

‘红富士’苹果郁闭园间伐处理对果园结构、光能利用以及产量品质的影响

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摘要:【目的】结构郁闭是造成成龄红富士果园产能降低、品质下降、效益不高的重要因素。间伐改造是成龄苹果园提质增效有效方法。通过间伐处理,改善果园光效结构,达到提高光能利用率和产量、品质和经济效益的目的。**方法**以16 a(年)生‘红富士’苹果为试材,以隔行去行(处理I)、隔株去株(处理II)和隔行间株(处理III)3种方式进行郁闭果园改造,以未改造郁闭园(CK)作为对照。**结果**叶面积指数表现为处理I<II<III<CK;树冠透光率、散射辐射透过系数(TCDP)和直接辐射透过系数(TCRP)均表现为处理I>II>III>CK;光合速率(P_n)和羧化效率(CE)均表现为处理I>II>III>CK;胞间二氧化碳浓度(C_i)、气孔导度(G_s)和蒸腾速率(T_r)均表现为处理II>I>III>CK;4年间各个处理的平均单果质量、着色指数、优质果率和可溶性固形物含量均优于CK;间伐改造后,除第一年产量显著降低外,第二年基本上能恢复到改造前水平,第三年和第四年产量略有提高。**结论**3种改造方式均能不同程度地改善果园微域环境,提高果实品质,尤以处理I改造效果显著,持续效应时间长。

关键词:‘红富士’苹果;郁闭园;间伐;冠层;叶面积指数;光合速率;产量;果实品质

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Effects of different tree-removal methods on orchard structure, solar energy utilization and fruit quality in overcrowded ‘Red Fuji’ apple orchards

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Abstract:【Objective】Since early 1980s, the close planting in apple orchards has become popular for sake of early-bearing and high yield. As the trees grew up, the canopy overlapped each other, and then the trees in those apple orchards became overcrowded. Therefore, the light conditions within the orchards deteriorated, fruiting position on the canopy moved outward, disease and pest problems got worse, fruit yield and quality decreased, and the rotten fruits increased. All of these problems have restricted the sustainable development of apple production, so the transformation of overcrowded apple orchards has become very important for sustainable apple production. Overcrowd canopies of apple trees are the important factor causing the decreased fruit quality, yield reduction and low efficiency. Tree-removal is one of effective management practices in mature overcrowded apple orchards to improve quality and increase efficiency. The aim of the trial is to study the effects of different tree-removal methods on orchard structure, solar energy utilization and fruit quality in overcrowded apple orchards.**Methods** ‘Red Fuji’ apple trees of 16 years old were used, which were grafted on the ‘Ping Yi Tian Cha’ rootstock. Three different tree-removal methods were designed for renovation of the overcrowded apple or-

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chards: interlaced row removal (Method I), interlaced tree removal in a row(Method II), and one tree removal for every four trees in alternate rows (Method III). Those without any removal served as the control (CK). After the completion of transformation, three plants with similar growth potential were selected as sample materials for each treatment. The data of the current year were used for analysis, and the other data were continuously measured for four years from 2012 to 2015. The measurement methods were as follows: the tree canopy volume, canopy coverage rate and transition rate between rows were calculated according to the tree height, crown diameter and trunk height; the branch composition of apple tree structure including spur, middle-shoot, long-shoot and extended growing shoot was calculated every year; the CI-110 canopy analyzer (made by CID Company of U.S.A.) was used to measure the canopy indicators, spacing between trees and spacing between rows of, and the relevant software and Zhang Jixiang's method (to delete the outermost ring of sensitive film of the fisheye camera) were adopted to analyze the leaf area index (LAI), mean leaf inclination (MLA), the transmit coefficient for diffuse penetration (TCDP), transmit coefficient for radiation penetration (TCRP), canopy extinction coefficient (K) and leaf distribution (LD); the CIRAS-II made by PP-Systems of U.S.A. was used to measure photosynthesis rate. At 10:00 in the morning of September, the net photosynthesis rate, transpiration rate and intercellular CO₂ concentration of the mature leaves of peripheral shoots that were 1.5 m above the ground were measured with the photosynthetic system analyzers. Meanwhile, carboxylation efficiency and water use efficiency were calculated. Carboxylation efficiency = net photosynthesis rate/intercellular CO₂ concentration; water use efficiency = net photosynthesis rate/transpiration rate; the average fruit weight, fruit firmness, soluble solid content, and quality indicators were measured in the laboratory when the fruit was naturally matured. 【Results】The crowded apple orchards with different treatment methods had a great difference in appearance. Compared with CK, three different methods got different degree of optimization, such as the ratio of spurs, short shoots and medium shoots increased while long shoots and extended growing shoots decreased; in the first year, the coverage rate and shoot quantities per 666.7 m² declined significantly and recovered year by year; the transition rate between the rows of treatments I and II declined significantly; the order of leaf area index was I<II<III<CK, the TCDP and TCRP were I>II>III>CK; net photosynthetic rate (P_n) and carboxylation efficiency (CE) were I>II>III>CK, and intercellular CO₂ concentration (C_i), stomatal conductance (G_s) and transpiration rate (T_r) were II>I>III>CK. From 2012 to 2015, fruit appearance and internal quality such as the average fruit weight, color index, the rate of high quality fruits and soluble solid content with different tree-removal methods were better than those from CK. The yields of three different treatments were significantly lower than CK per 666.7 m² in the first year, but the yield recovered in the second year, and the yields of method I and II were significantly higher than CK in the third and fourth year. 【Conclusion】In this study, three kinds of transformation treatments could completely improve the micro-environment of orchards and the fruit quality. However, the method I could increase the yield per 666.7 m² and improve the fruit quality remarkably, and the lasting effect was longer than other treatments. Therefore, it was recommended that the method I was better than others.

Key words: ‘Red Fuji’ apple; Overcrowded orchards; Tree-removal; Canopy; LAI; Photosynthesis; Yield; Fruit quality

山东省苹果主产区绝大部分苹果园都是在20世纪80—90年代建园,为了实现高产,普遍采用乔砧密植栽培模式^[1-3],这种栽培模式满足了当时生产

的需要,起到了积极的作用。但是,随着树龄的增长,树冠的增大,产生了树冠之间交接、果园郁闭、光照条件恶化、病虫害发生严重、结果部位外移、产量

和品质下降、果实着色不佳、烂果率上升、商品率降低等诸多问题,造成了现在卖果难的现象,制约了苹果产业的可持续发展^[4-6],但现在依然是烟台各苹果主产县的主要模式。要解决郁闭园出现的种种问题,必须对郁闭果园实施优化改造,只有解决了果园的通风透光问题,才能从根本上解决果园的郁闭问题和提高果实的品质。

目前生产上对郁闭园的改造多采用2种方法:一种是通过改造个体的空间分布以达到降低树冠内的郁闭程度^[4,7],主要是通过提干、去大枝的方法对树形进行适当的改造和修剪,调节树冠内部的主枝、侧枝和结果枝组的合理分布来实现;另一种是通过改变栽植密度从整体上改善果园的群体结构,主要是通过间伐植株的方法来实现^[6,8]。前者的优点是改造后果实品质提高的同时对果园的产量没有大的影响,果农心里容易接受,而缺点是对管理技术要求高,管理不善1~2 a(年)后又会重新出现果园郁闭问题;后者的优点是改造彻底,改造技术手段简单易实施,改造效果持续时间长,缺点是对第一年的产量有很大的影响,果农接受的心里难度大。通过调研发现,由于果农管理水平参差不齐,仅仅从果树个体结构进行改造的果园,绝大部分果园又出现郁闭问题,如果此时采取间伐的方法从群体结构入手进行改造,又会面临新的问题,比如间伐后,周边的植株往往出现偏冠和园象不整齐等。为探讨适宜苹果郁闭园的改造方式,笔者通过隔行去行、隔株去株、隔行间株(局部间伐密度大的植株)3种间伐方式对郁闭园进行改造,并进行了连续4 a的跟踪调查,详细对比分析了3种改造方法对果园群体结构、个体结构、微域环境、叶片光合性能、果实品质和产量的影响,旨在为苹果郁闭园微域环境改善、果实品质和产量的提高提供科学依据。

1 材料和方法

1.1 试验材料

试验于2011年冬在招远市玲珑镇虎王村以16 a生‘红富士/平邑甜茶’为试材,以间伐的方法进行郁闭苹果园改造。改造前,树形为主干疏层形,呈3层分布,基部主枝粗大,且距离地面较低。园相如表1 CK所示,株行距为3.0 m×3.5 m,南北行向,666.7 m²枝量9.65万条,行间交接率达18.57%,果园郁闭,严重影响果园的通风透光。

1.2 改造方法

郁闭果园改造采取3种方式。分别为隔行去行(处理I:即隔一行伐除一行,减少50%的植株)、隔株去株(处理II:即在行内隔一株伐除一株,减少50%的植株)和隔行间株(处理III:即两行每4株植株伐掉1株,减少25%的植株),以未改造园片为对照(CK)。

1.3 测定项目

改造完成后,每个处理选择3株生长势基本一致的植株为试材,以改造当年数据作为基础数据,2012—2015年连续4 a对下列指标进行持续跟踪测定,测定方法如下:

1.3.1 果园结构指标的测定 树冠体积:树冠近似椭球体,体积 $V=4/3\pi abc(m^3)$,式中a、b、c分别代表椭球体的半径,即分别为冠高、南北冠幅和东西冠幅的一半;果园覆盖率:树冠投影面积与株行距的百分比;行间交接率:(行间冠径-行距)/行距×100%;666.7 m²枝量:根据3株树的一年生枝量的平均数折合计算。

1.3.2 树体结构指标的测定 统计单株的一年生叶丛枝(0~0.5) cm、短枝(0.5~5) cm、中枝(5~15) cm、长枝(15~30) cm、发育枝(>30) cm的数量,并计算各种类型枝所占比例。

1.3.3 冠层结构参数的测定 利用CI-110冠层分析仪(美国CID公司生产)对所选植株的树冠下、株间和行间进行定点测定图像采集。利用仪器自带软件分析叶面积指数(LAI)、平均叶倾角(MLA)、直射辐射透过系数(TCRP)、散射辐射透过系数(TCDP)和冠层消光系数(K),取其平均值。

1.3.4 叶片光合速率的测定 应用美国PP-Systems公司生产的CIRAS-II型便携式光合系统测定仪测定叶片的光合速率变化。于9月份上午10:00分别测定距离地面1.5 m处的外围中枝成熟叶片的净光合速率、蒸腾速率和细胞间隙CO₂浓度。并计算羧化效率(CE)和水分利用效率(WUE)。羧化效率=净光合速率/细胞间隙CO₂浓度,水分利用效率=净光合速率/蒸腾速率。每处理测定15枚叶片取其平均值。

1.3.5 叶片SPAD值、百叶厚度和百叶质量的测定 应用叶绿素仪-502(日本美能达)测定距离地面1.5 m处的外围无果短枝或中枝成熟叶片的SPAD值,每个处理测定25枚叶片,3次重复,取其平均值,

以及测定其百叶厚度和百叶质量。

1.3.6 产量和品质指标的测定 统计各样本树的单株质量,以平均值折合计算 666.7 m^2 产量;对各样本树随机采摘30个果实分别用电子台秤称量单果质量和数显糖量计测定可溶性固形物含量,并求其平均值;果面着色指数= $\sum(\text{各级果数}\times\text{代表级值})/(\text{总果数}\times\text{最高级值})\times100\%$;光洁度指数= $\sum(\text{各级果数}\times\text{代表级值})/(\text{总果数}\times\text{最高级值})\times100\%$ 。

2 结果与分析

2.1 不同间伐处理对果园结构参数的影响

2011年冬郁闭园改造完成后,果园结构如表1所示,处理I和II间伐50%的植株量,在树冠体积保持不变的情况下,定植密度、果园覆盖率和 666.7 m^2 枝量比对照降低了约50%,处理III间伐25%的植株量,定植密度、果园覆盖率和 666.7 m^2 枝量比对照降

表1 改造完成后的果园结构
Table 1 Variations of apple orchard structure in different treatments

处理 Treatment	行向 Row direction	株行距 Planting density /m	树冠体积 Tree canopy volume/ m^3	行间交接率 Transition rate Between row/%	果园覆盖率 Coverage rate of crown/%	666.7 m^2 枝量 666.7 m^2 total shoots
I	南北行 North-south direction	3.0×7.0	23.14	-40.71	62.37	48 300
II	东西行 West- east direction	3.5×6.0	23.14	-33.00	62.37	48 300
III	南北行 North-south direction	—	23.14	13.93	93.55	72 400
CK	南北行 North-south direction	3.0×3.5	23.14	18.57	124.73	96 500

低约了25%。定植密度、果园覆盖率和 666.7 m^2 枝量与间伐植株的数量保持一致。

试验期间(如图1所示),3个处理的冠径和树冠体积均迅速增加,处理I和II增加幅度大于处理

III。改造后果园覆盖率均逐年增加,至改造后第4年,3个处理的果园覆盖率依然低于CK。处理I和II的行间交接率逐年增加,在4 a间没有交接,处理III行间交接率虽然降低,但幅度较小为13.93%,并在

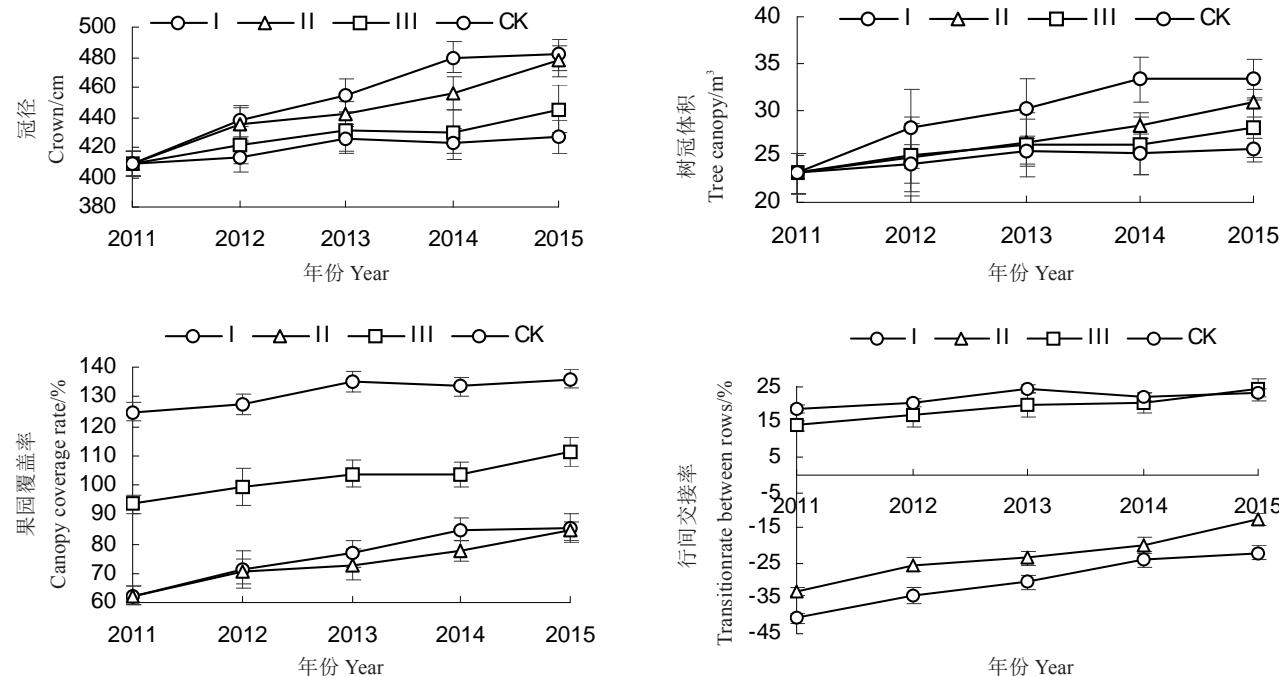


图1 不同处理对果园结构参数的影响

Fig. 1 Dynamic variation of apple orchard structure in different treatments

试验期间交接幅度逐渐增大,至第4年与CK接近。

2.2 不同处理对树体结构参数的影响

由表2可以看出,郁闭园(CK) 666.7 m^2 留枝量在9.69万~9.82万条,长枝和发育枝占比较高,第3年和第4年 666.7 m^2 留枝量恢复到7万多条,

40%,严重影响了果园的透光通风条件。改造后第1年,处理I和II枝量恢复速度快(666.7 m^2 留枝量分别为6.28万条和6.31万条),长枝和发育枝占比较高,第3年和第4年 666.7 m^2 留枝量恢复到7万多条,

表2 不同处理对树体结构参数的影响

Table 2 Dynamic variations of apple tree structure in different treatments

处理 Treatment	年份 Year	枝类组成 Branch composition/%					单株总枝量 Total shoot	折合 666.7 m ² 枝量 Total shoots per 666.7 m ² ($\times 10^4$)
		叶丛枝 Leave witchs	短枝 Spur	中枝 Mid-branch	长枝 Long branch	发育枝 Development branch		
I	2012	12.1	29.5	25.2	24.3	8.9	1 978	6.28
	2013	15.5	30.4	23.3	22.6	8.2	2 126	6.75
	2014	21.9	35.4	19.5	17.3	5.9	2 262	7.18
	2015	22.7	34.8	18.9	18.2	5.4	2 277	7.23
II	2012	11.7	27.1	24.6	26.7	9.9	1 988	6.31
	2013	14.8	29.4	21.4	25.9	8.5	2 107	6.69
	2014	20.8	33.2	20.6	19.2	6.2	2 243	7.12
	2015	22.8	32.8	19.9	18.7	5.8	2 265	7.19
III	2012	17.8	24.6	25.9	21.4	10.3	1 583	8.04
	2013	18.3	26.8	24.9	20.3	9.7	1 624	8.25
	2014	18.2	27.6	23.2	22.2	8.8	1 618	8.22
	2015	17.9	25.3	24.1	23.5	9.2	1 656	8.41
CK	2012	18.5	23.5	25.4	22.8	9.8	1 526	9.69
	2013	18.2	24.6	24.4	24.3	8.5	1 531	9.72
	2014	19.6	23.2	25.1	22.7	9.4	1 540	9.78
	2015	18.4	23.8	24.3	24.4	9.1	1 547	9.82

并保持稳定,长枝和发育枝所占比例下降,叶丛枝和短枝比例升高,维持在55%左右;而处理III改造效果虽有改善,但相比处理I和II不显著。

2.3 不同处理对叶面积指数(MLA)和平均叶倾角(MLA)的影响

从图2可以看出,各处理不同程度地降低了

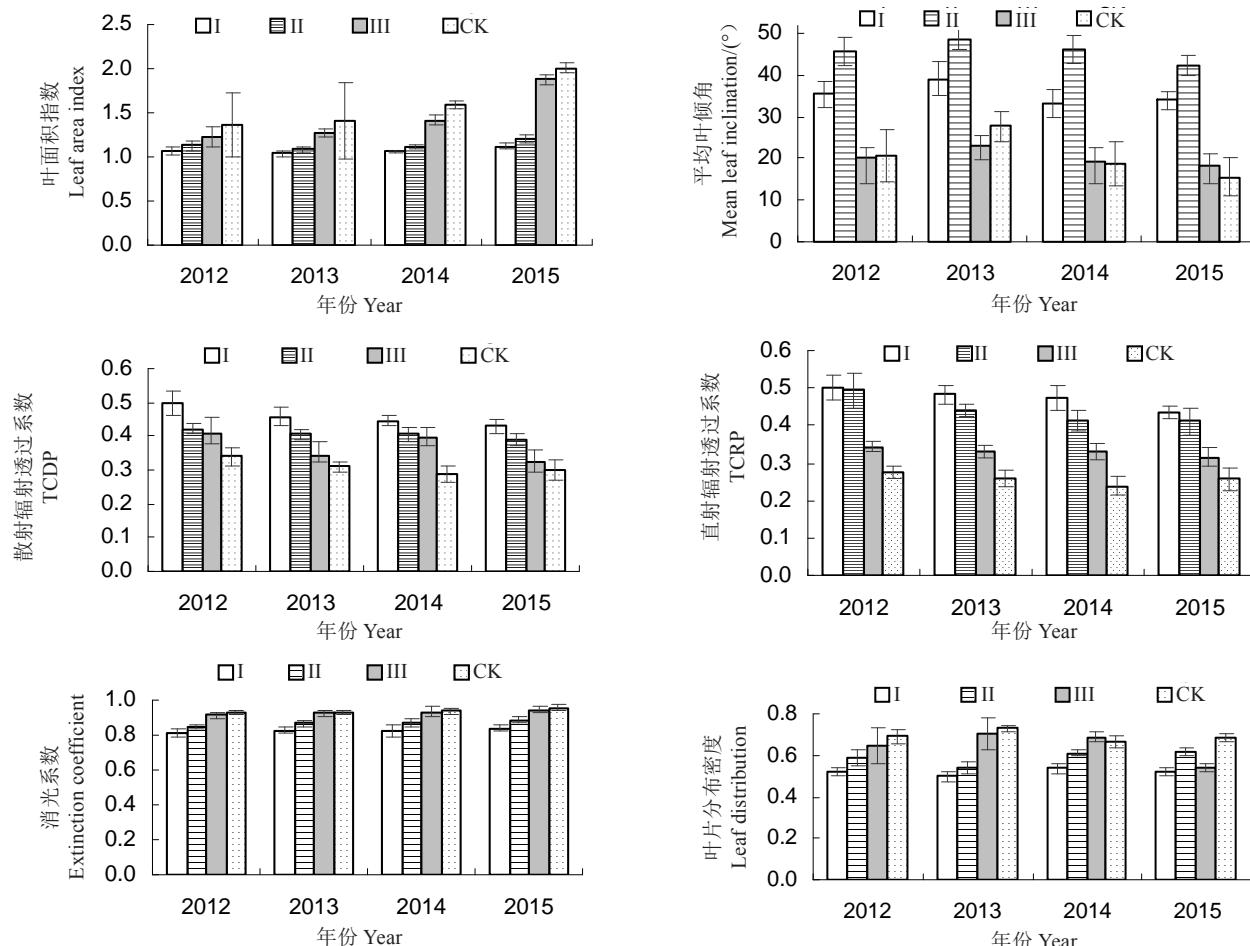


图2 不同处理对冠层结构参数的影响

Fig. 2 Dynamic variation of apple tree canopy structure in different treatments

LAI, 随着改造年限的延长, 各处理的LAI均有增加的趋势, 其中处理I和II的LAI显著低于CK, 而处理III的LAI虽比CK低, 但是没有达到显著水平。而不同处理对MLA的影响表现为: 处理I和II的MLA明显大于处理III和CK, 其中处理II最大, 处理III和CK差异不显著。

2.4 不同处理对冠层TCDP和TCRP的影响

各处理均能较大幅度地提高TCDP和TCRP, 其中处理I和II提高幅度尤为显著, 且在改造后4年间依然保持较好的效果。而冠层消光系数(K)的变化和TCDP、TCRP的变化相反(图2), 具体表现为: 处理I和II的K值显著降低, TCDP和TCRP显著升高, 而处理III和对照相比变化不显著。

叶片分布密度(LD)的变化如图2所示, 处理I和II显著低于处理III和对照。改造后4年间, 处理I、II、III和对照的变异系数分别为0.015、0.033、0.073和0.026。LD的变异系数代表冠层内叶片的分布均匀程度, 变异系数越小, 说明叶片相对分布的更加均匀, 处理I的变异系数最小, 叶片分布相对其他处理而言最均匀。

2.5 不同处理对百叶质量和百叶厚度的影响

由图3得知, 与对照相比, 3种改造方式均能增加百叶质量和百叶厚度, 特别是改造后第1年增加幅度最大, 随改造时间的延长呈下降的趋势; 3种改造方式之间相比较, 处理I和II之间没有显著差异, 但均显著高于处理III。

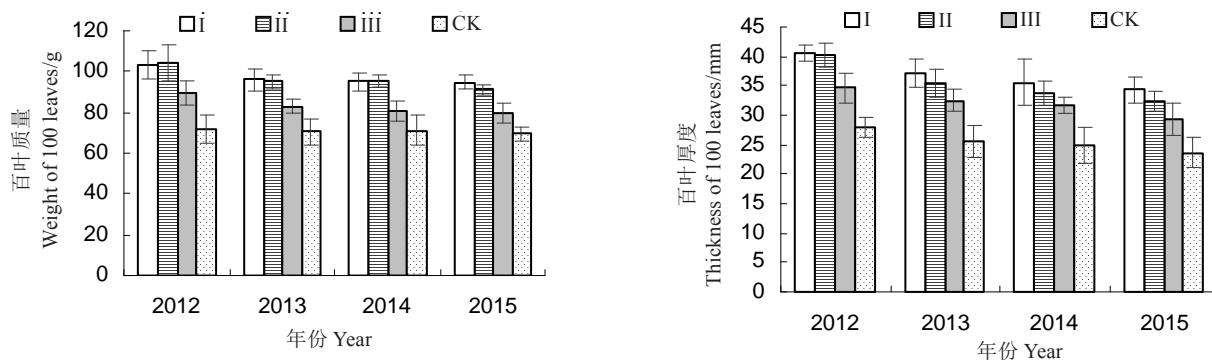


图3 不同处理对百叶质量和厚度的影响

Fig. 3 Dynamic variation of weights and thickness of 100leaves in different treatments

2.6 不同处理对树冠透光率和叶片SPAD值的影响

由图4可以看出, 3种改造方式对树冠透光率的影响, 与TCDP、TCRP的变化一致, 均不同程度地提高树冠透光率, 与对照相比, 处理I和II分别提高了

93.2%和65.2%。树冠透光率和叶片SPAD值呈极显著正相关(p 值0.990), 表明在一定范围内树冠透光率越大, 叶片SPAD值越大。

2.7 不同处理对光合作用各项指标的影响

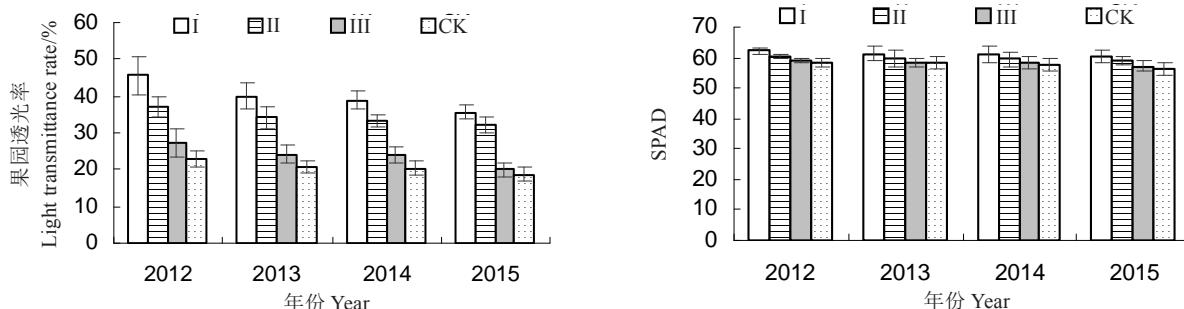


图4 不同处理对果园透光率和叶片SPAD的影响

Fig. 4 Effects of different treatments on light transmittance rate and SPAD

果树的净光合速率(P_n)、胞间CO₂浓度(C_i)、气孔导度(G_s)、蒸腾速率(T_r)、羧化效率(CE)和水分利用效率(WUE)等均能直接或间接地反映果树的树体状况和生产能力^[14]。由图5可以看出, 各处理条

件下, P_n 、 C_i 、 G_s 、 T_r 和CE变化趋势基本一致, 处理I和处理II均明显地高于对照, 处理III前期高于对照, 后期各项指标和对照相比差异不显著。其中 P_n 、 G_s 、 T_r 和CE处理I最大, 分别为16.15 μmol·m⁻²·s⁻¹、155.5

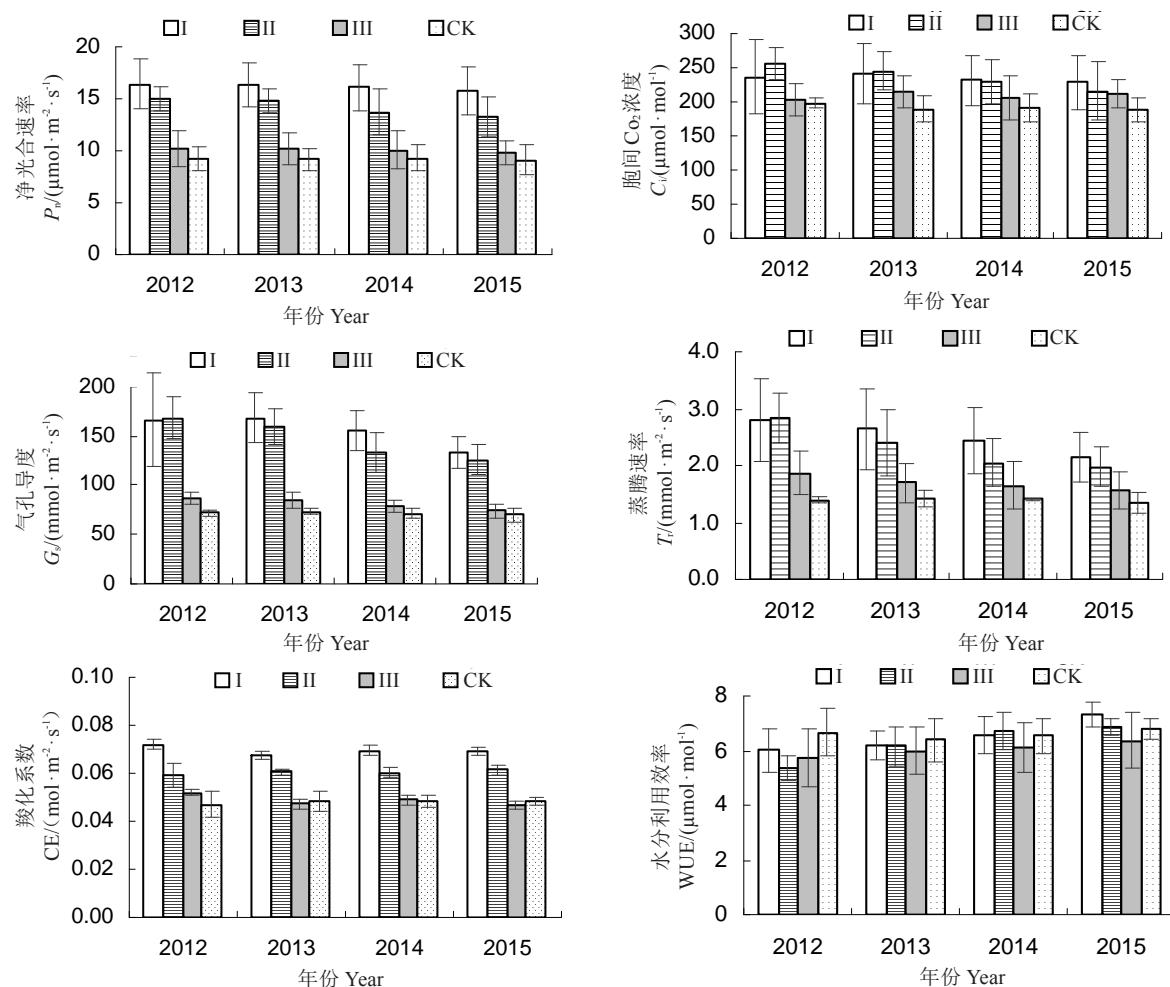


图5 不同处理对叶片光合参数的影响

Fig. 5 Dynamic variation of photosynthetic parameters of leaf in different treatments

$\text{mmol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$ 、 $2.51 \text{ mmol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$ 和 0.069 , 分别比对照提高了 75.59% 、 116.48% 、 80.07% 和 44.79% ; 而 C_i 在处理II出现最大值($236.24 \mu\text{mol} \cdot \text{mol}^{-1}$), 比对照提高了 23.19% ; 各处理对WUE的影响差异不显著, 且没有规律性。

2.8 不同处理对果实产量和品质的影响

由表3可以看出, 不同处理对改造后第一年的 666.7 m^2 产量有较大的影响, 其中处理I和II的 666.7 m^2 产量显著地降低, 但第二年产量迅速恢复, 基本达到改造前的水平, 第三、四年产量超过对照, 从4 a的平均产量来看, 与对照基本持平。

不同处理对单果质量、着色指数、优质果率和可溶性固形物含量有不同程度地影响。处理I和II的提高幅度较大, 与对照相比, 单果质量分别提高了 15.9% 和 12.7% , 着色指数分别提高了 23.7% 和 21.0% , 优质果率分别提高了 38.0% 和 36.5% , 可溶性固形物含量分别提高了 14.4% 和 10.4% ; 处理III

与对照相比, 虽有提高, 但与处理I和II相比, 效果不明显。3种处理对光洁指数的影响不显著且没有规律性。

3 讨 论

光照是影响果实品质的主导因子, 不但影响果实的着色, 而且还对碳水化合物的合成、运输以及树势和树体干物质的积累等有重要影响^[9-11]。所以打开光路是郁闭园改造的有效措施, 只有改善果园的风光条件, 才能从根本上改善郁闭园的微域环境, 从而提高果实品质和产量。本试验采取“间伐+常规修剪”的模式对郁闭园进行改造, 即在改造当年, 进行一次性间伐, 疏除下层距离地面较近的主枝, 改造完成后, 修剪由果农自主完成。改造后连续4 a对改造效果进行跟踪调查, 并对相关指标进行测定。

本试验使用冠层分析仪对LAI、MLA、TCDP、TCRP、K和LD进行分析, 冠层分析仪法测定LAI与

表3 不同处理对果实产量和品质的影响

Table 3 Dynamic variations of fruit quality and yield in different treatments

处理 Treatment	年份 Year	折合666.7 m ² 产量 666.7 m ² yield/kg	平均单果质量 Average mass/g	着色指数 Colouring index/%	光洁指数 Fruit shining index/%	优质果率 High quality fruit rate/%	w(可溶性固形物) TSS/%
I	2012	2 976.5	206.3	93.7	98.4	86.5	14.5
	2013	4 310.5	210.4	94.2	97.9	85.0	14.7
	2014	4 885.4	222.8	94.0	98.0	83.5	13.5
	2015	4 890.5	235.8	95.6	95.5	85.0	14.5
	平均	4 265.7	218.8	94.4	97.5	85.0	14.3
	Average						
II	2012	3 010.5	200.1	91.8	97.2	85.6	14.2
	2013	4 215.4	209.8	93.6	96.3	84.5	14.2
	2014	4 870.5	221.1	90.0	95.0	85.8	13.1
	2015	4 650.0	219.6	93.8	94.0	80.5	13.8
	平均	4 186.6	212.7	92.3	95.6	84.1	13.8
	Average						
III	2012	3 850.5	192.9	88.5	96.2	79.8	13.2
	2013	4 225.4	197.6	90.1	96.1	78.5	13.5
	2014	4 350.6	191.9	81.0	89.0	75.0	12.8
	2015	4 225.4	208.7	88.5	90.5	68.5	12.5
	平均	4 163.0	197.8	87.0	93.0	75.5	13.0
	Average						
CK	2012	4 510.5	181.6	80.6	92.3	65.0	12.2
	2013	4 450.0	190.5	78.4	92.2	63.8	12.8
	2014	4 335.6	182.9	75.5	82.0	62.5	12.6
	2015	4 425.5	200.1	70.8	85.5	55.0	12.4
	平均	4 430.4	188.8	76.3	88.0	61.6	12.5
	Average						

传统方法相比结果偏小,但是二者呈极显著的正相关,可以利用此方法对各处理间果园郁闭参数进行快捷方便的对比^[12-15]。果园郁闭带来的直接影响是果园透光率严重不足和TCDP急剧下降,以及冠层消光系数K的大幅度升高,说明郁闭果园树冠的内膛和下部区域长时间处在一个弱光照的环境,严重影响了果园的生态微域环境。前人已经证明,弱光对作物产量的影响是负效应,严重地影响了作物的产量和品质^[9-10],优良的透光通风条件为果园的优质高效生产奠定了基础^[16-19]。通过对改造园片的冠层分析,发现LAI急剧下降,K值降低,TCDP和TCRP提高,叶片分布相对均匀,间伐打开了该园片区的光路,改善了通风透光条件,提高了果实的着色指数和优质果率。

果树的光合能力是果园产量和果实品质形成的基础。处理I和处理II的 G_s 和 P_n 显著高于对照,说明对照的微域环境影响了叶片的 G_s ,但 C_i 却没有降低, P_n 下降幅度较大,说明叶片光合作用的下降是非气孔限制因素引起的,有可能是长时间的光照不足造成叶片光合机构的损伤成为制约郁闭园叶片光合速率的主要因子^[20]。

由于处理I和II间伐植株数量较多,严重影响了

第一年的产量,但是第二年基本上能恢复到改造前的水平,第三年、第四年甚至还有提高,由于改造彻底,果园整体在改造第三、四年依然能保持改造的优势,外观品质、内在品质和优质果率比CK显著提高。由于处理III改造不彻底,改造初期效果较好,从第三年开始,果园整体再次出现郁闭现象。

处理I和II两种改造方式在间伐掉植株的数量(间伐50%的植株)上是一致的,但从改造后的实际表现的效果来看,处理I的效果优于处理II,这可能与行向、太阳入射角等因素有关,还需要进一步的证明。而处理III,由于间伐植株数量较少,间伐的位置较不规则,随着时间的推移,再次出现郁闭现象,改造持续效果没有处理I和II显著。

4 结 论

3种改造方式均能不同程度地改善果园的透光通风条件,对果园产量、果实品质和优质果率都有一定程度地提高。在间伐植株数量相同的情况下,隔行去行(处理I)比隔株去株(处理II)效果更为明显,隔行去行显著提高果园透光率、散射和直射透过系数、叶片的净光合速率和羧化效率,果实品质和优质果率。本试验条件下以隔行去行的改造措施效果最优。

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