

1 **Photosynthetic characters of canopy and storage root yield of sweet potato**
2 **(*Ipomoea batatas* L.) grow in different soil compaction**

3
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6 **Abstract**

7 Soil compaction is a critical constraint that restricts the attainment of high and stable yields
8 of sweet potato. Photosynthesis is a key factor in yield formation. But the mechanism of soil
9 compaction affects the photosynthesis and storage root (SR) yield of sweet potato remains
10 elusive. A field experiments were carried out with two varieties in control, loose, and
11 compacted soil conditions, canopy apparent photosynthesis (CAP), gas exchange parameters
12 and PIabs of the functional leaves, SR yield were measured, and the relationship between
13 yield and photosynthetic characters was studied as well. Compared with the control, the SR
14 yield was significantly increased in loose soil with an average increase of 27.03%~38.74%,
15 but decreased in compacted soil with an average reduction of 17.87%~15.92%. Both
16 loosening and compaction treatments increased the leaf area index (LAI), and the increase in
17 the latter is significantly higher than that in the former. Canopy interception rate in loosening
18 treatment was much higher than that of compaction soil. The CAP showed a similar change in
19 yield, with a strong positive correlation to SR yield and single storage root weight. Loose soil
20 also improved gas exchange parameters, PIabs, the reverse was found in compacted soil.
21 Compared to the control, the loose treatment significantly improved economic coefficient and
22 reduced leaf starch content, while the compaction treatment showed the opposite trend. Path
23 analysis revealed that the net photosynthetic rate (Pn) had the most total effect and higher
24 direct effect on increasing CAP. Therefore, soil compaction primarily regulates SR yield
25 through CAP, with Pn exerting a significant impact on CAP. Enhanced soil compaction led to
26 reduced photosynthate output in functional leaves, resulting in decreased Pn and increased

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27 LAI. Consequently, an inappropriate canopy structure with low canopy interception is
28 formed.

29 **Keywords:** canopy apparent photosynthesis, PI_{abs} , gas exchange parameters, storage root
30 yield, soil compaction, sweet potato.

31

32 1. Introduction

33 Sweet potato is a globally significant tuberous crop, with a total production of 8.64×10^7
34 tons on 7.25×10^6 hectares, and an average yield of 11.9 tons/hectare (FAOSTAT, 2023). It
35 demonstrates remarkable adaptability and thrives in diverse terrains, including hilly,
36 mountainous, and plains (Sun et al. 2022). There has been a substantial increase in soil
37 compaction, which is widely recognized as one of the primary challenges to soil fertility, crop
38 productivity, and food safety (Keller et al. 2019). Soil compaction led to a substantial
39 decrease in SRs yield, with reductions ranging from 30% to 90% (Shi et al. 2019). This
40 phenomenon is frequently observed not only in plains (Bogunovic et al. 2018), but also in
41 hilly and mountainous regions (Xoconostlecázares et al. 2010). Hence, it is crucial to make
42 clear the impact of soil compaction on sweet potato yield in order to maximize production
43 potential.

44 The bulking rate and single weight of sweet potato SRs decreased with increasing soil
45 compaction, while the root tip number and hypocotyl diameter of soybean showed a
46 significant increase (Li et al., 2024). The soybean root system may change due to limited
47 water and nutrient availability in the soil, caused by restricted gas diffusion between roots and
48 the rhizosphere (Horák et al. 2022). The development of sweet potato SRs is mainly
49 influenced by photosynthesis, as they store photosynthate. However, there are conflicting
50 findings on the effect of soil compaction on photosynthesis. Some studies indicated that soil
51 compaction reduces photosynthesis rates (Mariotti et al. 2020; Huntensburg et al. 2021), which
52 was ascribed to a decrease in stomatal conductance, thus impeding CO_2 diffusion to the
53 mesophyll (Philip and Azlin 2005). Net photosynthesis (P_n), stomatal conductance (g_s), and
54 transpiration rates (E) of soybean were reduced up to 50% under compaction (Ferreira et al.,
55 2023). While the study in potato showed that photosynthesis rates did not differ between
56 compaction treatments after ground cover (Huntensburg et al., 2021). The response of
57 photosynthesis to soil compaction may vary across studies, however, a consistent observation

58 was the reduction in leaf size and plant carbon assimilation. But sweet potato leaves exhibited
59 an increase in size rather than decrease under soil compaction. This indicated that the
60 response mechanism of sweet potato to soil compaction differed from other crops. The CAP
61 provides a more precise indication of the photosynthesis of field crops (González and
62 Manavella, 2021), while chlorophyll fluorescence parameters have been widely employed to
63 identify disruptions in the photosynthesis apparatus caused by abiotic stress (Grzesiak 2009).
64 So our study aims to investigate the CAP variation at different development stages, gas
65 exchange parameters, chlorophyll fluorescence parameters of functional leaves, and quantify
66 how the CAP, and functional leaf photosynthesis of sweet potato respond to soil compaction
67 and how they affect SR yield.

68

69 **2 Materials and Methods**

70 **2.1 Materials and test design**

71 The field experiment was conducted at the Agricultural Test Station of Shandong
72 Agricultural University in Taishan District, Tai'an City, Shandong Province (36°09'N,
73 117°09'E; 128 m asl) during 2017 and 2018. The sweet potato cultivars used were Shangshu
74 19 (SS19) and Jixu 23 (JX23). The tested soil was sandy loam. Three compaction levels were
75 used: (1) compaction (C), where the 0–20-cm soil layer of the treatment was compacted by a
76 vibrating tamper (HS-75R, HANSA, Germany), with a bulk density of 1.40–1.50 g cm⁻³ and
77 a compaction of > 0.6 MPa and < 1.2 MPa; (2) control (no compaction, CK), where the bulk
78 density of the 0–20-cm soil layer was 1.30–1.40 g cm⁻³ and the compaction was
79 approximately 0.3–0.4 MPa; and (3) loosening (L), the bulk density in the 0–20-cm soil layer
80 was 1.20–1.30 g cm⁻³, and the compaction was approximately 0.1–0.2 MPa. The soil in this
81 treatment was mixed with organic fertilizer, sand, and common loamy soil. After mixing, the
82 organic matter content of the soil in the loosening was consistent with the other treatments.
83 The nitrogen, phosphorus, and potassium contents in the three treatments were adjusted to
84 similar levels using potassium sulfate and urea. In 2017, the available nitrogen, phosphorus,
85 potassium, and organic matter in the 0–20-cm soil layers were 79.47 mg kg⁻¹, 42.47 mg kg⁻¹,
86 112.33 mg kg⁻¹, and 1.30 %, respectively, and in 2018, it was 88.73 mg kg⁻¹, 35.22 mg kg⁻¹,
87 90.51 mg kg⁻¹, and 1.13 %, respectively. The physical properties of the soil under the three

88 treatments are shown in Table 1. The field experiment employed a two-factor split-plot
 89 experimental design with five replications, using cultivars as the primary plots and
 90 compaction as the subplots. Each plot covered an area of 20 m², with row spacing-80 cm and
 91 plant spacing-25 cm. Sweet potato was planted on May 10 and May 9, harvested on October
 92 22 and October 20 in 2017 and 2018, respectively.

93 **Table 1.** Physical characteristics of the soil (1 day before planting).

Year	Soil Layer (cm)	Treatments	Soil Compactness (kpa)	Soil bulk density (g/cm ³)	Soil Specific Gravity (g/cm ³)	Total Porosity (%)	Capillary porosity (%)	Non-capillary Porosity (%)
2017	5-10	L	126.49 c	1.26 c	2.58 a	51.35 a	24.86 b	26.49 a
		CK	301.16 b	1.33 b	2.64 a	49.81a	24.15 b	25.66 a
		C	541.63 a	1.46 a	2.73 a	46.38 b	31.78 a	14.60 b
	10-15	L	224.23 c	1.30 c	2.57 b	49.35 a	25.50 c	23.85 a
		CK	464.12 b	1.39 b	2.73 a	49.19 a	31.68 b	17.51 b
		C	927.74 a	1.49 a	2.75 a	45.71 b	38.30 a	7.41 c
2018	5-10	L	143.17 c	1.25 c	2.57 a	50.69 a	24.62 b	26.07 a
		CK	267.91 b	1.33 b	2.65 a	48.92 a	25.30 b	23.62 b
		C	826.07 a	1.47 a	2.74 c	46.66 b	31.21 a	15.45 c
	10-15	L	174.17 c	1.29 c	2.58 b	49.62 a	25.46 c	24.16 a
		CK	508.06 b	1.38 b	2.73 a	48.65 a	30.14 b	18.51 b
		C	1230.6 a	1.49 a	2.75 a	45.83 b	36.91 a	8.92 c

94 Note: Values followed by different lowercase letters within a column in the same year of the same varieties are
 95 significantly different among different treatments ($P < 0.05$). The same as below.

96
 97 Soil compaction was measured using a soil compaction metre (CP40 II, Cinstral Exports
 98 Pty Ltd T/A Rimik, Australia) at the seedling stage, early, middle and late stage of SR bulking.
 99 The soil volumetric moisture content in the 0–20 cm and 20–40 cm layers was measured
 100 every five days after transplanting to canopy cover. The moisture content per cubic metre (m³)
 101 = $H \times 1 \text{ m}^2 \times \text{soil volumetric water content (\%)}$, where H is the soil depth. The plot with the
 102 highest water content served as the standard for adjusting the water content in the remaining
 103 plots. From transplanting to canopy cover, irrigated all treatments 1~2 times to ensure the soil
 104 relative humidity of the control treatment was above 60%; the irrigation amount was
 105 consistent across all treatments. The other management is similiar to that of general field
 106 crops, with the climate for two growing seasons detailed in Fig. 1.

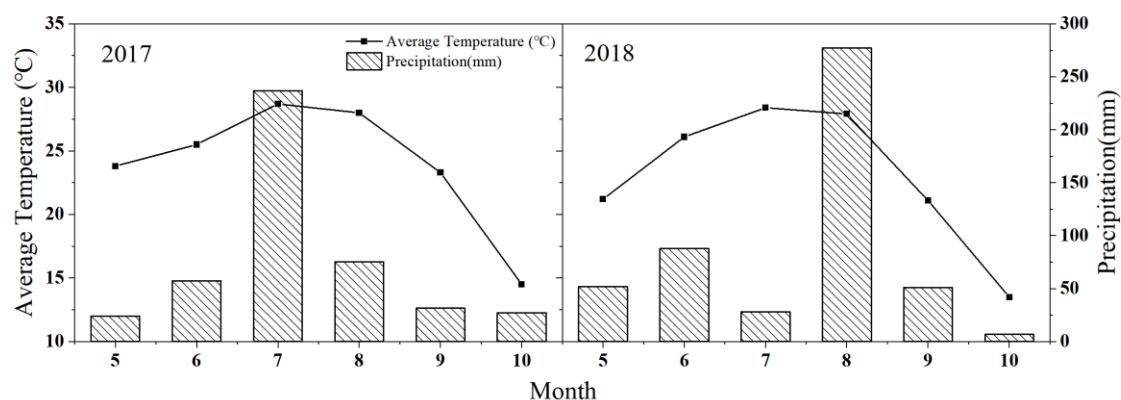


Fig. 1 Climate data for the two growing seasons of sweet potato.

2.2 Sampling and measurement method

2.2.1 Canopy apparent photosynthesis

The CAP was measured in a modified closed gas exchange system using an infrared gas analyser (GXH-305, China) (Hay and Porter, 2006), which was portable and easy to move in the field. The aluminum-framed chamber measured 0.80×0.90 m in area and 0.70 m in height, with the outer cover sealed using a high light transmittance mylene film (about 95% light transmittance). A 25 cm fan was placed at the top to mix the gas and balance the temperature. The CO_2 concentrations decreased linearly, usually measured within 60 seconds of the chamber closing. Two rows of sweet potatoes were chosen in the chamber, and measurements were taken every 20 days from 60 to 140 days after planting (DAP), between 9:00 and 11:00 A.M. Three sampling site with consistent growth were selected to mearsure for each treatment, and the respiration rates of soil were measured in the open spaces of the adjacent area. The CAP was calculated as follows:

$$\text{CAP} = \text{slope} \times n / A \quad (1)$$

Where the slope presents the reduce in the CO_2 concentration per unit time ($\mu\text{mol mol}^{-1} \text{s}^{-1}$), n is moles number of air in the chamber, and A standing for the ground area. The value of n equal to PV/RT , where P is the pressure in kPa, V is the chamber volume in L, T is the temperature in K, and R is the gas constant ($8.314 \text{ k Pa L mol}^{-1} \text{ K}^{-1}$).

130 2.2.2 Gas exchange measurements

131 Gas exchange measurements were conducted at 20-day intervals from 60 to 140 days
132 post-planting. In sunny, windless conditions, the photosynthetic rate of the fifth fully opened
133 leaf (with the highest photosynthetic rate) at the top of the stem was measured between 9:30
134 and 11:30 A.M. Fifteen leaves with similar growth were selected for each treatment across
135 three replications. The Portable Photosynthesis System (CIRAS-3, PP Systems International,
136 Inc. Amesbury, USA) was used. The measuring head was subject to the following conditions:
137 leaf temperature, 28 °C; reference CO₂ content, 380 ppm, and ambient air humidity. The
138 PPFD during the measurements was set to 1000 μmol (photon) m⁻² s⁻¹ throughout the
139 experiments. The P_n, E, g_s, and C_i in the intercellular spaces were automatically recorded.

141 2.2.3 Chlorophyll fluorescence parameters of the functional leaves

142 The parameters were measured every 20 days from 60 to 140 DAP. The MPEA chlorophyll
143 fluorescence meter (Hansatech Instruments Ltd., King's Lynn, UK) was connected to a
144 computer for precise value determination. Prior to fluorescence signal measurements, the
145 plants were dark-adapted for at least 30 minutes. The fifth unfolded leaf at the top of the stem
146 was measured. 15 leaves with similar growth characteristics were selected for each condition.

147 The following parameters were considered:

148 $PI_{abs} = RC/ABS \cdot [\phi P_o / (1 - \phi P_o)] \cdot [\psi_o / (1 - \psi_o)]$, the performance index of the absorbance
149 basis.

151 2.2.4 Canopy interception rate

152 From 60 to 140 DAP, the canopy interception rate of sweet potato was assessed using a
153 SunScan plant canopy analyzer (Delta-T Devices, UK). Measurements were carried out on
154 clear and calm days between 12:00 and 14:00. Incident and reflectance radiation were
155 measured above the canopy (15 cm above) and below the canopy (5 cm above the ground),
156 with each treatment replicated five times.

$$157 \text{ Canopy transmittance (\%)} = (PAR - PAR_0) / PAR \times 100 \% \quad (2)$$

$$158 \text{ Canopy reflectance (\%)} = PAR' / PAR \times 100\% \quad (3)$$

$$159 \text{ Canopy interception (\%)} = 100 - \text{Canopy transmittance (\%)} - \text{Canopy reflectance (\%)} \quad (4)$$

160 Where, PAR is the PAR above the canopy, PAR₀ is the PAR at the base of the ridges, and
 161 PAR' is the reflected light above the canopy.

162

163 2.3 Statistical analysis

164 Statistical analysis was conducted with IBM SPSS Statistics 25 (IBM Inc., Chicago, IL,
 165 USA). The statistical significance were assessed using ANOVA, followed by Duncan's
 166 multiple range test. Figures were generated using SigmaPlot software (SigmaPlot 12.0, Systat
 167 Software, San Jose, CA, USA).

168

169 3 Results

170 3.1 Effects of soil compaction on SR yield of sweet potato

171 Compared with the control, the SR yield was significantly increased in loosening treatment,
 172 and the average increase of two years was 27.03%~38.74%, while they were decreased in
 173 compaction treatment, and the average reduction was 17.87%~15.92%. The single storage
 174 root weight changed similar to the yield. The change of single SR weight and economic
 175 coefficient was similar to that of yield (Table 2). The result of statistical analysis indicated
 176 that treatment, the interaction between year and treatment had significant effect on yield.
 177 There were significant differences in the number of SRs, single SR weight and economic
 178 coefficients between treatments as well. That is, the soil compaction led to changes in SR
 179 yield, primarily through the regulation of individual SR weight.

180

181 **Table 2.** Effect of soil compaction on SR yield, its economic coefficient of sweet potato.

Year	Varieties	Treatment	Number of storage root (lump plant ⁻¹)	Fresh weight (g lump ⁻¹)	Storage root yield (t ha ⁻¹)	Economic coefficient (%)
2017	SS19	L	4.6 b	244.3 a	55.7 a	70.8 a
		CK	4.4 b	214.5 b	47.8 b	65.9 b
		C	5.7 a	141.5 c	40.2 c	61.8 c
	JX23	L	3.6 b	315.1 a	55.9 a	79.6 a
		CK	3.5 b	274.8 b	46.9 b	75.3 b
		C	4.4 a	188.9 c	41.1 c	63.7 c
2018	SS19	L	4.0 b	296.3 a	59.1 a	80.1 a
		CK	3.9 b	223.3 b	43.4 b	67.6 b
	JX23	C	4.6 a	148.9 c	34.4 c	56.4 c
		L	3.0 b	363.2 a	54.2 a	89.7 a
		CK	2.9 b	243.3 b	34.2 b	83.4 b
C	3.6 a	154.8 c	27.6 c	71.2 c		

Analysis of variance (<i>p</i> value)				
A (Year)	0.004	0.17	0.0023	0.018
B (Variety)	<0.001	<0.001	0.094	<0.001
C (Treatment)	<0.001	<0.001	<0.001	<0.001
A×B	0.60	0.0077	0.075	<0.001
A×C	0.23	0.0015	<0.001	<0.001
B×C	0.14	0.053	0.36	0.0023
A×B×C	0.39	0.42	0.57	<0.001

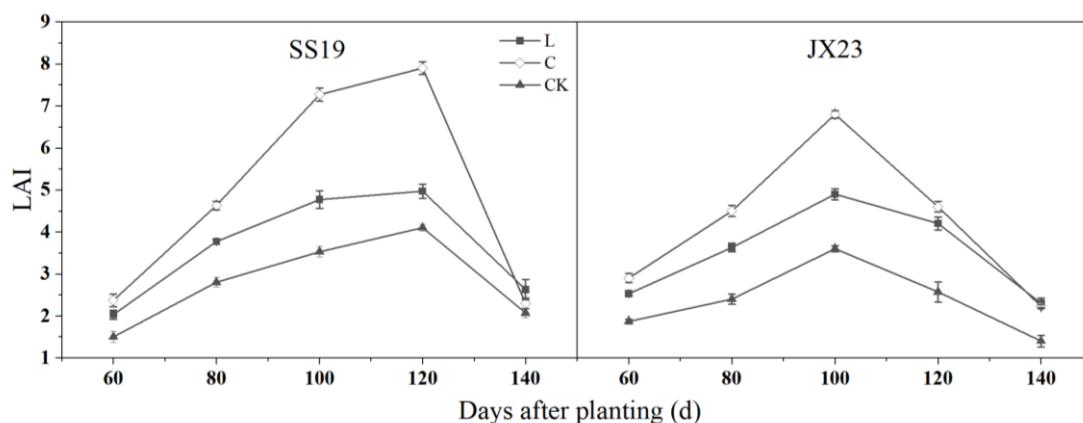
182 Note: Values followed by different lowercase letters within a column are significantly different among different
 183 treatments ($P < 0.05$). The same as below.

184

185 3.2 Effects of soil compaction on the photosynthetic area and canopy interception rate

186 3.2.1 LAI

187 During **SRs** bulking, the **LAI** first increased and then decreased, the peak values were
 188 observed at 120 and 100 **DAP** for SS19 and JX23, respectively. Compared to the control, the
 189 LAI was significantly increased in loosening and compaction treatments, with the average
 190 increase of 37.54% and 63.81. The highest LAI was obtained in the compaction treatment at
 191 120 and 100 **DAP** for JX23 and SS19. Subsequently, the LAI in the compaction treatment
 192 exhibited a more rapid decline compared to the other treatments after reaching its peak (Fig.
 193 2). In summary, the group structure of loosening treatment appeared to be suitable; however,
 194 the group is excessively large within the compact soil.



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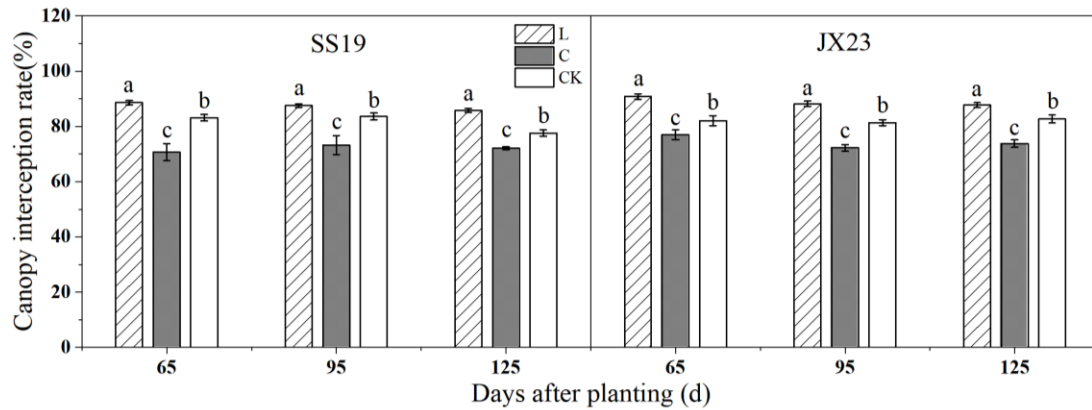
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Fig. 2 Effect of soil compaction on LAI (2018).

197 3.2.2 Canopy interception rate

198 Compared to the control, the loosening treatment had the highest canopy interception rate,
 199 while the compaction treatment showed the lowest despite having a higher LAI. This could
 200 be attributed to frequent leaf turnover in the compaction treatment, resulting in numerous

201 small leaves that may potentially cause localized light leakage (Fig 3).

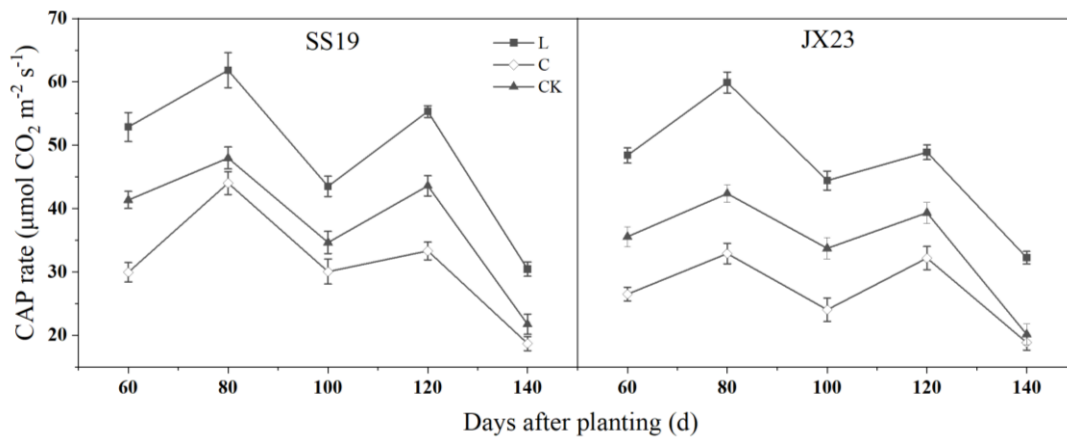


202 **Fig. 3 Effect of soil compaction on canopy interception rate (2018).**

203 **3.2 Effects of soil compaction on the CAP rate**

204 The CAP of sweet potatoes follows a bimodal curve, with peak values at 80 and 120 DAP
 205 and a trough at 100 DAP. The occurrence of the trough coincides with the rainy season,
 206 during which there was an increase in soil compaction due to sustained precipitation.
 207

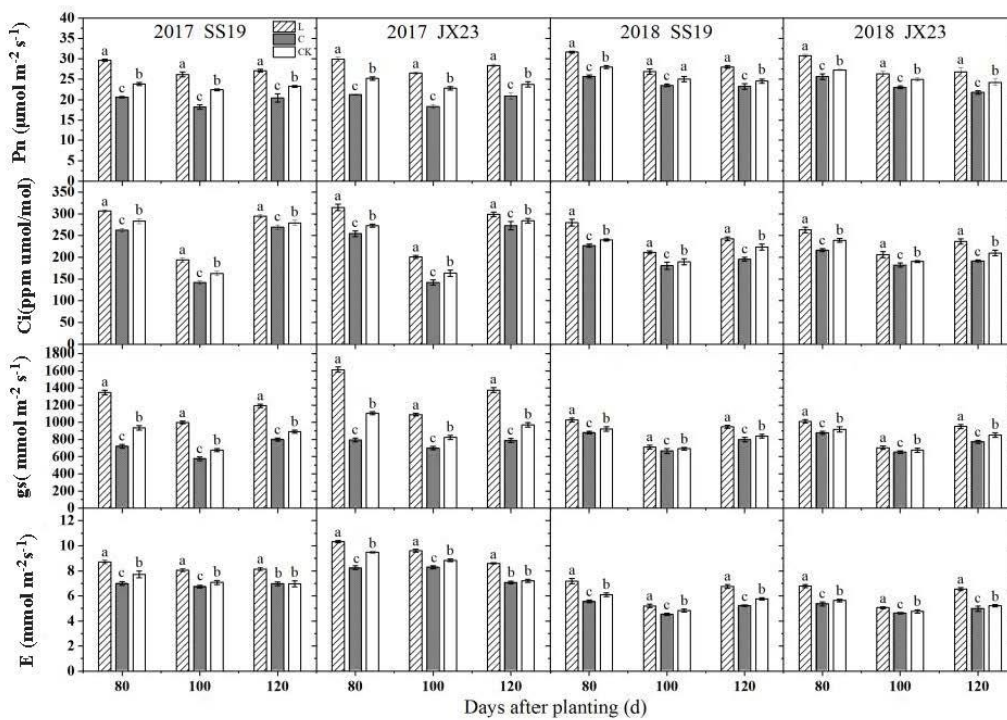
208 Compared with the control, the loosening treatment increased the CAP rate significantly
 209 with an average increase of 29.46% and 38.76%, for the SS19 and JX23, respectively, the
 210 greater significant increase appeared at 80 DAP and 140 DAP. And the compaction treatment
 211 decreased the CAP rate significantly with the average reduction of 17.31% and 20.21%, the
 212 most significant reduction appeared at 60 DAP and 80~100 DAP (Fig. 4). That is, soil
 213 compaction affected the CAP greatly in the early and middle growth stages, when the soil
 214 compaction was reduced the CAP was increased greatly during the late growth stage.



215 **Fig. 4 Effect of soil compaction on canopy apparent photosynthesis rate (2018).**

217 **3.4 Effects of soil compaction on the Gas exchange parameters of the functional leaves**

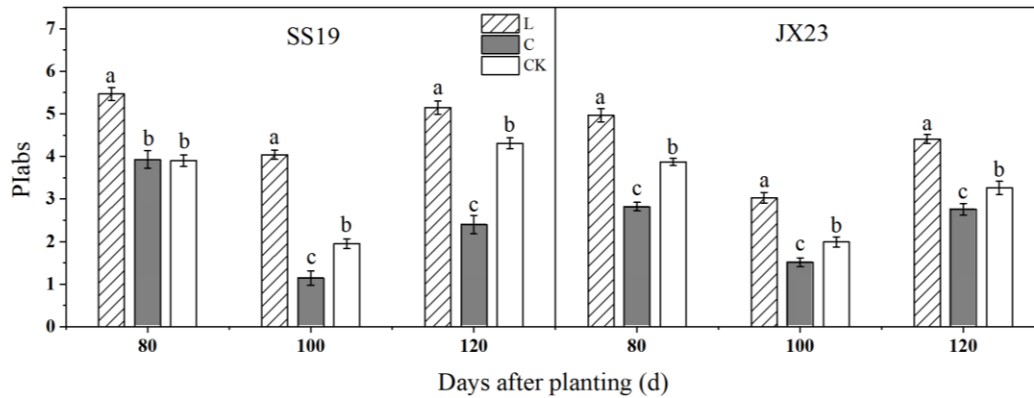
218 At 80, 100 and 120 DAP, the loosening treatment significantly improved the P_n , C_i , g_s and
 219 E of the functional leaves, whereas the compaction treatment had opposite effects, which was
 220 consistent with the 2-year data. In 2017, the gas exchange parameters exhibited significant
 221 variation at the trough of CAP rate (100 DAP), whereas in 2018, a noticeable alteration was
 222 observed in the second peak of CAP rate (120 DAP) (Fig. 5). The occurrence of periods
 223 characterized by significant inter-annual variability is primarily linked to the temporal
 224 distribution of intense precipitation.



225
 226 **Fig. 5** The effect of soil compaction on gas exchange parameters in leaves of sweet potato.

227 **3.5 Effect of soil compaction on PIabs**

228 PIabs is the performance index of the PS II reaction centre, which reflects the overall
 229 performance of PS II. The loosening treatment significantly increased the PIabs of the
 230 functional leaves by 55.63% and 38.50% in SS19 and JX23, respectively, compared to the
 231 control treatment. In contrast, the compaction treatment led to a significant decrease in PIabs
 232 by 28.33% and 22.29%, respectively (Fig. 6). Hence, loose treatment is benefit to
 233 improvement of the overall performance of PS II .



234

235

Fig. 6 The effect of compaction on PIabs of leaves of sweet potato (2018).

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3.6 Determining the main influencing factors of the canopy apparent photosynthesis

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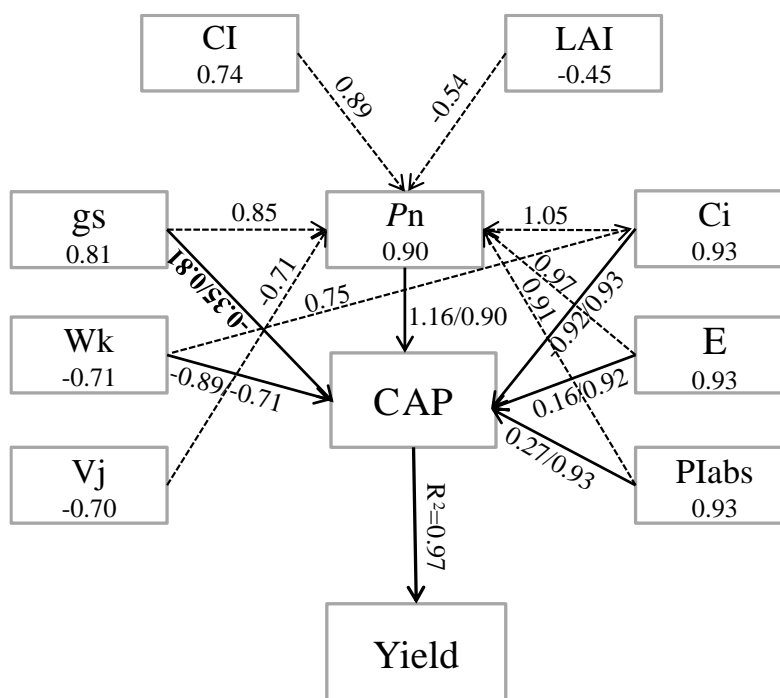
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The regression equation $Y = 38.38 + 4.67X_1 + 1.61X_2 + 0.15X_3 - 0.34X_4 - 0.029X_5 + 2.03X_6 - 18.00X_7 - 115.61X_8 + 2.24X_{10}$ ($F = 29.58$, $R^2 = 0.938$, $P = 0.0001$) was obtained by stepwise regression using the CAP rate as the dependent variable and, LAI (X_1), canopy interception (X_2), P_n (X_3), C_i (X_4), g_s (X_5), E (X_6), V_j (X_7), W_k (X_8), ψ_o (X_9), and PIabs (X_{10}) as the independent variables. The correlation analysis revealed a significant positive correlation between P_n , canopy interception, C_i , g_s , E , ψ_o and PIabs with the CAP. Path analysis revealed that gas exchange parameters and PIabs were the primary contributors to increased CAP. Gas exchange parameters, particularly P_n and C_i , had the most significant direct effects, and the overall impact of P_n was mainly driven by its direct effects, while most other factors were primarily influenced by the indirect effects of P_n (Fig. 7).



247
 248 **Fig. 7** The path analysis among functional leaf photosynthesis, canopy apparent
 249 photosynthesis and storage root yield. **Note:** Dashed and solid lines indicate indirect and
 250 direct impacts, respectively. The number above or below the arrow line indicates the direct
 251 effects / total effects. R^2 represents the correlation coefficient. The number in the box
 252 indicates the correlation coefficient between the item in box with the CAP.
 253

254 4 Discussion

255 4.1 Effects on SR yield of sweet potato

256 This study found a significant increase in SR yield when soil compaction was reduced
 257 (Table 2), consistent with previous research (Shi et al. 2019). Improving photosynthesis can
 258 increase crop yields (Dong et al. 1993), as more than 90% of crop outputs are directly related
 259 to photosynthesis (González and Manavella, 2021; Chen et al. 2022). Within the realm of
 260 field crops, the CAP exerts a pronounced impact on yield formation. However, limited
 261 research has been conducted on the effect of soil compaction on sweet potato photosynthesis
 262 and its correlation with SR yield. This study revealed that variations in single SR weight were
 263 the primary contributing factor to differences in SR yields (Table 2). A significant positive
 264 correlation was obtained between the CAP and SR yield ($r= 0.99, P<0.05$), as well as the
 265 single SR weight ($r= 0.90, P<0.05$). Our previous research has revealed that reducing soil
 266 compaction resulted in higher single SR weight by increasing dry matter accumulation in the
 267 SRs (Shi et al. 2019). Consequently, soil compaction mainly affects the accumulation of

268 photosynthates in SRs by regulating the CAP, thus impacting single SR weight and leading to
269 variations in SR yield.

270

271 **4.2 Effects on the photosynthetic characteristics of sweet potato**

272 CAP is closely linked to the canopy architecture and positively correlated with light
273 interception (Bhusal, et al., 2017). The LAI is an important index of canopy architecture. But
274 the correlation between CAP rate and LAI varies among different crop species. The CAP was
275 closely associated with changes in green leaf area in maize (Liu et al. 2015), whereas, the
276 LAI was similar among varieties with distinct CAP rate in wheat (Tang et al. 2017).
277 Moreover, an appropriate LAI can enhance the group's light distribution and interception
278 ability (Maddonni et al 2001). The increase of soil compaction reduced ground cover
279 expansion, decreased plant leaf area, shortened canopy cover duration, and restricted light
280 interception (Assaeed et al. 2008). This study revealed that the loosening treatment appeared
281 the highest CAP rate (Fig. 3), the greater LAI (Fig. 2) and the most canopy interception rate
282 (Fig. 4), compared with the control treatment. The compaction treatment got the highest LAI
283 but the lower canopy interception rate (Fig. 2, 4). This may be because compaction treatment
284 led to excessive growth of stems and leaves, resulting in frequent alternation of new and old
285 leaves. The CAP rate in the compaction treatment was reduced as well (Fig. 3). The previous
286 study has improved that a suitable canopy structure, high chlorophyll content, and prolonged
287 leaf duration can enhance CAP and biomass yield (Tang et al., 2017). Therefore, reducing soil
288 compaction promotes appropriate canopy architecture, improves light penetration, and
289 enhances the CAP.

290 Reducing soil compaction has been shown to enhance the net photosynthetic rate of leaves
291 in various crops such as cucumber, strawberry, peanut, ginger, soybean, and potato (Du et al.
292 2010), while its increase has demonstrated an opposite effect. These findings were consistent
293 with previous research on the physiological and agronomic response of soybean cultivars to
294 soil compaction in the Brazilian Cerrado (Maddonni et al. 2001; Ferreira et al., 2023). While
295 the other study in potato showed that P_n did not differ between compaction treatments after
296 ground cover (Huntenburg et al., 2021). In this study, we found P_n , C_i , E and g_s were
297 increased in the loosening treatment but decreased in the compaction treatment (Fig. 4). The

298 significant fluctuations were most pronounced during and after the rainy season (at 80 and
299 120 DAP). The variation in P_n for loosening and compaction treatments was less than that of
300 the CAP rate. Furthermore, the PIabs were enhanced in the loosening treatment (Fig. 6), other
301 chlorophyll fluorescence parameters showed relatively small changes (Supplementary Table
302 1,). And Photosynthesis critically depends on the electron flow through PSII (Hussain et al.
303 2019), which functions as a fundamental photosynthetic unit within the thylakoid membrane
304 of a chloroplast. The accumulation of starch within chloroplasts may result in the perturbation
305 of thylakoid membranes, leading to a reduction in the photosynthetic efficiency of leaves.
306 When soil compaction was intensified, leaves accumulate a lot of starch, while the loosening
307 treatment leaves have high sucrose and low starch content (Supplementary Table 2).
308 Meanwhile, the economic coefficient of compaction treatment was reduced (Table 2). So the
309 excessive accumulation of starch in functional leaves was the primary factor contributing to
310 the reduction in P_n . The emphasis of the next research step should be on the output of leaf
311 photosynthetic products.

312 Linear regression, correlation analysis, and path analysis were employed to identify the key
313 factors influencing the CAP rate due to soil compaction. The results indicated a highly
314 significant positive correlation between gas exchange measurements (P_n , C_i , E and g_s) and
315 the CAP rate. Gas exchange measurements (P_n , C_i , and E) had the most significant overall
316 impact on enhancing the CAP. The total effects of P_n were derived primarily from direct
317 effects, which were the most substantial among the items, while the most items were derived
318 mainly from indirect effects of P_n (Fig. 7). Overall, the primary determinant of SR yield under
319 soil compaction was the CAP rate. When modulating the CAP rate, it was crucial to consider
320 gas exchange parameters, particularly in controlling the P_n .

321 322 **5. Conclusions**

323 Soil compaction primarily influenced sweet potato SRs yield by modulating their CAP rate.
324 P_n and canopy architecture were the primary determinant of CAP rate. As soil compaction
325 increased, the reducing photosynthate output of leaves leads to starch accumulation, resulting
326 in a marked reduction in photosynthetic rate and a substantial increase in LAI.

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