial biomass and the decomposition rate of litter affect the soil nutrient content (Wang et al., 2020; Yang et al., 2019), which affects crop development and the formation of yield (Wang et al., 2022). It is crucial to explore the soil contents and plant nutrients and the link between them to comprehend the process of ecosystem nutrient balance, plant nutrient limiting factors and habitat restoration mechanisms of desertification areas.

Ecological stoichiometric ratios are thought to be one of the most accurate indicators of the status of nutrient availability in the environment for plant growth and can be used to assess organism growth, development, elemental species, and their utilization values (D. Yang et al., 2019). Therefore, stoichiometric ratios can be used to forecast how plant species will adapt to the scarce resources in their environment (Hättenschwiler and Bracht Jörgensen, 2010). The primary chemical building blocks for plant growth are carbon (C), nitrogen (N), and phosphorus (P), and carbon (C) being the dominant element and the primary component of the dry matter of the plant body and nitrogen (N) and phosphorus (P) being significant elements that are crucial for the composition of various proteins and genetic material (Xiang et al., 2006). C:N and C:P can be used to convey the rate of plant growth, and their ratio can be used to calculate how effectively plants use soil N and P. N:P can be used to identify the nutrients that limit production (Y.-F. Yu et al., 2014). As a result, ecological chemometrics research can shed light on the mechanisms that control the nutrient interactions between plants and soil. This is crucial for understanding how C, N, and P components interact, for managing regional soil nutrient levels, and for sustainable land use (Wen et al., 2015).

Cyperus esculentus is a perennial herbage of Cyperaceae Sargassum, which can be used as pasture, and the tubers are high-quality oilseeds and have high yielding, quality, and drought resistance. At present, it is widely planted in the arid areas of western China, and irrigation control and film mulching are common technical measures adopted in the planting of Cyperus esculentus L. Therefore, we set up a correlation experiment with irrigation and film mulching treatments for Cyperus esculentus L., The purpose is to investigate: (1) the effects of film mulching on the growth and above-underground biomass of Cyperus esculentus, (2) the effects of film mulching and irrigation on soil plant nutrients and stoichiometry, and (3) The supply limitation of soil nutrients on the growth of Cyperus esculentus in this area.

Materials And Methods

Study area and climate conditions

The experiment was conducted from May to October 2020. The area is located in Hala yu gong township (41°36' N, 86°3' E) in southwestern of Korla city. The area experiences a temperate continental monsoon climate, with annual mean temperatures of 11°C, maximum annual average evaporation of 2788.2 mm, and annual mean precipitation of 57 mm. The region interactions mean minimum temperatures of -9°C in January and mean maximum temperatures of 26.50°C in July. The average elevation in the area is 904 m, and there are 170 to 190 days without frost. Sandy loam is the predominant soil type in the study region (using the Chinese classification). We gathered soil samples from 0 ~ 40 cm deep before planting. We determined the following parameters from the soil samples: field moisture capacity of 18%, soil bulk density of 1.58 $g \cdot cm^{-3}$, soil organic matter content of 4588.55 $mg \cdot kg^{-1}$, and available nitrogen concentration is 28.41 $mg \cdot kg^{-1}$. The available P concentration is 73.783 $mg \cdot kg^{-1}$, the pH is 7.6, and the available K is 9.89 $mg \cdot kg^{-1}$.

Experimental design

The randomized complete block design (2 × 3), and consisted of 6 treatment combinations (2 film control × 3 irrigated), with three replicates in each treatment (18 plots in all). Two film controls comprised film mulch (FM) and no film mulch(NFM), and each film control had three irrigations of Cyperus esculentus L., named 3431.40 $m^3 \cdot ha^{-2}$(T1), 4133.85$m^3 \cdot ha^{-2}$(T2), and 5316.45 $m^3 \cdot ha^{-2}$(CK). In the local area, according to the farmers' irrigation experience, the conventional irrigation amount in this area is 5000.00 ~ 5316.45 $m^3 \cdot ha^{-1}$. Therefore, we designed 5316.45 $m^3 \cdot ha^{-2}$ as the local conventional irrigation, and the other irrigation included 4133.85 $m^3 \cdot ha^{-2}$, and 3431.40 $m^3 \cdot ha^{-2}$.

Collection of plant and soil samples

Plant aboveground biomass was measured in each treatment from 5 to 10 months in 2020 in a random quadrat (0.1 m×0.1 m). Afterwards, the plants were cleansed, and dried in an oven at 75°C for 48 h, and the aboveground biomass was estimated using dry biomass. After the aboveground plants were removed, the soil was sampled in the same plots. Soil samples were taken at depths of 0 ~ 10 cm, 10 ~ 20 cm, 20 ~ 40 cm, and 0 ~ 40 cm. To evaluate the chemical components of the soil components, the soil samples were air dried, sieved (using an 80 mesh sieve), and employed.

Laboratory analysis

Using a Multi CN/3000 analyzer, the soil carbon (SOC), leaf total carbon (LTC), root total carbon (RTC), and tuber total carbon (TuTC) were all calculated (Analytic Jena AG, Germany). Using a Kjeltec KTM 2300 analyzer, the total nitrogen in the leaf(LTN), root(RTN), tuber(TuTN), and soil total nitrogen (STN) with $H_2SO_4 + K_2SO_4 + CuSO_4$ was determined (Foss, Rose Scientific Ltd., Denmark). After $H_2SO_4 + H_2O_2$ digestion, the total P in the leaves(LTP), roots(LTP), and tubes(LTP) was analyzed using molybdenum antimony colorimetric spectrophotometry.

The soil samples were then collected at a depth of 0 ~ 40 cm for the examination of soil organic carbon (SOC), soil total nitrogen (STN), and soil total phosphorus (STP). SOC was determined by using the dichromate heating-oxidation method (Liu, 1996). The amount of STN was measured using the modified Kjeldahl method (Miller and Keeney, 1982). The quantity of STP was determined using the molybdenum blue colorimetric technique (Shima Seiki UV2450).

Statistical investigation

The Shapiro-Wilks test was used to determine whether the data were normal using SPSS 22.0 to analyze all of the data. In our research, single-factor ANOVA was used to test the differences between C, N, P and the physical and chemical properties of different treatment plants and soil. Pearson correlation analysis was used to analyze the relationship between plant (leaves, root, tuber)biomass, plant(leaves, root, tuber), and soil ecological chemometrics. The Origin2021 were used for figures.

Results

Influence of irrigation and film mulching on soil C N and P content and stoichiometry

Analysis of variance showed that the effects of film mulching and irrigation on soil nutrients and stoichiometry were significantly different(Appendix. S1). The SOC, STN and STP of the soil (0 ~ 40 cm) were 2.55 g·kg^{-1} and 24.10 g·kg^{-1}, and 9.78 g·kg^{-1} respectively(Fig. 1a, c, d). The contents of soil SOC, STN, and STP were mainly concentrated in the soil surface reaching the highest value in the 0 ~ 10 cm soil layer, where the average content of SOC was 22.76% and 67.31% higher than that in the 10 ~ 20 cm and 20 ~ 40 cm soil layers, the average content of STN was 45.58% and 64.13% higher than that in the 10 ~ 20 cm and 20 ~ 40 cm layers, and the average content of STP was 34.67% and 69.04%% higher than that in the 10 ~ 20 cm and 20 ~ 40 cm layers. The interaction between irrigation and film mulching treatments has a significant impact on SOC, STN, and STP contents (Appendix. S1). On the one hand, the contents of soil SOC, STN, and STP in the different treatments first increased and then decreased. On the other hand, in contrast to the other treatments, the contents of soil nutrients first increased and then decreased with increasing of irrigation amount. Moreover, the contents of SOC, STN, and STP in the soil were decreased by film mulching (Fig. 1a, c, e), and were significantly higher than the other treatments under T2NFM (P< 0.05).

With all data, the SC:N, SC:P, and SN:P ratios at 0 ~ 40 cm were 0.07 ~ 0.13, 0.19 ~ 0.43, and 1.66 ~ 3.63, respectively (Fig. 1b, d, f). Due to the numerous variations in SOC, STN, and STP contents, the SC:N, SC:P, and SN:P ratios exhibit erratic changes. The ratios of SC:N, SC:P, and SN:P were majorly influenced by irrigation and film mulching (Appendix. S1), with the exception of T1, which significantly stimulated the ratios at a depth of 0 ~ 40 cm (Fig. 1b, d, f).

Influence of irrigation and film mulching on C N and P content of leaves, roots and tubers

Changes in nutrients in leaves, roots, and tubers of C. esculentus under different treatments(Fig. 2). Overall, the TN, root TP, and tuber TN and TP contents of C. esculentus leaves, roots, and tubers showed a trend of increasing and then declining under different treatments, dropping a maximum under the T2NFM treatment, but the difference between treatments was not significant (P> 0.05). However, the TC content in the leaves, roots, and tubers of C. esculentus showed little change under the different treatments (Fig. 2, Appendix. S2-S4). However, leaf TP and root TN first increased and then decreased under the different treatments. The maximum value appeared under the T2NFM treatment and the minimum value appeared under the T1NFM treatment, and the difference between the two treatments was significant (P 0.05) (Fig. 3, Appendix. S2-S4).

The TC, TN, and TP in leaves, roots, and the tubers, C:N, C:P, and N:P changes differently under different treatments, among which the C: N in leaves, roots, and tubers changed relatively stably under different treatments, while C: P and N: P generally showed a downward trend under different treatments, with no significant difference between treatments ($P > 0.05$) (Fig. 3, Appendix. S2-S4).

Influence of irrigation and film mulching on above and underground biomass

Tillers and plant heights are key parameters of plant biomass and final yield (Rotili et al., 2021; Xing et al., 2021), and the biomass level affects farmers' excitement for C. esculentus production and affects the final output of the plant. Different treatments significantly affected tiller number, plant height, and aboveground biomass (Appendix. S5). Tiller number and plants tended to increase with increasing irrigation (Fig. 4), with the FM treatment being higher than the NFM treatment, and both significantly higher ($P < 0.05$) than the other treatments under the CKFM treatment.

The total biomass of C. esculentus increased after 20% water reduction, with the leaf, root, tuber, underground biomass, and total biomass of C. esculentus increasing by 16.36%, 126.08%, 22.03%, 19.88%, and 18.74%, respectively, under the film mulching control. The aboveground biomass of C. esculentus under each treatment generally showed an increasing-decreasing-increasing trend. Overall, the above-underground biomass of C. esculentus initially increased and eventually declined in response to all treatments. After FM treatment, C. esculentus leaf, root, tuber, subterranean biomass, and total biomass were all higher than under NFM treatment. The leaf, root, tuber, underground biomass, and total biomass of C. esculentus all increased initially under the same FM treatment control conditions before decreasing with an increase in irrigation; the maximum value appeared under the T2FM treatment, and the minimum value appeared under the T1NFM treatment; T2FM treatment was significantly higher than other treatments (P 0.05).

In general, the root mass ratio decreased as irrigation increased and was considerably greater under the T1FM treatment than unde the other treatments. When irrigation water was increased, the root mass ratio essentially fell and was higher under the T1FM treatment than under the other treatments (P 0.05). In conclusion, the number of tillers and plant height peaked at CKFM, while the above- and underground biomass of C. esculentus both peaked at T2FM. Coupling planting with appropriate watering and mulching could enhance the development of C. esculentus yield.

Correlation among C, N, and P contents in leaves, roots, tuber, soil, and biomass

The relationship between biomass and leaf, root, tuber, soil C, N, and P contents and he stoichiometric ratio showed that (Fig. 5, Appendix. S6-S11), SOC and STN were significantly positively correlated ($P < 0.01$), and STP was significantly positively correlated ($P < 0.05$); STN was positively correlated with STP ($P < 0.01$); STP was positively correlated with RTN, root biomass, tuber biomass, underground biomass and total biomass ($P < 0.01$). LTC was positively correlated with LTP ($P < 0.01$), tuber biomass, and underground biomass ($P < 0.05$), and TuTC was positively correlated with tuber biomass and underground biomass ($P < 0.05$); There was a significant positive correlation between LTN and LTP ($P < 0.05$), RTN and RTP ($P < 0.05$), and STP ($P < 0.01$); There was a significant positive correlation between TN and TP in tubers ($P < 0.01$).

Discussion

Response of soil nutrient content and stoichiometric characteristics of C. esculentus to irrigation and film mulching

Crop litter, root stubble residues, root exudates, soil microbial activity, and soil nutrient efficacy are thought to be the main factors impacting soil stoichiometric ratios in agricultural areas (Y. Sun et al., 2020; Yin et al., 2013). The results of our study demonstrated that the SOC, STN, and STP contents in the soil gradually decreased with increasing soil depth (Fig. 1), which was because litter and animal residue manure are the main sources of soil nutrients, and after bacterial decomposition, nutrients enter the soil surface first. The change patterns of SOC, STN, and STP contents in the soil remained the same in our study (Fig. 1a, c), which was probably because the nutrients in the soil primarily originated from organic matter formed by the decomposition of plant residues in the soil; additionally, the contents of SOC, STN, and STP in the soil showed a trend of first increasing and then decreasing under different treatments, with the maximum under the T2NFM treatment (Fig. 1).This trend may be rooted in the fact that irrigation quantity influences soil moisture, which in turn impacts plant roots' ability to absorb nutrients (Gu et al., 2019; C. Li et al., 2022). The mineral nutrients in the soil dissolve into the water and are absorbed by the root system when the soil moisture is appropriate, which decreases the amounts of nutrients in the soil. The water potential of the plant roots was lower than that of the surrounding environment when the soil's water content was insufficient. The nutrients stored in the roots are released into the soil, where they are absorbed and reduced by plants. This causes a buildup of nutrients in the soil, which has an impact on plant growth and development(Dou et al., 2022; S. Liang et al., 2021); The gas permeability, porosity, respiration, and microbiological activity of the soil are all negatively impacted by excessive soil moisture, which decreases the amount of SOC, STN, and STP in the soil.

Plastic film mulching can improve the soil moisture content and temperature, directly affecting the mineralization rate of soil nutrients, and then affecting the change of soil nutrient content. Plastic film mulching can improve soil conditions by increasing biomass (Z. Liu et al., 2017), and increasing the content of SOC, STN, and SAP in soil (Ravanbakhsh et al., 2019; Yu et al., 2021). However, some research shows that using film mulch reduces the contents of SOC, STN, and SAP in soil (M. Zhang et al. 2022). In our study, the contents of SOC, STN, and STP under the FM treatment were lower than those under the NFM treatment in the soil (Fig. 1a-c), which could be due to fewer input sources for C and N nutrients than under the NFM treatment.

Soil stoichiometry reflects the composition of soil organic matter and the effectiveness of nutrient balance, as well as the mineralization and fixation of C, N, and P (Sardans et al., 2012). The C:N ratio of the soil in this region was 0.06 ~ 0.26, which was lower than the national C:N ratio of 11.3(Gren, 2008) under different treatments in our study which indicated that soil C contents were more deficient than N in this region. The soil C:N ratio and organic matter decomposition rate are inversely related, and lower soil C content indicates higher organic matter decomposition and mineralization rate, indicating that soil C was more deficient than N in this region (Santos et al., 2020). Secondly, this area's soil C:N fluctuates rather steadily with soil depth under various treatments, suggesting that water has less of an impact on this region's soil C:N; Soil C:P was a symbol to balance the mineralization, release, absorption, and fixation of phosphorus in organic matter, and a form to reflect the availability of phosphorus, which was of great significance to the study of soil physical and chemical properties (Poblete Grant et al., 2022). In our study, the C:P ratio in the soil of C. esculentus was 0.14 ~ 0.45, which was lower than the national average level of 52.7 (Agren, 2008), suggesting that the net mineralization rate of P in our area may be higher, and the potential to release P content was relatively high. P was closely related to plant growth and was indicated in the soil of C. esculentus (Poblete-Grant et al., 2022); As an indication of nitrogen saturation and nutritional limitation of nitrogen and phosphorus elements in soil (Y. Yan and Lu, 2020), the N:P(2.64) was lower than the N:P (3.9) in the land soil of China in our study (Gren, 2008) and N:P 14 in the soil, which indicated that soil N was deficient and that there was nitrogen limitation during plant growth in this area.

Response of nutrient content and stoichiometric characteristics of C. esculentus leaves, roots, and tubers to irrigation and film mulching

The nutrients of plant organs reflect the status of nutrient balance among plant organs and their adaptation to the environment to some extent(Ma et al., 2017). Our study showed that the SOC content in leaves, roots, and tubers of C. esculentus did not significantly change under the different treatments. Carbon is less impacted by the environment and has a more stable composition as a structural component of the plant body (Wen et al., 2019). However, the TN and TP contents of leaves, roots, and tubers increased first and then decreased under different treatments, and reached the maximum value under the T2NFM treatment (Fig. 2). The transport of nitrogen and phosphorus from the soil to plants through the root system is reduced in arid locations, which may result in a decrease in the amounts of N and P in leaves and roots(Hu and Schmidhalter, 2005; W. Q. Wang et al., 2015). When the water is excessive, the oxygen in the soil is insufficient, and the ability of roots to absorb nitrogen and phosphorus is limited by hypoxia, which may reduce the nutrient content (K. A. Fisher et al., 2016).

The Changes in C:N, C:P, and N:P in leaves, roots, and tubers of C. esculentus showed different patterns of change under different treatments. The C:N of leaves, roots, and tubers were largely steady and C:P generally tended to decrease under different treatments, with the difference between treatments being insignificant (Fig. 2). It is due to the leaf, root, and tuber C:P of C. esculentus being affected by their own SOC and TP contents, while the SOC structure in the leaf, root, and tuber of C. esculentus are relatively stable (Wen et al., 2019), and the single and low mobility of phosphorus in the plant (X.-S. Liang et al., 2022). N:P ratios typically serve as a direct indicator of the impact of soil N and P nutrient limitations on plant growth (Y. Li et al., 2022). In our study, we discovered that N:P 14 in leaves, roots, and tubers of C. esculentus, indicating that the growth and development of C. esculentus are mostly controlled by the N element under the influence of irrigation and film mulching in this area. Therefore, N fertilizer should be applied during the growth process to promote the normal growth of crops.

Above-underground biomass response of C. esculentus to irrigation and film mulching

Water is the key factor restricting the development of agriculture in northwest arid areas. Related studies revealed that mulching promotes soil temperature, moisture, and water storage capabilities, especially with full ground film mulching, which is a crucial issue constraining the development of agriculture in the arid northwest (T. Sun et al., 2018). Our study demonstrates that the aboveground biomass of C. esculentus. was affected by film mulching. Mulching was able to increase biomass and raise soil temperature, promote plant growth, and increase plant biomass and yield when compared to the NFM treatment (Mo et al., 2020; Niu et al., 2020; Shi et al., 2022). However, the aboveground biomass of C. esculentus first increased and then decreased with increasing irrigation, and the above-underground biomass reached the maximum value in the T2 treatment. With the increase of irrigation, the soil water content, microbial species, and activity, which improved the rate of soil nutrient mineralization and increased the number of nutrients available to plants, improved the environment for root growth and was favorable for the development of aboveground underground biomass. However, soil respiration was inhibited, root uptake of nutrients from the environment was hindered, discourages upward transport of water and nutrients in the soil, reduced photosynthetic assimilation and material translocation capacity, and ultimately resulted in a reduction in aboveground biomass when irrigation exceeded certain threshold values of soil moisture. (Xie et al., 2022; Yuan et al., 2020). Therefore, favorable moisture conditions are favorable for crop growth and the formation of final yields.

Correlation between soil nutrients and C, N, and P contents of Cyperus esculentus leaves and roots and biomass

Soil nutrients and water status directly affect the uptake and utilization of nutrients by plants, thus causing changes in plant organ stoichiometric ratios (D. Yang et al., 2019), and the two interact with each other. This study showed that soil SOC was significantly and positively correlated with STN and STP; STN was significantly and positively correlated with soil STP (Fig. 5), which was due to the consistency of changes in SOC, STN, and STP contents, which were closely linked and showed relatively uniform changes in element storage and consumption (L. I. Li et al., 2016). Soil nutrients and water play an important role in nutrient uptake by plants, and some studies have shown that SOC content is closely related to plant TC and TN content, and plant nutrient uptake and utilization is enhanced when SOC content is high and the soil is well aerated internally, and the root system has an increased ability to absorb mineral elements and transfer absorbed soil nutrients to the aboveground part (Das et al., 2022), In contrast, TC and TN did not correlate with above-ground biomass of C. esculentus in our study (Fig. 5), probably because of the low air humidity, arid climate, poor soil, extremely slow mineralization of organic matter in the soil, and low levels of nutrients in the soil that can be directly absorbed and used by plants, especially the lack of fast-acting N (G. S. G. Fisher, 1986; Vitousek and Howarth, 1991), and secondly, urea is commonly used in agricultural production to supplement N, but urea cannot be adsorbed by the soil and is easily lost with water; or the ammonia formed after conversion is also volatile (W. X. Li et al., 2020), resulting in plant growth inhibition and yield impairment. Soil adsorption of P is relatively strong and not easily leached (S. Chen et al., 2021), and related studies have shown that soil STN and STP are significantly correlated with biomass and yield ($r = 0.69$, $P < 0.001$) (X. J. Wang et al., 2018). The present study showed that STP was significantly and positively correlated with root biomass, tuber biomass, underground biomass, and total biomass. Leaf TC was significantly and positively correlated with leaf TP, tuber biomass, and belowground biomass, and tuber TC was significantly and positively correlated with tuber biomass and belowground biomass, indicating that the nutrients absorbed and utilized in plant leaves are not only from the soil, but also from the plant's nitrogen fixation and photosynthesis (BU et al., 2010), and the products of photosynthesis are distributed to various organs of the plant to promote crop growth and final yield. The products of photosynthesis are distributed to all organs of the plant to promote crop growth and final yield composition.

Conclusion

Irrigation and film mulching significantly affected the C, N, and P stoichiometry of the soil, but alleviated the effects of soil nutrient levels on the C, N, and P stoichiometry of leaves, roots, and tubers; Soil and plant nutrient N:P 14, the growth and development of crops in this area are limited by N, so nitrogen fertilizer should be applied during the critical growth period to promote the healthy development of crops. Film mulching increased the biomass of leaves and tubers of salsa bean, reaching the maximum value in the T2FM treatment. Therefore, under the film mulching condition, the irrigation mode with irrigation of 4133.85 $m^3 \cdot ha^{-2}$ has obvious economic and water-saving benefits. Overall, film mulching has an important impact on the growth of crops in arid areas, and the appropriate amount of irrigation will promote the healthy development of plants.

Abbreviations

SOC	Soil organ carbon
STN	Soil total nitrogen
STP	Soil total phosphorus
FM	Film mulching
NFM	No flim mulching
LTC, LTN, LTP	Total carbon of leaf, total nitrogen of leaf, total phosphorus of leaf
RTC, RTN, RTP	Total carbon of root, total nitrogen of root, total phosphorus of root
TuTC, TuTN, TuTP	Total carbon of tuber, total nitrogen of tuber, total phosphorus of tuber

Declarations

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Author information

Authors and affiliations

Department of Ecology, College of Resource and Environmental, Xinjiang University, Urumqi, Xin Jiang 830000, China

Ya Ding, and Fanjiang Zeng

Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Urumqi, Xin Jiang 830000, China

Zhihao Zhang , Li Li , and Fanjiang Zeng

Authors Contributions

DY: investigation, methodology, formal analysis, and writing of the original draft.

ZZ: methodology, formal analysis

LL: methodology and review and editing

FZ: conceptualization, supervision, project administration, and funding acquisition.

All authors contributed to the article and approved the submitted version

Ethics declarations

Competing interests

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Data Availability

The result analysis data set in the current research paper can be obtained from the corresponding authors according to reasonable requirements.

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Figures

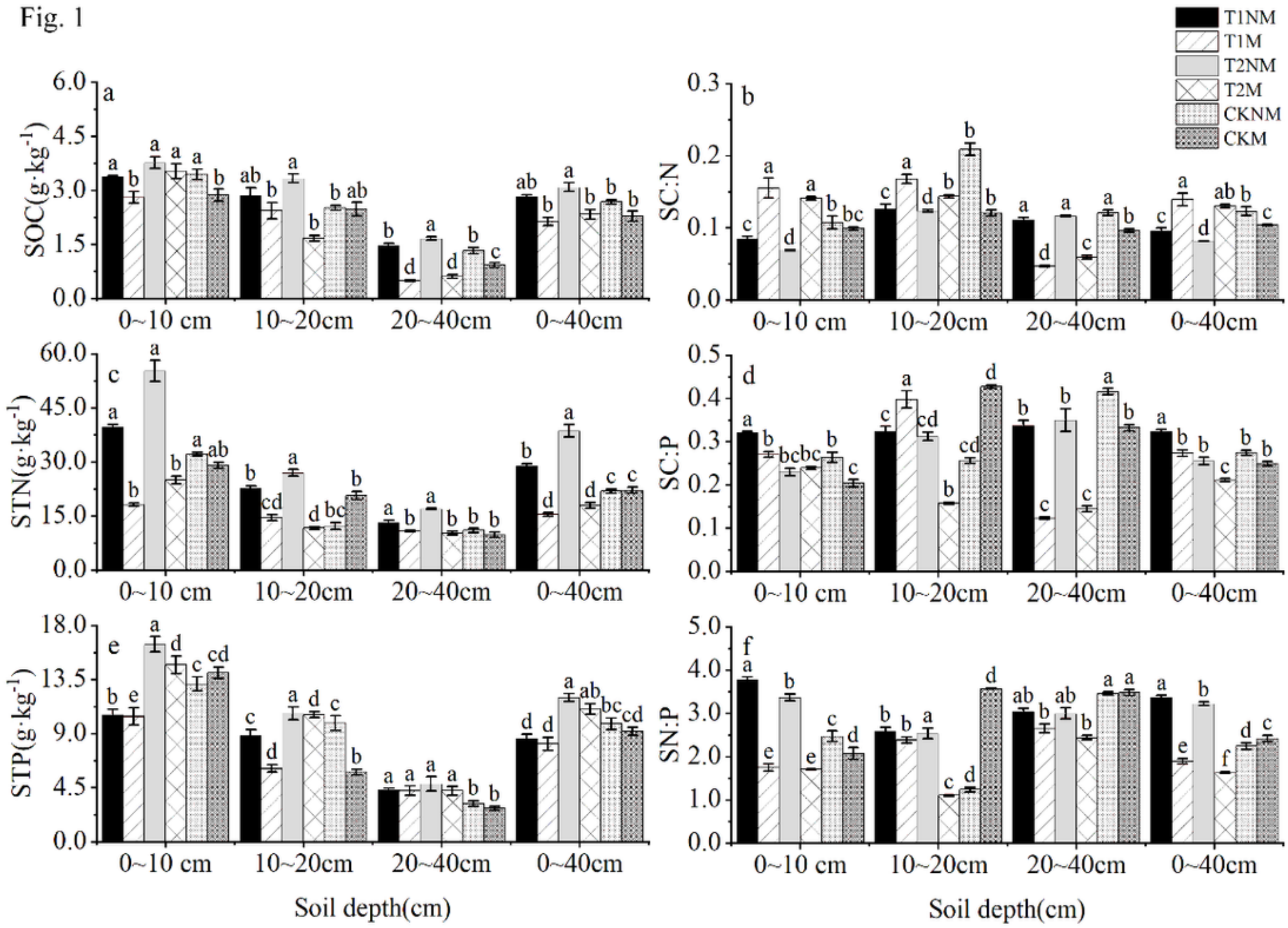

Figure 1

Effects of film mulching and irrigation on the C, N, and P contents of soil(0~40 cm) and stoichiometry. Values of a variable labeled with different lowercase letters indicate differences between treatments (ANOVA followed by Duncan's test, $P < 0.05$).

Fig. 2

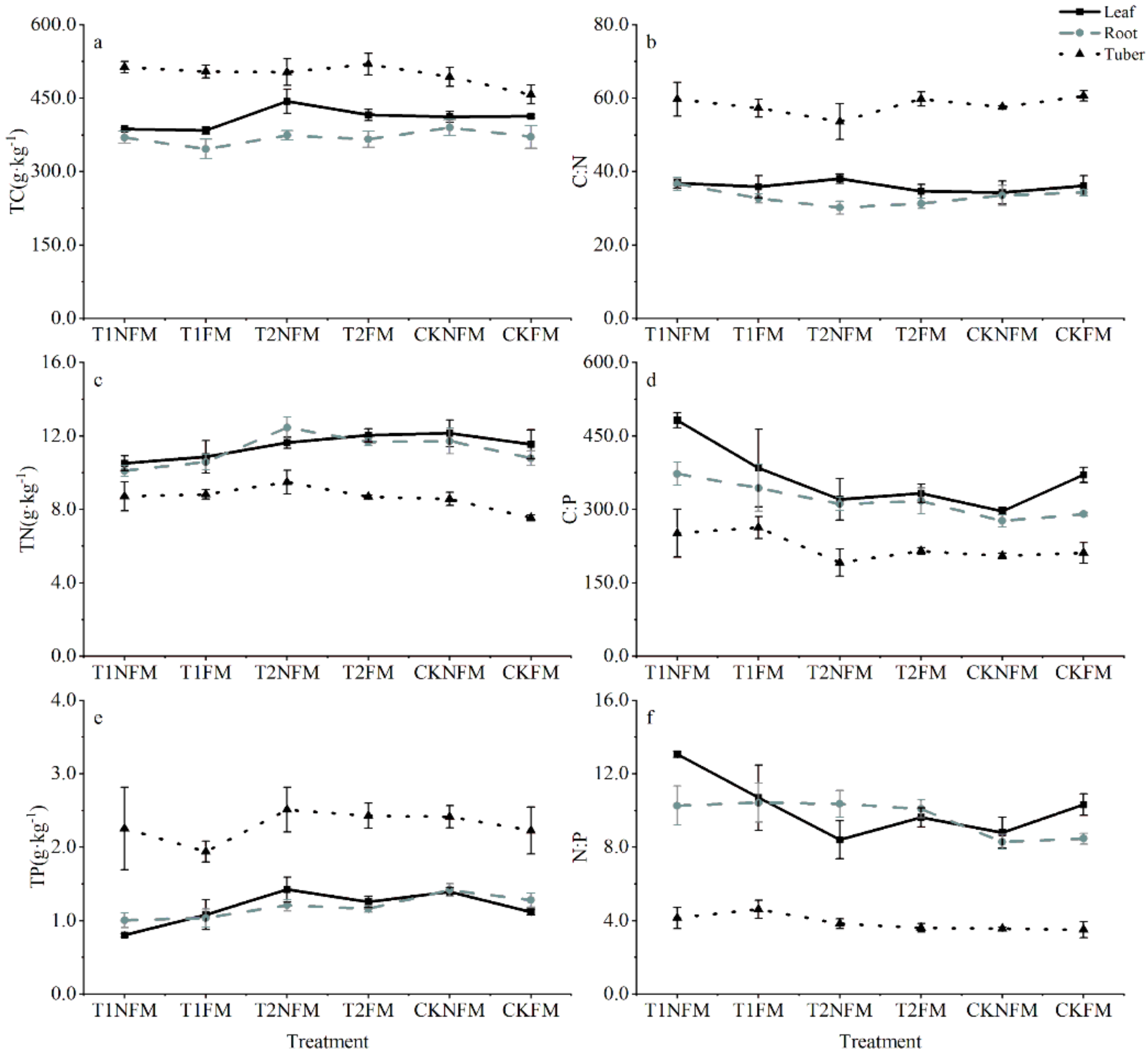

Figure 2

The TC, TN, and TP concentrations and stoichiometry of the leaves, root, and tubers of C. esculentus affected by film mulching and irrigation

Fig. 3

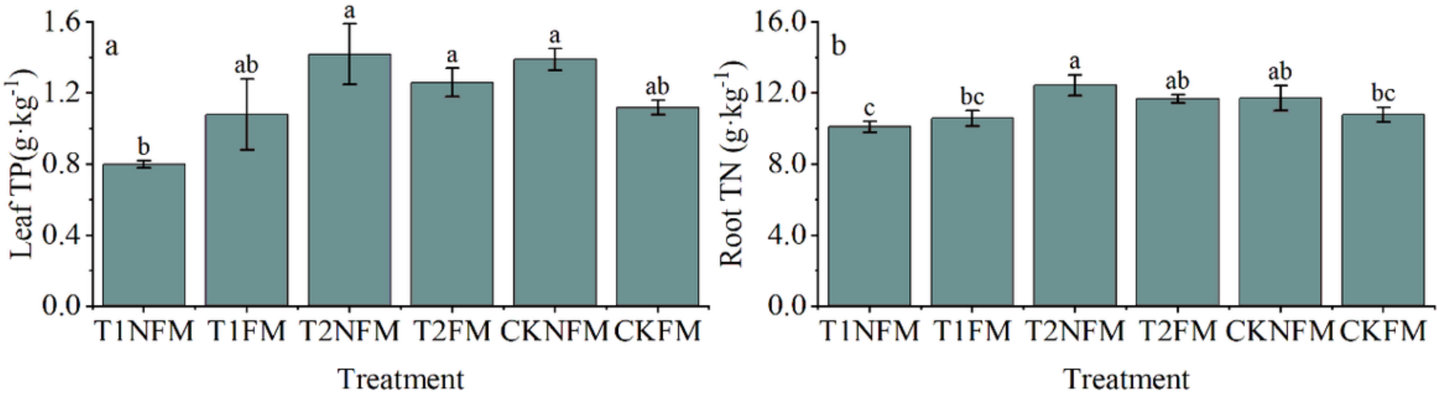

Figure 3

The leaves TP and root TN concentration of C. esculentus affected by film mulching and irrigation. Values of a variable labeled with different lowercase letters indicate differences between treatments (ANOVA followed by Duncan test, $P < 0.05$).

Fig. 4

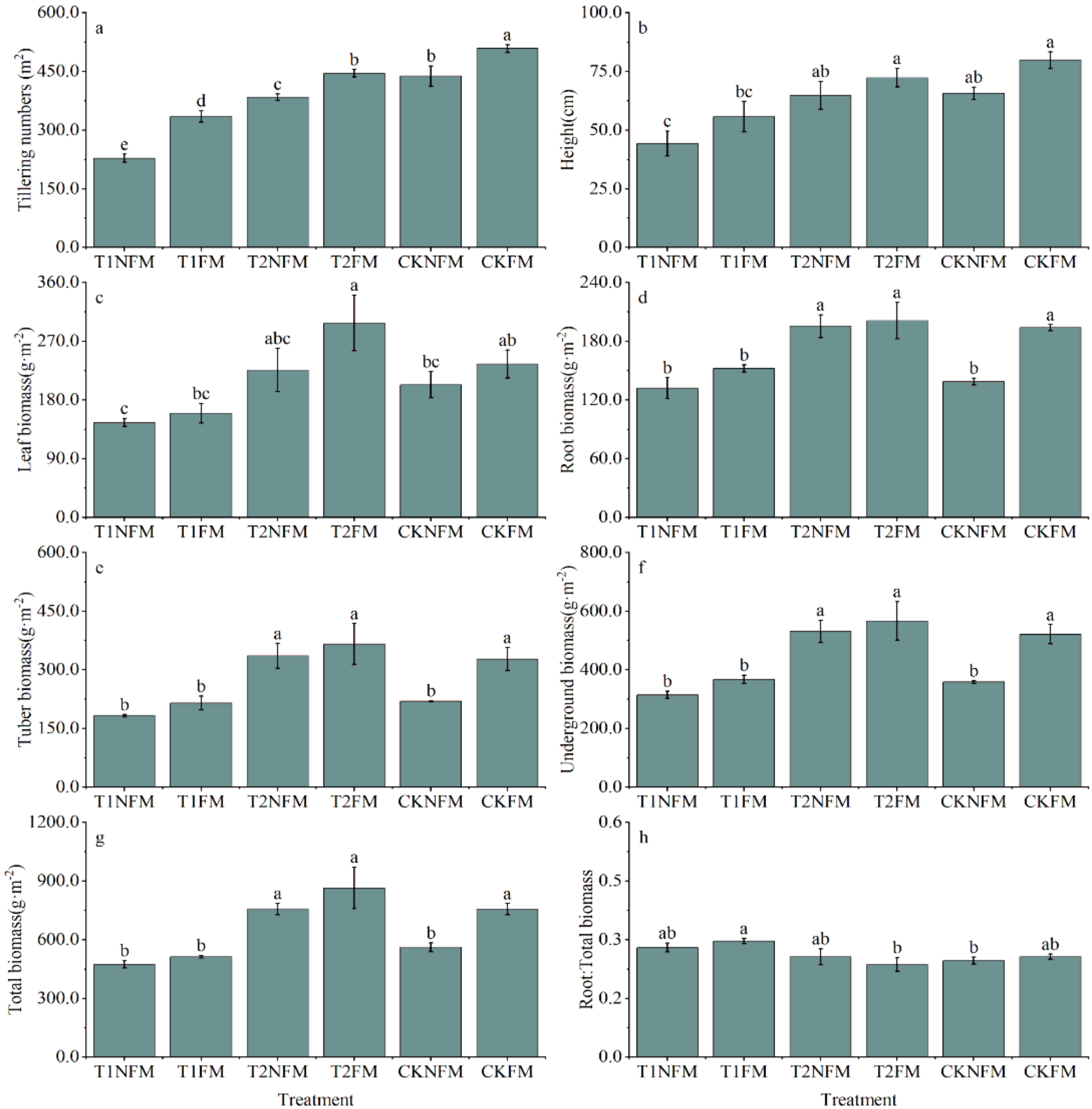

Figure 4

Effect of mulching and irrigation on leaf, root, and tuber biomass of C. esculentus. Values of a variable labeled with different lowercase letters indicate differences between treatments (ANOVA followed by Duncan test, $P < 0.05$).

Fig. 5

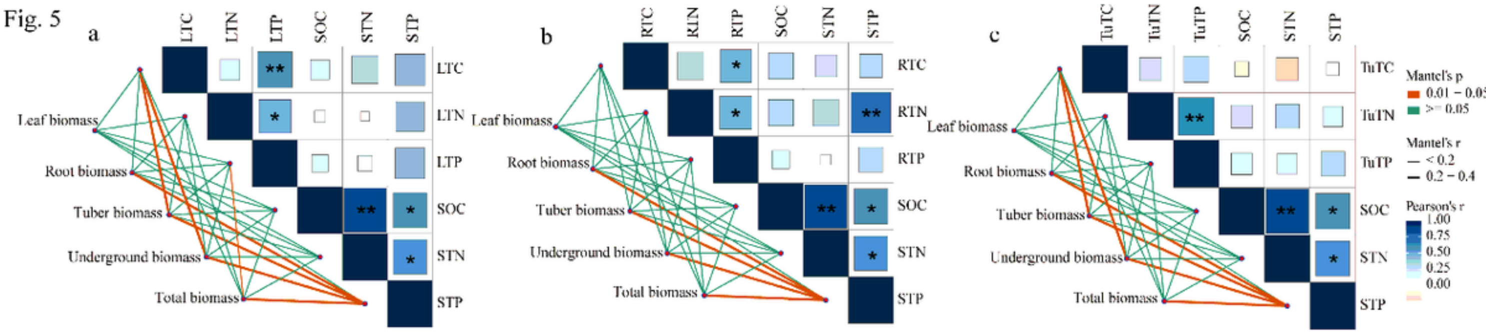

Figure 5

Correlation between biomass and leaf, root, tuber, and soil nutrients of C. esculentus. The correlations between the aboveground biomass of C. esculentus and soil C, N, and P nutrients. Network graphs with the Pearson index between constituents. SOC, soil organic carbon; STN, soil total nitrogen; STP, soil total phosphorus; LTC, total carbon of leaf, RTC, total carbon of root, TuTC, total carbon of tuber; LTN, total nitrogen of leaf, RTN, total nitrogen of root, TuTN, total nitrogen of tuber; LTP, total phosphorus of leaf, RTP, total phosphorus of root, TuTP, total phosphorus of tuber. The solid-red lines indicate significant correlations ($P < 0.05$). The thickness of the solid lines indicates the values of the correlation. The size of the square indicates the absolute values of the correlation coefficient. The ** or * indicate significant correlations ($P < 0.05$) in the different indexes. The shading from white to blue represents gradation from a low to a high positive correlation.

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