國立臺灣大學生物資源暨農學院園藝學系

碩士論文

Department of Horticulture
College of Bioresources and Agriculture
National Taiwan University

Master Thesis

摘除老葉、走莖與花對臺灣冬季草莓生長發育與生產之影響

Defoliation, runner removal and flower removal affect growth and fruiting in 'Toyonoka' strawberries for winter production in subtropical Taiwan

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中華民國 98 年 6 月

June, 2009


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致謝

本論文能順利完成，不僅是個人的努力，還需仰賴許多人的指導與協助，在此我以最誠摯的心意，由衷地向你們說聲「謝謝」。

在研究所碩士班兩年修業期間，首先感謝 李國譚老師悉心指導及砥礪，激勵我思考與勇於面對困難。楊雯如老師教導我邏輯建構和在生活上之照顧。與林宗賢老師對與建議總是讓我受益良多。在苗栗試驗期間，張哲嘉老師給予我的指導、建議、幫助與照顧，窩心極了。蔡智賢老師在論文上之指導與建議。讓學生論文更具完整性。

栽培與關懷，謝謝他帶著我去見識更高更遠的世界，還給了我充分的機會與空間，鼓勵我勇敢的往前飛，引導我對自己的未來譜出不同以往的願景，並且在健康生活上給予叮嚀和鼓勵，讓我在學術上與生活上都留下許多深刻且精彩美好的體驗與成長。

試驗期間，幸獲得吳秋燕女士提供試驗場所與材料，李廉、本忞

目錄

表目錄

圖目錄

摘要

摘除走莖、葉片管理與疏花疏果作業為草莓田間栽培的慣行作業，但這些田間操作對草莓植株生理與生產上的影響及帶給農民的效益尚未經詳細評估，因此本論文分為兩部分進行探討。一為以摘除走莖（RR）、摘除老葉（LR）、摘除走莖加上老葉（RR + LR）與對照組（CK）等四處理，探討摘除老葉與走莖對草莓植株生長、光合作用能力與產量之影響。田間試驗結果顯示，栽培期內摘除老葉與走莖不會影響第一期、第二期開花時間與第一期果實採收日數，但第二期果實數（$p = 0.007$）與採收日數（$p = 0.002$）受葉面積影響，隨著葉面積增加果實採收日數亦增加。對全季而言，隨著葉面積增加產量、果實數及單果重亦增加；摘除走莖則可以提昇產量、果實單果重及果實可溶性固形物。另以盆栽植株為材料測量葉片光合作用，於摘除老葉後 1 日，葉片光合作用能力提昇 15%至 30%。試驗結束後測得植株鮮重與乾重，摘除老葉降低植株總鮮重、地下部鮮重、總乾重、地上部乾重與地下部乾重，而摘除走莖則無影響。

另一試驗以摘除每期第一級花（或果實）（primary flower removed, PR）、摘除每期第四級以後之花朵（或果實）（quaternary flower removed, QR）、摘除每期第五級以後之花朵（或果實）（fifth flower removed, FR）與對照（CK）等處理探討不疏花疏果對草莓植株生長、果實發育及產量之影響。各處理對植株葉面積生長影響不顯著，僅在處理後 56 日 PR 葉面積較其他處理高 150 平方公分；處理後 70 日 PR 與 QR 葉面積高於其他處理 150 平方公分。疏花疏果處理僅對第二、三期三級果實有所影響且皆以 PR 表現較佳。疏花疏果對各期可銷售產量、可銷售總產量及第一、二期及全季可銷售果實可溶性固形物皆無影響，僅減少不合品果實數。

關鍵字：草莓、摘除老葉、摘除走莖、疏花疏果、葉面積、光合作用、產量

Abstract

Removing runners, old leaves and flowers are three major routine tasks in a strawberry (*Fragaria ×ananassa* Duch.) field for winter berry production in central Taiwan. However, their effects on growth and fruit development have yet to be evaluated. To document the effects of partial defoliation and runner removal on plant growth, photosynthesis and yield, field and potted plants were treated with: 1) LR: partial defoliation of old leaves; 2) RR: runner removed; 3) LR + RR; 4) CK: controls. Neither defoliation nor runner removal affected the initial dates of first bloom, second bloom, and first harvest, but affected second harvest. Multiple linear regressions indicated that canopy leaf area had greater overall effects than the existence of runners on runnering and fruiting. Pot experiment showed that removing old leaves (leaf ages about 45days) temporary increased photosynthesis of the remaining leaves by 15% to 30%. Neither defoliation nor runner removal affected of crown fresh weight but deceased fresh weight of root. In addition, defoliation but not runner removal deceased dry weight of crowns and roots.

To document the effects of flower or fruit thinning on plant growth, fruit development and yield, field plants were treated with: 1) PR: primary flower or fruit removal; 2) QR: quaternary or fruit removal; 3) FR: fifth flower or fruit removal; 4) CK: controls. Leaf area development, yield of individual harvest, total seasonal yield and soluble solids content were not affected by flower removal treatments. PR increased tertiary fruit growth of second crop and third crop. The results indicated that flower or fruit thinning increased average weight of marketable berries without compromising yield.

Keywords: strawberry, removing runners, removing old leaves, flower or fruit thinning, yield, photosynthesis.

第一章　總論－前人研究及試驗假說

一、前言

草莓 （*Fragaria* ×*ananassa* Duch.）屬薔薇科（Rosaceae）多年生草本作物。栽培上因地理環境與氣候條件等因素而分為兩種栽培系統。一為溫帶地區慣用的地毯式栽培系統（matted row system），為多年生栽培系統，種苗於第一年春季定植於田間後，夏季長日環境下長出大量走莖及子株，秋季因氣溫下降與日長變短，植株進入休眠前有少數花芽分化，栽培者以稻草或麥稈覆蓋植株幫助植株抵禦低溫越冬，翌年春天打破休眠後植株持續花芽分化並於春末開花，初夏採收果實其後再度產生大量走莖及子株，冬季時植株再進入休眠，依此模式栽種 4 至 5 年後更新植株。另一為熱帶與亞熱帶的一年生高畦栽培系統（hill row system），此區域夏季氣候大多為高溫、多雨與高濕，不適合草莓植株生長，因此於秋季末或冬季初期定植並在冬季至春末採收果實（Hancock, 1999a）。

臺灣地區位處於熱帶與亞熱帶之間，在冬季利用高畦生產草莓，主要的栽培品種為‘豐香’（‘桃園一號’），為相對短日型（facultative short day）。於臺灣主要草莓栽培區中一般於 9 月中至 10 月初之間定植，行株距約為 20 至 30 公分，定植後約 1 個月植株即能感受彼時之相對低溫及短日而進行生殖生長，並於 11 月間開第一次花，開花至採收約為 35 日。由於在 11 月至翌年 3 月間亞熱帶之低溫並不致誘發草莓植株休眠，故植株持續生長並感受低溫及短日而開花結果，產期可由 12 月持續至翌年 4 月，約可以採收三至四期果實（李, 1993; 黃, 2006; Hancock, 1999）。在栽培前期及末期因日長及溫度影響，植株同時發育新葉、生長走莖、分化花芽與開花結果。走莖生長可能與其他器官競爭養分，而葉片過多遮蔽花及果實影響授粉與轉色，且老葉易感染病蟲害，增加病蟲害管理成本與影響田間操作管理，故農民習慣於栽培期間內持續摘除走莖及老葉。摘除走莖應可使生長中的果實獲得更多養分；摘除健康狀況不佳且處於新葉下位蔽陰處之老葉對植株整體光合作用效能影響應不大；但若所摘除之葉片健康狀況仍佳便可能減少植物整體的光合作用效能及光合產物之累積。

另一方面草莓花序為聚繖花序，同一花序中花數及果實數隨花序分枝而愈來愈多，果實大小則愈來愈小，摘除花序上後開之小花應有助於養分集中於先開之花朵及果實而生產少量但果形大及品質較好之果實。摘除花或果實可達到增加著果率、果實間養分的分配與提供其他果實充分的生長空間等效果；但摘除花或果實也可能使總產量降低而減少栽培上之經濟效益。

二、草莓植株生長特性

（一）走莖生長

草莓走莖是由植株短縮莖（crown）基部葉片的腋芽發育而成，發育成熟的走莖有兩個節點與節間，第二節點向上形成不定芽，向下形成不定根而成為另一新植株（Darrow, 1966; White, 1927）。草莓植株走莖產生數會因品種不同而異。而在相同品種中，草莓母株大小與走莖發生有正相關，植株愈大產生的走莖愈多。大苗株定植後可能有較小型苗株為佳的生長勢，而增加走莖數發生（Skirvin *et al*., 1987）。目前大多數草莓商業栽培品種為相對短日型（facultative short day）草莓，於低溫短日環境花芽分化，高溫長日的環境下產生走莖，溫度與日長反應之臨界值則因品種而異（Darrow, 1966; Hancock, 1999b）。‘Redchief’與‘Guardian’草莓以日夜溫 26 ℃/22 ℃ 配合暗中斷處理亦可促進走莖發育（Durner *et al*., 1984）。

（二）葉片生長及光合作用

草莓葉片圍繞植株基部生長為 5 片葉 2 輪的螺旋葉序，因此第六片葉會與第一片葉正對，而每片葉都是由三片小葉組合而成的三出複葉。第一個葉原基形成與下一個葉原基形成的間隔期約 8 至 12 天，葉片的壽命因品種、氣候、栽培地區與田間管理方式不同而異，在美國馬里蘭州地區栽培‘Howard 17’草莓，其葉片壽命為 21 至 77 天之間，平均壽命為 54 天（Darrow, 1966）。維吉尼亞野草莓（*Fragaria virginiana*）栽培於光週期為 15 小時、溫度週期為 12 小時、日夜溫度為 25 ℃/18 ℃，且在 678、286、151 及 64 $\mu E \cdot m^{-2} \cdot s^{-1}$ 等不同的光強度下，平均葉片壽命分別為 51、62、74 及 79 天，因此葉片壽命亦受光強度影響（Jurik *et al*., 1979）。影響葉片生長與功能的重要環境因素為溫度，‘Chandler’及‘Sweet Charlie’品種栽培於日夜溫度

20 ℃/ 15 ℃、30 ℃/ 25 ℃、40 ℃/ 35 ℃之環境下，以日夜溫度 30 ℃/ 25 ℃下之葉片有較其他二處理者更高之淨二氧化碳同化速率、氣孔導度與水分利用效率，且有較高葉綠素含量與更穩定的光合作用系統，因此植株總葉面積、葉片數與葉片乾物重皆優於生長於其他環境下之植株（Kadir and Sidhu, 2006）。但對‘Earliglow’與‘Kent’草莓而言，在日夜溫度 25 ℃/12 ℃的栽培環境下其葉片生長優於在 18 ℃/12 ℃、25 ℃/22 ℃與 30 ℃/22 ℃等栽培環境下之植株。因此草莓植株葉片生長不僅受栽培環境影響也因品種不同而異（Wang and Camp, 2000）。

將現在草莓親本之一，維吉尼亞野草莓植株栽培於日夜溫度 25 ℃/18 ℃下，光合作用在光強度為 1490、245 及 64 $\mu E \cdot m^{-2} \cdot s^{-1}$ 等環境下，皆於葉齡 10 天的葉片始測得淨光合作用，葉齡 17 至 27 天淨光合作用率達最高峰，葉齡 30 天後淨光合作用率急速下降，葉齡 40 天淨光合作用率僅為最大值的 40%。當葉片自然老化過程中，葉片顏色會出現明顯的變化（Jurik *et al*., 1979）。草莓葉片光合作用屬於 C3 型，‘Elsanta’草莓生長於光強度 600 $\mu mol \cdot m^{-2} \cdot s^{-1}$、50%相對濕度及 25 ℃的環境下，成熟葉片每平方公分的氣孔數為 28000 至 32000 之間，蒸散率為 1.6 至 1.8 $mmol \cdot m^{-2} \cdot s^{-1}$，光合作用效率為 8-12 $\mu mol \cdot m^{-2} \cdot s^{-1}$（Blanke, 2002）。葉片淨光合作用效率會因栽培環境不同而異，Oda（1997）以‘Hokowase’草莓為試驗材料在不同光照強度、二氧化碳濃度及葉片溫度等條件下測定葉片之光合作用能力，結果顯示葉片溫度於 23 ℃至 28 ℃之間，其葉片淨光合作用表現最佳。若將葉片溫度設定為 23 ℃之環境下，葉片淨光合作用能力隨著二氧化碳濃度或光強度增加而增加。葉片淨光合作用效率亦會受栽培管理影響，‘Selva’草莓栽培於 1350 mL 與 250 mL 等不同大小容器下，分別以不同的光合作用光子流量密度測定草莓植株完全展開葉之二氧化碳交換率；栽培於 1350 mL 草莓植株，不論在任何光合作用光子流量密度下皆高於栽培於 250 mL 之草莓植株（Giannina *et al*., 1997）。但不論任何栽培系統中葉片淨光合作用效率皆與果實產量成正相關（Hancock *et al*., 1989）。

（三）根系生長

草莓根為鬚根系（fibrous root system），根系由植株基部發生，新根為白色，在縱向的伸長生長與橫向的增厚生長後，根便木栓化，其顏色由白色漸轉變為黃色或褐色等較深的顏色。根較有活力的部分為根尖，根尖易新生白色的側小根，

其主要功能為吸收水分與養分；顏色深的老根則以傳導與固定植株為主。草莓根系在土壤中的分佈多集中於土下 15 公分內，其中 25%至 50%之根系分佈於土壤下 7.5 公分；而 50%至 90%之根系分佈於土壤下 15 公分（Galletta and Himelrick, 1990）。根部生長發育與溫度有密切相關，‘Earliglow’與‘Kent’草莓栽培於日夜溫度 18 ℃/12 ℃、25 ℃/12 ℃、25 ℃/22 ℃以及 30 ℃/22 ℃等環境下，植株根系乾物重以日夜溫度 18 ℃/12 ℃為最佳（Wang and Camp, 2000）。草莓植株地上部生長亦與根系生長相關，當地上部生長勢較佳時，則根系在生長速率、鮮重及乾重皆有較好之表現（Mohamed, 2002; Reekie *et al*., 2007）。

（四）開花結果

草莓花序由短縮莖頂芽生長點及其下方數個側芽分化形成為聚繖花序，栽培種多具兩性花且自花授粉、果實為聚合果（Galletta and Himelrick, 1990）。目前栽培種草莓依對光週的反應不同可分成三種類型。大多數商業栽培品種為相對短日型、少數為日中型（Day-neutral type）及長日型（Everbearing type）（Hancock, 1999a; Konsin *et al*., 2001; Nicoll and Galletta, 1987; Scott and Lawrence, 1975）。在中緯度地區相對短日型草莓一年只能生產一季，於夏末秋初短日冷涼氣候下花芽分化，冬季進入休眠，翌年春天溫度回升後持續花芽分化於春末夏初開花結果（Galletta and Bringhurst, 1990），而花芽分化之臨界溫度與日長依品種而異（Morishita and Yamakawa, 1991; Sønsteby and Nes, 1998）。Ito 與 Saito（1962）提及相對短日型品種（‘Robinson’）其花芽誘導受光週期與溫度影響，短日配合 15 ℃的環境下易使誘導草莓植株花芽形成，若溫度低於 15 ℃不論日長的長短，植株皆易誘導花芽形成。日中性型與長日型的特性為一年中春末至秋初會持續的開花結果，直到低溫抑制生長為止，但長日型需在長日的環境下才能開花，而日中性型在適度涼溫下不論長短日下皆可開花（Durner *et al*., 1984; Galletta and Bringhurst, 1990）。

臺灣地區冬季草莓主要栽培的品種為‘豐香’（‘Toyonoka’、‘桃園一號’），其開花結果習性屬於相對短日型，在日夜溫度 23 ℃/18 ℃的栽培環境下其花粉活力、花序數、花朵數與果實數皆顯著多於 30 ℃/25 ℃；但對果實生長與果實成熟而言則是以 30 ℃/25 ℃較佳（Ledesma and Sugiyama, 2005; Ledesma *et al*., 2008），而李（1998）指出‘豐香’草莓植株以日夜溫度 25 ℃/20 ℃、20 ℃/15 ℃及 15 ℃/13 ℃

皆可提早花期。在臺灣地區草莓栽培前期產量較少且有較佳銷售價格，因此提早產期與提昇早期產量為重要課題之一（李, 1993）。在草莓苗假植期利用高冷地假植、短日、遮光及斷根等方式可促進花芽分化，提早開花結果（朱, 2007; 李和吳, 1985）。在果實品質方面，Wang 與 Camp（2000）等人以‘ Earliglow’與‘Kent’草莓為試驗材料，於日夜溫度 18 ℃/12 ℃、25 ℃/12 ℃、25 ℃/22 ℃以及 30/22 ℃等環境下，果實及果肉色澤皆隨著日夜溫度增加而有較佳表現。可溶性固形物、可滴定酸、糖酸比及維生素 C 含量皆隨著日夜溫度增加而降低，因此在高日夜溫度的栽培環境下有較佳的果實外觀，但果實內容物則是以低日夜溫度之栽培環境下表現較佳。

三、摘除走莖、葉片與花對草莓植株之影響

（一）摘除走莖對草莓植株之影響

利用多年生地毯式栽培系統生產草莓，當年走莖發生數與翌年的產量有極高的正相關（Galletta and Himelrick, 1990）。‘Midway’與‘Guardlian’草莓栽培於多年生地毯式系統中，若植株於生長期間摘除走莖會導致翌年總產量減少（Hancock *et al*., 1982）。‘Cardinal’草莓栽培於地毯式系統中，摘除走莖亦得到相同趨勢（Buckley and Moore, 1982）。商業草莓生產需注意營養生長與生殖生長之間的平衡（Darrow, 1929），走莖生長會與其他器官競爭光合產物與養分，限制植株葉面積生長、根系生長與減少單株果實產量（Darrow, 1936; Savini *et al*., 2008），但摘除走莖可以減少農藥的用量與增加採收的方便性（Darrow, 1936）。在一年生高畦栽培系統（annual hill row system）中走莖的管理更是重要，‘Dover’與‘Tuffs’草莓植株於 10 月中定植，栽培期每兩週摘除走莖一次則可增加前期產量與總產量（Albregts and Howard, 1986）。走莖生長亦可以化學藥劑調節，栽培期間以 Prohexidione-Calcium、Paclobutrazol、Mepiquat Chloride 等化學藥劑噴施植株可抑制走莖生長，提高葉片之淨光合作用能力，使植株體內有較高的碳水化合物，進而促進根系生長及提昇果實產量，但抑制走莖的效果受藥劑種類、噴灑時機、噴灑濃度與噴灑次數而有所不同（Black, 2004; Nishizawa, 1993; Reekie *et al*., 2005; Reekie *et al*., 2007; Sachs and Iszak, 1975）。

（二）摘除葉片對草莓植株之影響

草莓栽培期間摘除老葉可減少病蟲害並維持行株距以方便栽培管理（Galletta and Himelrick, 1990），但摘除的時機與被摘除葉片之狀態皆需要列入評估。在多年生地毯式栽培系統中，Guttridge（1959a; 1959b）指出老葉中含有抑制花芽創始之物質會減少翌年之花序數。多數草莓栽培品種在果實採收後，若進行除葉處理僅留下健壯之葉片，可促進翌年草莓植株花序形成進而提昇產量（Guttridge *et al*., 1960）。一年生高畦栽培系統中，在栽培前期摘除成熟之葉片會使生長勢衰落，造成植株鮮乾重、花序數降低、單果重與可銷售產量減少（Albregts *et al*., 1992; Mohamed, 2002），隨摘除葉片數增加而新生葉片數與走莖發生數皆減少（Chandler *et al*., 1988）。然在栽培後期摘除新生葉控制營養生長使花與果實獲得更多養分，反而增加結果率、果實數與產量（Reekie *et al*., 2005; Reekie *et al*., 2007）。Carlen 等人（2007）在開花期摘除 50%葉片數降低植株葉面積及葉果比例，最終使產量減少或是僅能維持產量。對‘豐香’草莓全季產量而言，在定植 3 個月後每週優先摘除老葉與病葉使每株葉數維持至 10 片。可達到方便田間管理與提高可銷售果實等效果（黃等, 2006）。因此摘除葉片之時機、摘除葉片生理狀況及摘除之葉片數皆會影響產量且需謹慎評估。

（三）摘除花或果實對草莓植株之影響

在多年生地毯式栽培系統中，相對短日型草莓品種‘Elsanta’與‘Korona’以冷藏種苗的方式提高苗品質，但植株提早在定植後六週開花，此時營養生長不足無法提供生殖生長足夠養分反使產量降低，此時除花可增加葉片數與走莖生長勢，進而增加翌年產量（Daugaard, 1999）。栽培日中性型草莓‘Tribute’與‘Brighton’亦有相同的趨勢，在定植後持續兩個月摘除花序，可增加次年第一季與第二季產量（Pritts and Worden, 1988），除花亦可增加‘Tribute’草莓植株葉面積，因葉面積增加而使植株能透過葉面光合作用固定較多二氧化碳，因此在植物體內之總非結構性碳水化合物及乾物重皆較高（Schaffer *et al*., 1986）。Carlen等人（2007）以多個草莓品種為試驗材料給予摘除花或摘除葉片處理，探討葉片與果實之關係，結果顯示除花可以提高葉果比進而增加果實可溶性固形物。當葉面積與果實重量之比例小於15（$cm^2 \cdot g^{-1}$）時，果實可溶性固形物與葉果比有直線正向相關。在高緯度地

區利用溫室生產秋冬季草莓（‘Chambly’, ‘Glooscap’, ‘Honeoye’, ‘Kent’, ‘Midway’, 及 ‘Sparkle’），疏花亦有提高果實品質之效果（Khanizadeh *et al*., 1993），摘除第一級花可以提昇第二級果的單果重；摘除第二級花或摘除第一級花與第二級花皆可以提昇第三級果的單果重。在臺灣地區利用冬季栽培生產桃園三號草莓，無論是摘除第一級花或是維持每株不同果實數皆不影響開花始期與採收始期但可提高果實單果重，然疏果增加人工成本且降低總產量（李, 2001）。不論在多年生地毯式栽培系統或是一年生高畦栽培統中，適當摘除花或果實皆可以使養分集中於植株或較少數果實而提高果實單果重。

四、試驗假說

摘除葉片、走莖與花應會改變草莓植株整體光合產物的製造與分配，進而影響植株各器官發育生長。走莖生長與果實發育競爭養分（Albregts and Howard, 1986; Darrow, 1936; Savini *et al*., 2008），摘除走莖應可減少植株分配至走莖以提供其生長所需之養分，相對地使生長中的果實獲得更多養分而增加大果率、合格品果實數及產量。‘豐香’草莓株型為披狀，葉片下授粉與果實著色不良，病蟲害防治效率不佳（李等, 1993），臺灣地區一般田間管理隨時摘除葉齡超過 60 天之老化葉片，但葉齡超過 45 天之老葉，光合作用淨光合作用速率低，不一定可以提供植株足夠的光合產物 （Jurik *et al*., 1979），因此摘除葉齡超過 45 天之老葉應不影響植株整體光合作用效能與植株生長勢但可促進果實轉色。草莓花為聚繖花序，開花具有次序性，果實大小與重量亦呈現隨級數增加而減少之趨勢（Galletta and Himelrick, 1990），在栽培期間約可以採收三至四期果實，不同結果期相互交疊且競爭養分，因此適當摘除花應可增加葉果比、合格品果實數與單果。

五、結論

摘除走莖、葉片管理與疏花疏果作業為草莓田間栽培的慣行作業，但這些田間操作作業對草莓植株生理與生產上的影響及帶給農民的效益尚未經詳細評估。本論文第二章－摘除老葉與走莖對臺灣地區冬季草莓生產之影響，主要為透過實

際的田間試驗，藉由摘除老葉與走莖處理了解對其草莓植株於栽培期內營養生長及果實發育，驗證摘除葉齡 45 天之老葉不影響草莓植株生長及摘除走莖可增加產量。第三章－摘除老葉與走莖對臺灣地區冬季草莓植株葉片光合作用能力與根系生長之影響，則是利用盆栽試驗，方便觀察根系生長與測定葉片光合作用能力等優點，經由摘除老葉與走莖處理探討植株地上部與地下部之關係及了解對成熟健康的葉片光合作用能力之影響，驗證摘除葉齡 45 天之老葉不影響草莓植株生長勢與光合作用能力及摘除走莖可使其他器官分配到更多光合產物，期望能與第二章之試驗互相呼應。由第二章與第三章之試驗得知較適宜之走莖與葉片管理方式後，第四章－摘除花對臺灣地區冬季草莓生產之影響，則探討不同程度疏花對增加可銷售果實產量與產生大形果實之效益，驗證摘除花序上後開之小花是否有助於養分集中於先開之花朵及果實。期望藉由本論文之試驗結果提供農民作為栽培參考，達到方便栽培管理及提高收益等目的。

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第二章　摘除老葉與走莖對臺灣地區冬季草莓生產之影響

摘要

為探討摘除老葉與走莖等田間栽培慣行作業，對草莓植株生理與生產上的影響，本試驗在臺灣苗栗地區，以相對短日型草莓‘豐香’（‘桃園一號’，*Fragaria* ×*ananassa* Duch. cv. ‘Toyonoka’）為試驗材料，施以摘除老葉（leaf removal, LR）、摘除走莖（runner removal, RR）、摘除老葉加上摘除走莖（leaf and runner removal, LR + RR）與對照（control, CK）等 4 處理。試驗處理始於 2007 月 11 月 13 日結束於 2008 年 4 月 5 日，試驗期間每週調查及測量植株總葉面積、花序第一朵花開花之時間、採收期、走莖發生數、走莖長度與可銷售果實產量，進而探討摘除走莖與葉片對草莓植株之影響。試驗結果如下，走莖發生數（$r^2 = 0.65$）與生長（$r^2 = 0.75$）皆與植株總葉面積呈正相關，隨著葉面積增加而走莖發生數與生長皆有增加的趨勢。摘除老葉與走莖不會影響第一期、第二期開花日期與第一期果實採收日數。第二期果實數（$p = 0.046$）與採收日數（$p = 0.002$）則受葉面積影響，隨著葉面積增加而果實採收日數亦增加之趨勢。第一期果中，葉面積與可銷售果實產量呈正相關（$p < 0.001$）；而走莖生長與果實產量呈負相關（$p = 0.001$），摘除走莖可提高可銷售大型果產量、可銷售果實數與可銷售果實單果重。第二期果中，葉面積對可銷售產量（$p = 0.039$）、可銷售果實數（$p = 0.046$）與可銷售果實可溶性固形物（$p = 0.014$）之影響皆高於走莖，葉面積增加便提高可銷售產量、可銷售果實數與可銷售果實可溶性固形物。對全季而言，隨著葉面積增加可以提昇可銷售總產量、可銷售果實數及可銷售果實單果重；摘除走莖則可以提昇可銷售果實單果重進而增加可銷售總產量。

關鍵字：草莓、摘除老葉、摘除走莖、葉面積、產量

一、前言

臺灣地區冬季利用高畦系統（hill row system）生產草莓，栽培種為相對短日型 ‘豐香’（‘Toyonoka’、‘桃園一號’），於低溫短日環境花芽分化，長日高溫的環境下發走莖（朱,2007；Hancock, 1999a）。臺灣地區草莓植株在栽培初期（9 月至 11 月）與栽培後期（3 月至 4 月）因日長及溫度亦有走莖發生數較多的現象（李, 1993）。走莖生長可能與其他器官競爭光合產物影響植株生長、開花與結果，進而減少產量（Pritts and Worden 1988），摘除走莖可以增加栽培管理的方便性（Darrow, 1966）與提高前期產量與總產量（Albregts and Howard, 1986）。故生產期間摘除走莖與葉片管理為田間栽培中的兩項重要工作。但是在栽培初期草莓植株若因生長不佳、感染病蟲害等因素而死亡造成田間缺株的現象，此時摘除走莖便失去利用走莖誘植補株的機會。李等人（1993）報告指出，桃園一號品種株型披狀，葉片下授粉與果實著色不良，病蟲害防治效率不佳，葉片提供植株所需的光合產物。但老葉的淨光合作用速率低，不一定可以提供植株足夠的光合產物（Jurik *et al*., 1979）。摘除老葉對植株影響不大且可以促進果實轉色與減少變蟲害，但摘除負責供應植株生長之成熟葉卻可能造成植株生長勢衰落。黃（2006）建議對‘豐香’全季產量而言，在定植 3 個月後每週優先摘除老葉與病葉剩至 10 片葉最為適合。在臺灣現在的栽培制度下，栽培者會摘除走莖，然而尚無報告有關於‘豐香’在栽培期間摘除走莖對產量是否有正面的效益。一般田間管理隨時摘除老化之葉片（葉齡約 60 至 65 天，葉緣褐化、葉身枯萎與破裂），尚無報告關於‘豐香’在栽培期間摘除葉片葉齡與產量之間的相關性。因此本試驗目的，即為透過摘除老葉與走莖等處理了解對草莓植株生長與栽培生產之影響。

二、材料與方法

（一）試驗地點與材料

本試驗於臺灣苗栗縣大湖鄉（東經 120.51°、北緯 24.25°）進行。試驗園之海拔高度約 260 公尺，2007 年 10 月至 2008 年 4 月之溫度如附錄一圖附 1-1。園區採南北向高畦雙行栽培，每畦長 12 公尺、寬 0.9 公尺、高 30 公分、行株距為 30 公

分。試驗植株為利用走莖在傳統育苗圃自行繁殖之'豐香'（桃園一號，*Fragaria* × *ananassa* Duch. cv. 'Toyonoka'）裸根苗。植株於 2007 年 10 月 13 日定植於試驗田中，定植時於每一植穴中同時混入 6.5 公克的複合肥料(N: P_2O_5: K_2O: MgO = 10: 10: 10: 3，興農）作為基肥。試驗期間按照一般田間管理隨時摘除老化之葉片（葉齡約 60 至 65 天，如附錄一圖附 3. C 及 D）。肥培、灌溉與病蟲害防治按當地栽培生產模式進行。

（二）除葉與除走莖處理

實驗處理始於 2007 年 11 月 16 日並隨即進行測量及調查至 2008 年 4 月 5 日止。本試驗採用完全逢機區集設計（randomized complete block design, RCBD），生長勢一致之受試植株計 40 株選自同一畦之同一行，試驗區依方位分為南北 2 區集。各區集中每植株為 1 實驗單位，每處理 5 重複。試驗處理分別為摘除老葉（leaf removal, LR）：每週摘除葉齡超過 45 天之葉片（葉緣出現褐化之葉片，附錄三圖附 3. A 及 B），走莖任其生長；摘除走莖（runner removal, RR）：每週摘除所有新生之走莖；葉片按照一般傳統田間管理。摘除葉片加上摘除走莖處理（leaf and runner removal, LR + RR）：每週摘除葉齡超過 45 天之葉片及所有新生之走莖；對照組（CK）則不進行上述之除葉及除走莖處理，但按照一般田間管理隨時摘除老化之葉片（葉齡約 60 至 65 天，如附錄三圖附 3. C 及 D）。

（三）植株生長及果實發育調查

1. 營養生長

各植株包含除走莖處理者之走莖發生數量逐週調查記錄之，保留走莖者各走莖依次標定並逐週測量其長度。試驗期間逐週記錄受試植株之葉片數，並測量所有葉片之中軸長度，以估算生育期間全株葉面積變化。全株葉面積以葉片樣本中軸長度與葉面積之迴歸方程式估算之。於試驗期間每週自試區旁相鄰草莓植株隨機採集不同大小之葉片，測量葉片中軸長度並以葉面積儀（LI-3100, LI-COR, Lincoln, Nebr. USA）測量葉面積後進行回歸分析，得如下方程式（附錄二圖附 2-1）：

$LA = 2.556\ L^{1.8977}$

其中：

LA：葉面積 (cm^2)

L：葉片中軸長度(cm)

藉此關係式（$r^2 = 0.985$）與實際測得之葉片長度，即可估算植株上所有葉片之葉面積進而推估全株葉面積。

2. 花期與產期

於試驗期間每週記錄花序第一朵花開花之時間及採收日數。計算試驗開始後至每期第一朵花開花所需的日數；採收日數則為植株開花後至該期果實最終採收的日數。

3. 果實生長發育

於 2008 年 2 月 15 日標定每處理受試植株中花後 12 日之二級果共 8 顆，每週測量果實縱徑與橫徑至該果採收時。各果鮮果重之變化以果實樣本果徑與鮮重之迴歸方程式估算之。在調查期間自試區旁相鄰草莓植株隨機採集正常發育、不同大小及成熟度之果實計 100 顆，測量果實縱徑與橫徑後，假設果實為圓錐體推估果實體積，果實體積再與鮮重進行回歸分析，得如下方程式（附錄四圖附 4.）：

$$Fw = 1.3482 \times [(E/2)^2 \times L \times 3.14 / 3] + 0.1747$$

其中：

Fw：果實鮮重 (g)

E：果實橫徑 (cm)

L：果實縱徑 (cm)

利用各果實之果徑及此關係式（$r^2 = 0.990$）即可推估植株上果實鮮重之變化。

4. 果實產量與品質

各果實採收期以果實已均勻轉色為標準，採收後之果實以外觀及鮮重初分為合格品及格外品，畸形果或每個果實鮮重小於 5 g 為格外品且不予加入產量之計算及後續之品質分析；合格品再細分為大於 10 g 果實與介於 5 g 和 10 g 之間果實二級，試驗期間各植株之產量逐週記錄之。合格品果實以糖度計（Hand refractometer, N-1, Atago, Tokyo, Japan）測量果汁之可溶性固形物含量(^{o}Brix)。

（四）統計分析

本試驗為複因子完全逢機區集設計（randomized complete block design,

RCBD），共分為 2 區集，各區集中每植株為 1 實驗單位，每處理 5 重複。試驗所得之數據皆以便方分析（A nalysis of variance, ANOVA）比較，變異分析同時期各處理間之差異是否達顯著水準（$P \leq 0.05$）。全季走莖發生數以摘除老葉處理與摘除走莖處理為變方，再進行雙因子變異分析（Two way analysis of variance（ANOVA））以比較除葉與除走莖對其影響（$P \leq 0.05$）。植株總葉面積與走莖發數之關係、植株總葉面積與走莖生長長度之關係皆以一次簡單直線回歸分析與計算 Correlation Coefficient 與 P value。植株總葉面積及走莖生長與處理至開花日數、採收日數、果實產量、品質等之關係以複回歸分析（Multiple linear regression），計算 Correlation Coefficient 與 P value。各處理標定之果實其連續生長狀況，以 SigmaPlot 10.0 （SPSS Inc., USAS）進行繪圖並顯示標準差（stand error）並以變異分析同時期各處理彼此間之差異（$P \leq 0.05$），確定處理間之差異達顯著水準（$P \leq 0.05$），再進一步以最小顯著性差異（Least Significant Difference $LSD_{0.05}$, CoStat 6.2, CoHort Software, USA）判定各處理彼此間之差異。

三、結果

（一）葉片與葉面積變化

各試驗植株於 2007 年 11 月 16 日進行處理前，平均葉片數約為 4 片、全株平均葉面積為 200 平方公分。處理後 21 日植株進入第一期開花階段，CK、RR 與 LR + RR 葉面積約為 500 平方公分，高於 LR 處理 170 平方公分，各處理葉片數介於 4 至 5 片葉之間，並無顯著差異。處理後 56 日植株進入第一期果實大量採收階段，在此之前，各處理植株總葉面積及葉片數皆呈現直線上升之趨勢，當植株進入此階段，植株葉面積及葉片數皆趨於穩定。CK、RR 與 LR + RR 葉面積無差異，分別為 1150、1050 與 1050 平方公分，較 LR 處理 者高 450 至 500 平方公分，LR 處理葉片數為 6 片葉低其他處理。植株第二期開花階段為處理後 77 日，LR 葉面積低於 CK、RR 與 LR + RR 處理，葉面積分別為 750、1250、1200 與 1200 平方公分，LR 處理葉片數為 6 片葉低於其他處理者。處理後 112 日植株為第二期果實大量採收期及第三期開花階段，CK、LR、RR 與 LR + RR 處理者的葉面積別為 1200、650、1050 與 1100 平方公分，且 LR 顯著低於 CK、RR 與 LR + RR 等處理。處理後 133

日試驗結束，CK、LR、RR 與 LR + RR 處理的葉面積為 1200、600、1100、1200 平方公分，葉片數為 14、8、11 與 13 片葉，無論是葉面積或是葉片數目，LR 處理皆低於其他處理（圖 2.1）。

（二）走莖生長

於試驗結束當日（2008 年 4 月 5 日）測量植株葉面積與累加走莖發生數及走莖生長長度。結果顯示，摘除走莖會促進走莖數的發生（$p = 0.016$）（表 2.1），而走莖發生數與生長皆與葉面積呈直線正向相關，隨著葉面積增加而走莖的發生數與生長總長度皆有增加的趨勢，相關係數分別為 0.65（$p = 0.0002$）與 0.75（$p < 0.0001$）（圖 2.2）。

（三）各期花開花時間與採收期

結果顯示，第一期、第二期開花日數與第一期果實採收日數皆不受摘除老葉或走莖處理影響（表 2.2、表 2.3）。第二期果實數（$p = 0.046$）與採收日數（$p = 0.002$）則明顯受葉面積影響（表 2.3），葉面積較大之植株有較多果實數，果實數的增加便延長該期採收日數，因此隨著葉面積增加而果實採收日數亦增加之趨勢。

（四）果實生長

果實橫徑生長，無論在花後 12、19 及 26 日，各處理果實橫徑皆無顯著差異（圖 2.3A）。果實縱徑生長，花後 12 日各處理均為 10 mm，無顯著差異，花後 19 日 LR 處理為 15 mm 與 CK 無顯著差異，但低於 RR、LR + RR 等處理，而花後 26 日 LR 之果實縱徑為 24 mm 亦是所有處理中最小（圖 2.3B）。果實鮮重變化與果實縱徑生長有相似的趨勢，皆是花後 12 日各處理間無顯著差異，花後 19 日 LR、LR + RR 與 CK 無顯著差異，但低於 RR 處理，而花後 26 日 LR 之果實鮮重為所有處理中最小（圖 2.3C）。

（五）果實產量與品質

第一期果中，葉面積與果實產量呈正相關；走莖生長與果實產量呈負相關。因此產量隨著葉面積增加而增加，走莖生長則有降低產量的趨勢（表 2.2）。果實單果重與果實可溶性固形物皆與葉面積成正相關，其中 P value 分別為 < 0.001 及

表 2.1. 摘除老葉與摘除走莖對‘豐香’草莓植株走莖發生之影響

Table 2.1. The effect of defoliation and runner removal on runner production in winter ‘Toyonoka’ strawberry production in subtropical Taiwan[z].

Partial defoliation	Runner removal	Runner production / plant
−[y]	−	5.1
+	−	3.0
−	+	7.2
+	+	7.4
	P-value	
	LR	0.268
	RR	0.016*[x]
	LR×RR	0.168

[z]The experiment was carried out at the field, situated in Miaoli, Taiwan. ‘Toyonoka’ strawberry plants were planted on hill row in the field on 11 October 2007 and treated on 11 November 2007. Runnering number of individual ‘Toyonoka’ strawberry plant were measured and summed on the end of experience.

[y]−: no treatment; +: had treatment; LR: partial defoliation; RR: runner removed.

[x]Statistical analyses were conducted using two way analysis of variance (CoStat 6.2, CoHort Software, USA) and the means compared with a significance degree $\alpha = 0.05$. *represent significant differences between treatments at $P \leq 0.05$.

表 2.2. 摘除老葉與摘除走莖對‘豐香’草莓植株第一期果實生產之影響

Table 2.2. The effect of defoliation and runner removal on first crop flowering, berry produce, berry yield and berry quality in winter ‘Toyonoka’ strawberry production in subtropical Taiwan[z].

Parameters	Equation	Correlation coefficient	R[y] *P*-value	L *P*-value
Harvest days	H = 0.005R+0.008L+69.535	0.145	0.576	0.059
Yield (kg per plant)	Y = -0.127R+0.076L+111.406	0.444	0.001***	<0.001***
Number of fruits per plant	N = -0.006R+0.002L+11.954	0.119	0.070	0.205
Mean fruit weight (g)	W = -0.003R+0.004L+9.291	0.511	0.031*	<0.001***
Total soluble solids (°Brix)	B = 0.0008R+0.0005L+8.746	0.244	0.108	0.041*

[z]The experiment was carried out at the field, situated in Miaoli, Taiwan. ‘Toyonoka’ strawberry plants were planted on hill rows on 11 October 2007 and treated on 11 November 2007. First crop berry production began on 25 December 2007 and ended on 29 February 2008.Only marketable fruit (greater than 5 gram, no blemishes and misshaped) were weighed, measured total soluble solids content and included in yield. Relationships between leaf area, total runner length and other (days from flowering, harvest days, yield, number of fruits per plant, mean fruit weight and total soluble solids) by the multiple linear regression analysis.*, ** and *** represent significant differences between treatments at $P \leq 0.05$, ≤ 0.01 and ≤ 0.001.

[y]R: Total runner length; L: leaf area; H: Harvest days; Y: Yield; N: fruits number; W: Mean fruit weight; B: Total soluble solids (°Brix).

表 2.3. 摘除老葉與摘除走莖對‘豐香’草莓植株第二期果實生產之影響

Table 2.3. The effect of defoliation and runner removal on second crop flowering, berry produce, berry yield and berry quality in winter ‘Toyonoka’ strawberry production in subtropical Taiwan[z].

Parameters	Equation	Correlation coefficient	R[y] *P*-value	L *P*-value
Harvest days	H=-0.003R+0.0096L+124.636	0.282	0.557	0.002**
Yield (kg per plant)	Y=-0.034R+0.0706L+76.690	0.134	0.642	0.039*
Number of fruits per plant	N=-0.002R+0.0057L+6.648	0.129	0.743	0.046*
Mean fruit weight (g)	M=0.00003R-0.000009L +12.023	< 0.001	0.987	0.992
Total soluble solids (°Brix)	B=0.0007R+0.0007L+8.705	0.296	0.200	0.014*

[z]The experiment was carried out at the field, situated in Miaoli, Taiwan. ‘Toyonoka’ strawberry plants were planted on hill rows on 11 October 2007 and treated on 11 November 2007. Second crop berry production began on 15 February 2008 and ended on 5 April 2008. Only marketable fruit (greater than 5 gram, no blemishes and misshaped) were weighed, measured total soluble solids content and included in yield. Relationships between leaf area, total runner length and other (days from flowering, harvest days, yield, number of fruits per plant, mean fruit weight and total soluble solids) by the multiple linear regression analysis. *, ** and *** represent significant differences between treatments at $P \leq 0.05$, ≤ 0.01 and ≤ 0.001.

[y]R: Total runner length; L: leaf area; Y: Yield; N: Fruits number; W: Mean fruit weight; B: Total soluble solids (°Brix).

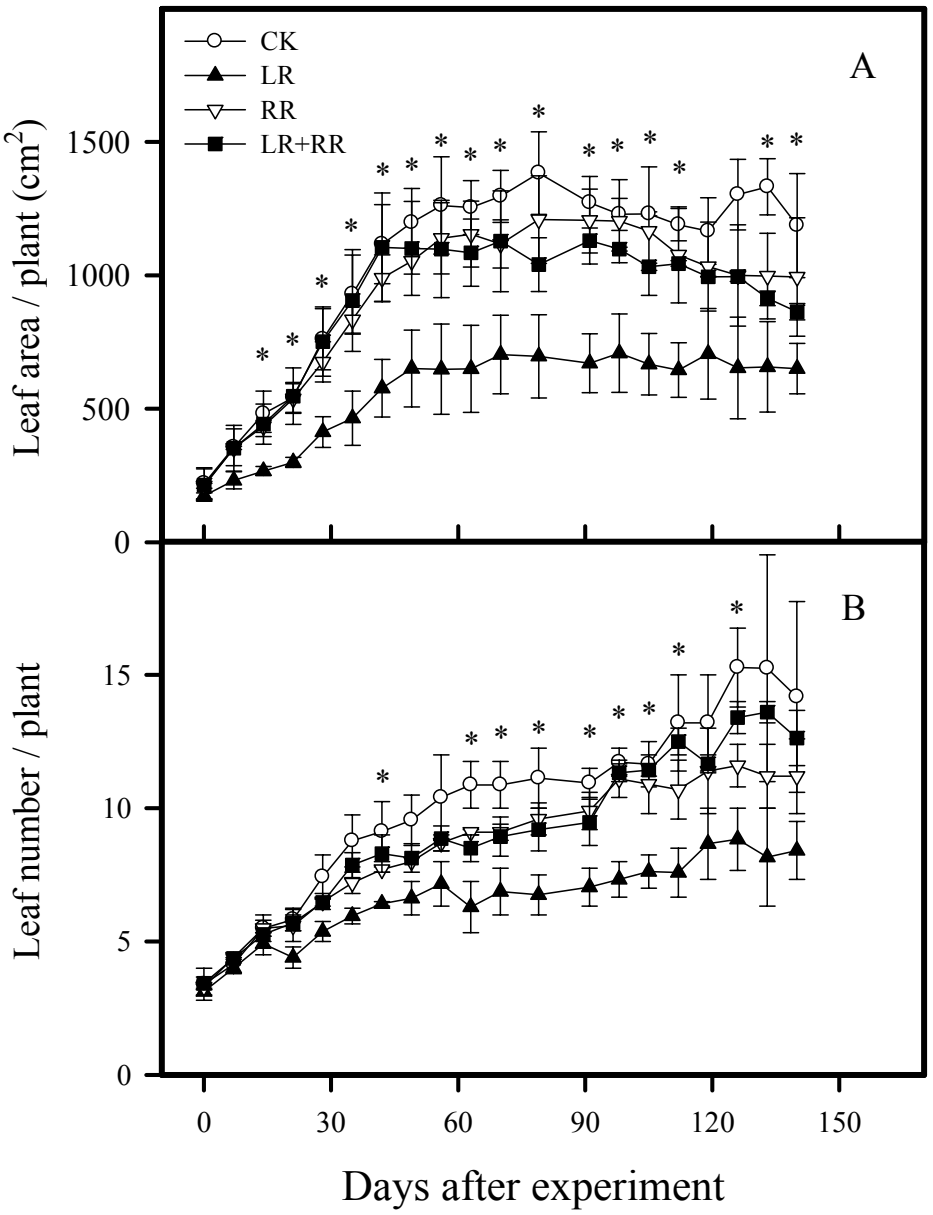

圖 2.1. 摘除老葉與摘除走莖對‘豐香’草莓植株全季葉面積與葉片數變化之影響。

Fig. 2.1. Effect of defoliation and runner removal on canopy and leaf development in winter ‘Toyonoka’ strawberry production in subtropical Taiwan. The experiment was carried out at the field, situated in Miaoli, Taiwan. ‘Toyonoka’ strawberry plants were planted on hill row in the field on 11 October 2007 and treated on 16 November 2007. Canopy leaf area development was measured from mid-November until 5 April 2008. Vertical bars indicate least significant difference (L.S.D.s) and asterisks denote significant difference among the four treatments at $P \leq 0.05$. *represent significant differences between treatments at $P \leq 0.05$.

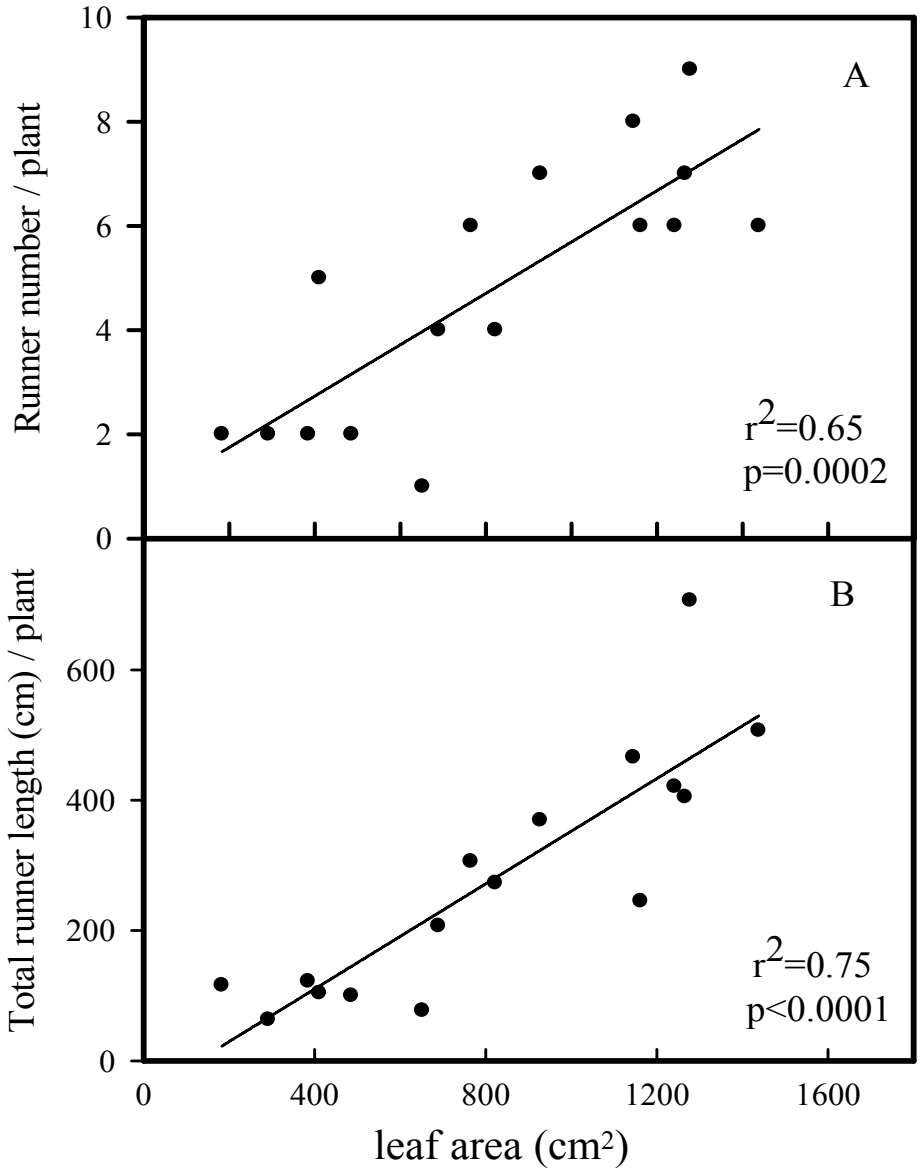

圖 2.2. 摘除老葉與摘除走莖對‘豐香’草莓植株走莖發生與生長之影響。

Fig. 2.2. Effect of defoliation and runner removal on runner development in winter ‘Toyonoka’ strawberry production in subtropical Taiwan. The experiment was carried out at the field, situated in Miaoli, Taiwan. ‘Toyonoka’ strawberry plants were planted on hill row in the field on 11 October 2007 and treated on 16 November 2007. Canopy leaf area, runnering number and total runner length of .individual ‘Toyonoka’ strawberry plant were measured and summed on the end of experience. Then used by simple linear regression. Relationship between leaf area and runner (A) and total runner length (B) in the end of experience.

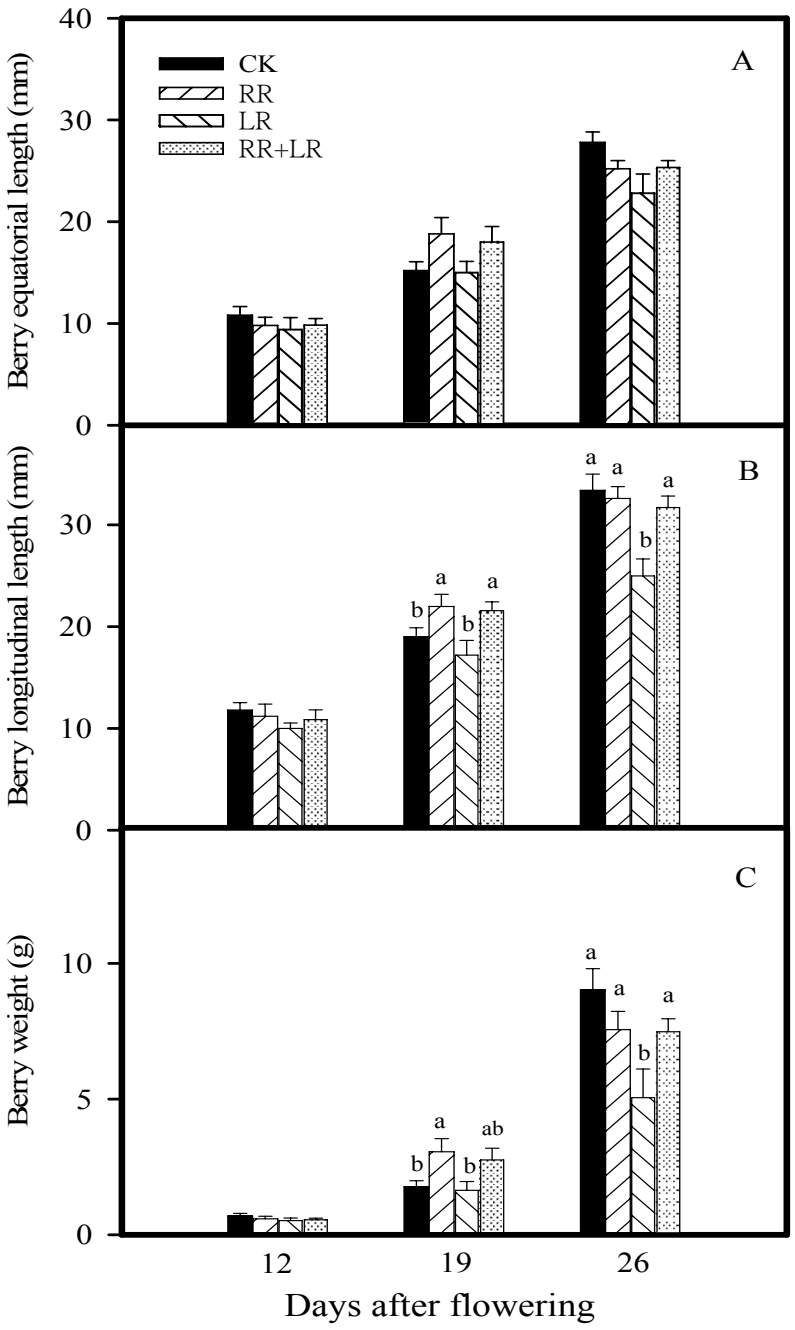

圖 2.3. 摘除老葉與摘除走莖對‘豐香’草莓植株第二期第二級果實生長之影響。

Fig. 2.3. Effect of defoliation and runner removal on secondary berry development of first crop in winter ‘Toyonoka’ strawberry production in subtropical Taiwan. The experiment was carried out at the field, situated in Miaoli, Taiwan. ‘Toyonoka’ strawberry plants were planted on hill row in the field on 11 October 2007 and treated on 16 November 2007. Berry development was measured weekly from 15 February until 29 March 2008. Vertical bars indicate least significant difference (L.S.D.s) and letters denote significant difference among the three treatments at $P \leq 0.05$ (n = 8).

0.0412（表 2.2）。第二期果，葉面積對產量、果實數與果實可溶性固形物之影響皆高於走莖，其中 P value 分別為 0.039、0.046 及 0.014，葉面積增加便提高產量、果實數與果實可溶性固形物（表 2.3）。對全季而言，隨著葉面積增加可以提昇產量、果實數及單果重；摘除走莖可減少植株分配至走莖之養分，提昇生產量、果實單果重及果實可溶性固形物（表 2.4）。

果實單果重大於 10 公克有較好的銷售價錢，因此將本試驗中可銷售果實單果重大於 10 公克之果實提出討論，以下將可銷售果實單果重大於 10 公克之果實簡稱為大果。葉面積增加與減少走莖生長提高第一期大果產量、果實數與果實單果重（表 2.5）。第二期果中，葉面積對大果產量、果實數與果實可溶性固形物之影響皆高於走莖，其中 P value 分別為 0.0388、0.0457 及 0.0140，葉面積增加提高產量、果實數與果實可溶性固形物（表 2.6）。針對全季大果產量，隨著葉面積增加皆可以提昇大果產量、果實數及單果重；而摘除走莖則亦可提昇生大果產量、果實數及果實可溶性固形物（表 2.7）。

四、討論

本試驗結果顯示草莓植株定植後經摘除走莖處理會促進走莖發生。Albregts 與 Howard （1986）在佛羅里達州利用與臺灣相同的栽培系統生產草莓，亦得到相同趨勢。兩試驗皆於 10 月中定植草莓植株，11 與 12 月為主要走莖發生之時期，此時兩地的最高溫度及平均溫度約為 25 ℃及 19 ℃，日長則為 11 小時。在此環境下相對短日型（facultative short day）草莓可自然產生走莖（Durner *et al*., 1984），當現存走莖遭摘除後在此環境下植株可再度產生走莖。走莖發生後若沒有摘除而任其自然生長，走莖生長與其他器官競爭光合產物與養分，限制植株葉面積生長（Darrow, 1936; Savini, *et al*, 2008）。

本試驗在第一期果開花結果期之前，各處理植株葉面積及葉片數皆呈現直線上升之趨勢，當植株進入開花結果期，植株葉面積及葉片數皆趨於穩定（圖 2.1）。其現像可能有兩因素造成，一為在開花結果期前，無花朵及果實等生殖器官與葉片競爭養分，因此推論營養生長階段，植株葉面積及葉片數皆有直線上升之趨勢。另一為當植株開始進入生殖生長階段，約為 12 月初期，此時試驗地區平均溫度約

表 2.2. 摘除老葉與摘除走莖對‘豐香’草莓植株第一期果實生產之影響

Table 2.2. The effect of defoliation and runner removal on first crop flowering, berry produce, berry yield and berry quality in winter ‘Toyonoka’ strawberry production in subtropical Taiwan[z].

Parameters	Equation	Correlation coefficient	R[y] *P*-value	L *P*-value
Harvest days	H = 0.005R+0.008L+69.535	0.145	0.576	0.059
Yield (kg per plant)	Y = -0.127R+0.076L+111.406	0.444	0.001***	<0.001***
Number of fruits per plant	N = -0.006R+0.002L+11.954	0.119	0.070	0.205
Mean fruit weight (g)	W = -0.003R+0.004L+9.291	0.511	0.031*	<0.001***
Total soluble solids (°Brix)	B = 0.0008R+0.0005L+8.746	0.244	0.108	0.041*

[z]The experiment was carried out at the field, situated in Miaoli, Taiwan. ‘Toyonoka’ strawberry plants were planted on hill rows on 11 October 2007 and treated on 11 November 2007. First crop berry production began on 25 December 2007 and ended on 29 February 2008.Only marketable fruit (greater than 5 gram, no blemishes and misshaped) were weighed, measured total soluble solids content and included in yield. Relationships between leaf area, total runner length and other (days from flowering, harvest days, yield, number of fruits per plant, mean fruit weight and total soluble solids) by the multiple linear regression analysis.*, ** and *** represent significant differences between treatments at $P \leq 0.05$, ≤ 0.01 and ≤ 0.001.

[y]R: Total runner length; L: leaf area; H: Harvest days; Y: Yield; N: fruits number; W: Mean fruit weight; B: Total soluble solids (°Brix).

表 2.3. 摘除老葉與摘除走莖對‘豐香’草莓植株第二期果實生產之影響

Table 2.3. The effect of defoliation and runner removal on second crop flowering, berry produce, berry yield and berry quality in winter ‘Toyonoka’ strawberry production in subtropical Taiwan[z].

Parameters	Equation	Correlation coefficient	R[y] *P*-value	L *P*-value
Harvest days	H=-0.003R+0.0096L+124.636	0.282	0.557	0.002**
Yield (kg per plant)	Y=-0.034R+0.0706L+76.690	0.134	0.642	0.039*
Number of fruits per plant	N=-0.002R+0.0057L+6.648	0.129	0.743	0.046*
Mean fruit weight (g)	M=0.00003R-0.000009L +12.023	< 0.001	0.987	0.992
Total soluble solids (°Brix)	B=0.0007R+0.0007L+8.705	0.296	0.200	0.014*

[z]The experiment was carried out at the field, situated in Miaoli, Taiwan. ‘Toyonoka’ strawberry plants were planted on hill rows on 11 October 2007 and treated on 11 November 2007. Second crop berry production began on 15 February 2008 and ended on 5 April 2008. Only marketable fruit (greater than 5 gram, no blemishes and misshaped) were weighed, measured total soluble solids content and included in yield. Relationships between leaf area, total runner length and other (days from flowering, harvest days, yield, number of fruits per plant, mean fruit weight and total soluble solids) by the multiple linear regression analysis. *, ** and *** represent significant differences between treatments at $P \leq 0.05$, ≤ 0.01 and ≤ 0.001.

[y]R: Total runner length; L: leaf area; Y: Yield; N: Fruits number; W: Mean fruit weight; B: Total soluble solids (°Brix).

表 2.4. 摘除老葉與摘除走莖對‘豐香’草莓植株全季果實生產之影響

Table 2.4. The effect of defoliation and runner removal on berry yield and berry quality in winter ‘Toyonoka’ strawberry production in subtropical Taiwan[z].

Parameters	Equation	Correlation coefficient	R[y] P value	L P value
Yield (kg per plant)	Y=-0.144R+0.136L+204.092	0.323	0.035	<0.001***
Number of fruits per plant	N=-0.006R+0.007L+19.457	0.395	0.330	0.024*
Mean fruit weight (g)	W=-0.003R+0.003L+10.227	0.439	0.021	<0.001***
Total soluble solids (°Brix)	B=0.0009R+-0.0002L+9.481	0.176	0.018*	0.209

[z]The experiment was carried out at the field, situated in Miaoli, Taiwan. ‘Toyonoka’ strawberry plants were planted on hill rows on 11 October 2007 and treated on 11 November 2007. Berry production began on 25 December 2007 and ended on 5 April 2008. Only marketable fruit (greater than 5 gram, no blemishes and misshaped) were weighed, measured total soluble solids content and included in yield. Relationships between leaf area, total runner length and other (days from flowering, harvest days, yield, number of fruits per plant, mean fruit weight and total soluble solids) by the multiple linear regression analysis. *, ** and *** represent significant differences between treatments at $P \leq 0.05$, ≤ 0.01 and ≤ 0.001.

[y]R: Total runner length; L: leaf area; H: Harvest days; Y: Yield; N: Number of fruits per plant; W: Mean fruit weight; B: Total soluble solids (°Brix).

表 2.5. 摘除老葉與摘除走莖對‘豐香’草莓植株第一期生產大於 10 克果實之影響

Table 2.5. The effect of defoliation and runner removal on first crop large berry yield and quality in winter ‘Toyonoka’ strawberry production in subtropical Taiwan[z].

Parameters	Equation	Correlation coefficient	R[y] *P*-value	L *P*-value
Yield (kg per plant)	Y=-0.137R+0.095L+63.064	0.591	< 0.001***	< 0.001***
Number of fruits per plant	N=-0.0067R+0.005L+4.795	0.462	0.003**	< 0.001***
Mean fruit weight (g)	W=-0.004R+0.003L+13.701	0.342	0.017*	< 0.001***
Total soluble solids (°Brix)	B=0.0008R+0.0005L+8.746	0.244	0.108	0.041

[z]The experiment was carried out at the field, situated in Miaoli, Taiwan. ‘Toyonoka’ strawberry plants were planted on hill rows on 11 October 2007 and treated on 11 November 2007. First crop berry production began on 25 December 2007 and ended on 29 February 2008. Marketable and large fruit (greater than 10 gram, no blemishes and misshaped) were weighed, measured total soluble solids content and included in yield. Relationships between leaf area, total runner length and other (days from flowering, harvest days, yield, number of fruits per plant, mean fruit weight and total soluble solids) by the multiple linear regression analysis. *, ** and *** represent significant differences between treatments at $P \leq 0.05$, ≤ 0.01 and ≤ 0.001.

[y]R: Total runner length; L: leaf area; H: Harvest days; Y: Yield; N: Number of fruits per plant; W: Mean fruit weight; B: Total soluble solids (°Brix).

表 2.6. 摘除老葉與摘除走莖對'豐香'草莓植株第二期生產大於 10 克果實之影響

Table 2.6. The effect of defoliation and runner removal on second crop large berry yield and quality in winter 'Toyonoka' strawberry production in subtropical Taiwan[z].

Parameters	Equation	Correlation coefficient	R[y] *P*-value	L *P*-value
Yield (kg per plant)	Y=-0.0396R-0.0552L-105.084	0.193	0.166	0.011*
Number of fruits per plant	N=-0.0054R-0.0034L-6.739	0.220	0.083	0.007**
Mean fruit weight (g)	W=-0.0002R-0.0006L-15.806	0.012	0.852	0.555
Total soluble solids (°Brix)	B=-0.0007R-0.0023L-9.441	0.121	0.513	0.049*

[z]The experiment was carried out at the field, situated in Miaoli, Taiwan. 'Toyonoka' strawberry plants were planted on hill rows on 11 October 2007 and treated on 11 November 2007. Second crop berry production began on 15 February 2008 and ended on 5 April 2008. Marketable and large fruit (greater than 10 gram, no blemishes and misshaped) were weighed, measured total soluble solids content and included in yield. Relationships between leaf area, total runner length and other (days from flowering, harvest days, yield, number of fruits per plant, mean fruit weight and total soluble solids) by the multiple linear regression analysis. *, ** and *** represent significant differences between treatments at $P \leq 0.05$, ≤ 0.01 and ≤ 0.001.

[y]R: Total runner length; L: leaf area; H: Harvest days; Y: Yield; N: Number of fruits per plant; W: Mean fruit weight; B: Total soluble solids (°Brix).

表 2.7. 摘除老葉與摘除走莖對'豐香'草莓植株全季生產大於 10 克果實之影響

Table 2.7. The effect of defoliation and runner removal on large berry yield and quality in winter 'Toyonoka' strawberry production in subtropical Taiwan[z].

Parameters	Equation	Correlation coefficient	R[y] *P*-value	L *P*-value
Yield (kg per plant)	Y=-0.197R+0.149L+130.737	0.447	0.006**	< 0.001***
Number of fruits per plant	N=-0.011R+0.008L+8.929	0.404	0.009**	< 0.001***
Mean fruit weight (g)	W=-0.001R+0.002L+14.562	0.208	0.206	0.009**
Total soluble solids (°Brix)	B=0.001R-0.00004L+9.193	0.224	0.007**	0.867

[z]The experiment was carried out at the field, situated in Miaoli, Taiwan. 'Toyonoka' strawberry plants were planted on hill rows on 11 October 2007 and treated on 11 November 2007. Berry production began on 25 December 2007 and ended on 5 April 2008. Marketable and large fruit (greater than 10 gram, no blemishes and misshaped) were weighed, measured total soluble solids content and included in yield. Relationships between leaf area, total runner length and other (days from flowering, harvest days, yield, number of fruits per plant, mean fruit weight and total soluble solids) by the multiple linear regression analysis. *, ** and *** represent significant differences between treatments at $P \leq 0.05$, ≤ 0.01 and ≤ 0.001.

[y]R: Total runner length; L: leaf area; H: Harvest days; Y: Yield; N: Number of fruits per plant; W: Mean fruit weight; B: Total soluble solids (°Brix).

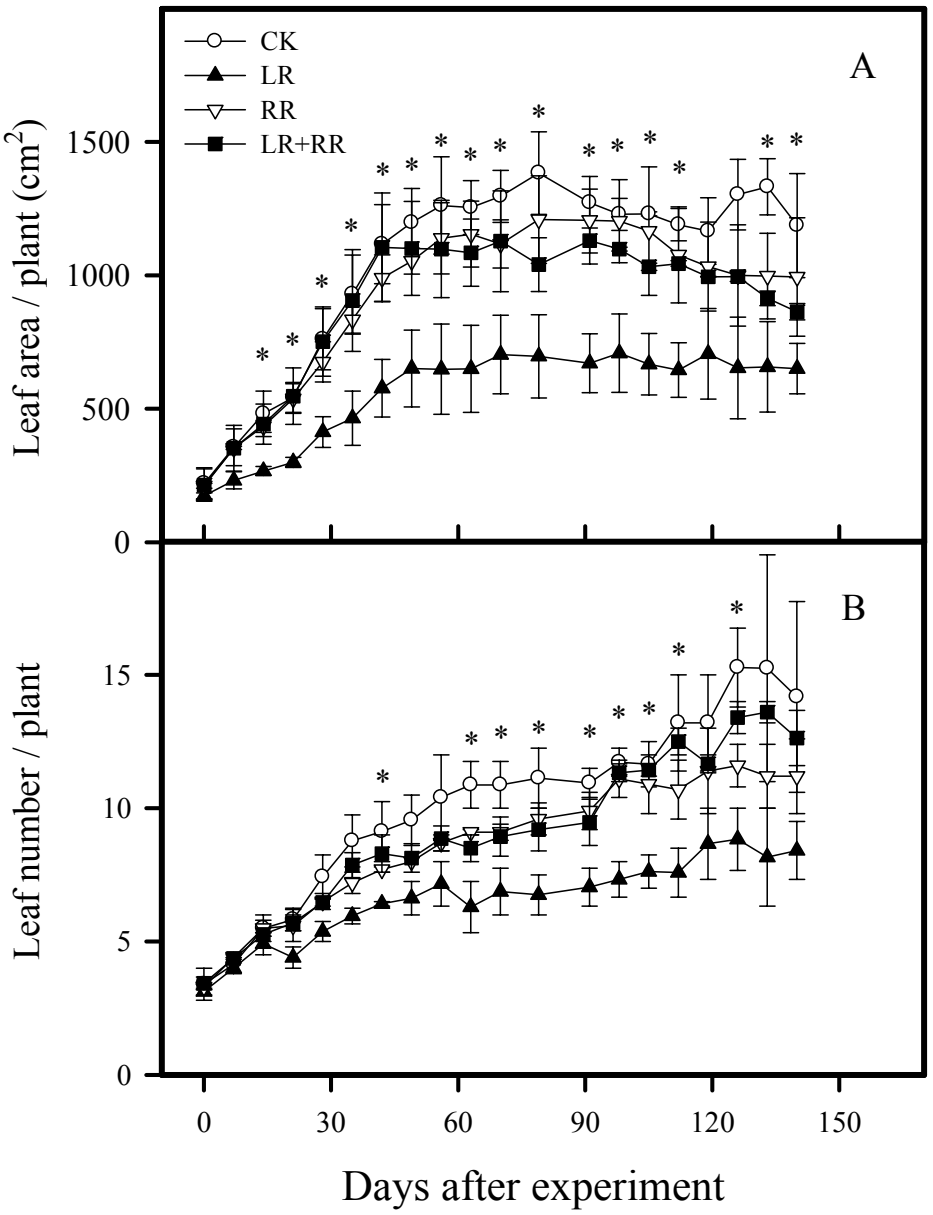

圖 2.1. 摘除老葉與摘除走莖對‘豐香’草莓植株全季葉面積與葉片數變化之影響。

Fig. 2.1. Effect of defoliation and runner removal on canopy and leaf development in winter ‘Toyonoka’ strawberry production in subtropical Taiwan. The experiment was carried out at the field, situated in Miaoli, Taiwan. ‘Toyonoka’ strawberry plants were planted on hill row in the field on 11 October 2007 and treated on 16 November 2007. Canopy leaf area development was measured from mid-November until 5 April 2008. Vertical bars indicate least significant difference (L.S.D.s) and asterisks denote significant difference among the four treatments at $P \leq 0.05$. *represent significant differences between treatments at $P \leq 0.05$.

為 20℃且開始下降。前人指出‘Chandler’、‘Sweet Charlie’、‘Earliglow’及‘Kent’等草莓品種，在平均溫度低於 20℃的栽培環境下其葉片生長差於在 23℃至 28℃等栽培環境下之植株（Kadir and Sidhu, 2006；Wang and Camp, 2000）。由此推論草莓除了因進入生殖生長而使葉片生長受限制，亦有可能受栽培地區溫度過低之影響而使葉片生長趨緩。

第一期果部分，葉面積與走莖生長皆影響產量，其中葉面積與果實產量呈正相關，而走莖生長與果實產量呈負相關。由葉面積之 P value 為<0.001 而走莖生長之 P value 為 0.001 可得知葉面積對第一期果產量之影響大於走莖生長（表 2.2）。因此葉面積大小為決定第一期果產量之重要關鍵，但摘除走莖可減少植株分配至走莖以提供其生長所需之養分，使果實獲得更多養分進而增加可銷售果實單果重與可銷售果實產量（Albregts and Howard, 1986; Black, 2004; Savini et al., 2008）。

第二期果部分，全株葉面積亦為影響產量之關鍵因子（p = 0.039），但此時走莖生長對產量的影響則為不顯著（ p = 0.642 ）（表 2.3）。第二期果生產期為 2008 年 1 月至 3 月之間，此時平均溫度介於 14 ℃至 17 ℃之間、平均日長為 10.5 小時，在此低溫短日下‘豐香’草莓極少產生走莖，故走莖數不增加，可減少植株分配至走莖提供生長之養分。此時由走莖節點所發育之葉片已成熟，其光合作用產生光合產物應可以提供走莖生長（ Savini *et al*, 2008 ）。由此可推論是在第二期果中，葉面積影響產量但走莖生長不影響產量的可能原因。

不論第一期果實產量、第二期果實產量或是全季果實產量，皆受葉面積影響（表 2.2、表 2.3、表 2.4），草莓植株生殖生長期間葉面積為決定產量的重要因子。此結果與 Carlen（2007）等人相似，若在草莓植株生殖生長階段，摘除 50%的葉片數而減少 15%至 35%之葉面積及葉果比，便減少或是僅能維持可銷售果實產量。但本試驗在第一期果開花結果期之後，植株葉面積及葉片數皆趨於穩定（圖 2.1）。Albregts（1992）等人及 Mohamed（2002）也提及栽培前期之植株生長勢與前期產量呈正相關，因此在栽培初期加速植株營養生長可能為增加產量的重要關鍵之一。

綜合以上，本試驗 LR、RR、LR + RR 與 CK 等 4 處理對草莓植株生理與生產上的影響。LR 處理可能因減少植株總葉面積而降低果實產量，因此建議葉齡小於 60 天之葉片，除非葉片健康狀況不佳、遮蔽花或果實應不予摘除。走莖生長不

僅與其他器官競爭養分，也增加田間栽培管理困難，因此建議摘除走莖不僅可以使生長中的果實獲得更多養分，亦方便田間管理。

表 2.2. 摘除老葉與摘除走莖對‘豐香’草莓植株第一期果實生產之影響

Table 2.2. The effect of defoliation and runner removal on first crop flowering, berry produce, berry yield and berry quality in winter ‘Toyonoka’ strawberry production in subtropical Taiwan[z].

Parameters	Equation	Correlation coefficient	R[y] *P*-value	L *P*-value
Harvest days	H = 0.005R+0.008L+69.535	0.145	0.576	0.059
Yield (kg per plant)	Y = -0.127R+0.076L+111.406	0.444	0.001***	<0.001***
Number of fruits per plant	N = -0.006R+0.002L+11.954	0.119	0.070	0.205
Mean fruit weight (g)	W = -0.003R+0.004L+9.291	0.511	0.031*	<0.001***
Total soluble solids (°Brix)	B = 0.0008R+0.0005L+8.746	0.244	0.108	0.041*

[z]The experiment was carried out at the field, situated in Miaoli, Taiwan. ‘Toyonoka’ strawberry plants were planted on hill rows on 11 October 2007 and treated on 11 November 2007. First crop berry production began on 25 December 2007 and ended on 29 February 2008.Only marketable fruit (greater than 5 gram, no blemishes and misshaped) were weighed, measured total soluble solids content and included in yield. Relationships between leaf area, total runner length and other (days from flowering, harvest days, yield, number of fruits per plant, mean fruit weight and total soluble solids) by the multiple linear regression analysis.*, ** and *** represent significant differences between treatments at $P \leq 0.05$, ≤ 0.01 and ≤ 0.001.

[y]R: Total runner length; L: leaf area; H: Harvest days; Y: Yield; N: fruits number; W: Mean fruit weight; B: Total soluble solids (°Brix).

表 2.3. 摘除老葉與摘除走莖對‘豐香’草莓植株第二期果實生產之影響

Table 2.3. The effect of defoliation and runner removal on second crop flowering, berry produce, berry yield and berry quality in winter ‘Toyonoka’ strawberry production in subtropical Taiwan[z].

Parameters	Equation	Correlation coefficient	R[y] *P*-value	L *P*-value
Harvest days	H=-0.003R+0.0096L+124.636	0.282	0.557	0.002**
Yield (kg per plant)	Y=-0.034R+0.0706L+76.690	0.134	0.642	0.039*
Number of fruits per plant	N=-0.002R+0.0057L+6.648	0.129	0.743	0.046*
Mean fruit weight (g)	M=0.00003R-0.000009L +12.023	< 0.001	0.987	0.992
Total soluble solids (°Brix)	B=0.0007R+0.0007L+8.705	0.296	0.200	0.014*

[z]The experiment was carried out at the field, situated in Miaoli, Taiwan. ‘Toyonoka’ strawberry plants were planted on hill rows on 11 October 2007 and treated on 11 November 2007. Second crop berry production began on 15 February 2008 and ended on 5 April 2008. Only marketable fruit (greater than 5 gram, no blemishes and misshaped) were weighed, measured total soluble solids content and included in yield. Relationships between leaf area, total runner length and other (days from flowering, harvest days, yield, number of fruits per plant, mean fruit weight and total soluble solids) by the multiple linear regression analysis. *, ** and *** represent significant differences between treatments at $P \leq 0.05$, ≤ 0.01 and ≤ 0.001.

[y]R: Total runner length; L: leaf area; Y: Yield; N: Fruits number; W: Mean fruit weight; B: Total soluble solids (°Brix).

表 2.4. 摘除老葉與摘除走莖對‘豐香’草莓植株全季果實生產之影響

Table 2.4. The effect of defoliation and runner removal on berry yield and berry quality in winter ‘Toyonoka’ strawberry production in subtropical Taiwan[z].

Parameters	Equation	Correlation coefficient	R[y] P value	L P value
Yield (kg per plant)	Y=-0.144R+0.136L+204.092	0.323	0.035	<0.001***
Number of fruits per plant	N=-0.006R+0.007L+19.457	0.395	0.330	0.024*
Mean fruit weight (g)	W=-0.003R+0.003L+10.227	0.439	0.021	<0.001***
Total soluble solids (°Brix)	B=0.0009R+-0.0002L+9.481	0.176	0.018*	0.209

[z]The experiment was carried out at the field, situated in Miaoli, Taiwan. ‘Toyonoka’ strawberry plants were planted on hill rows on 11 October 2007 and treated on 11 November 2007. Berry production began on 25 December 2007 and ended on 5 April 2008. Only marketable fruit (greater than 5 gram, no blemishes and misshaped) were weighed, measured total soluble solids content and included in yield. Relationships between leaf area, total runner length and other (days from flowering, harvest days, yield, number of fruits per plant, mean fruit weight and total soluble solids) by the multiple linear regression analysis. *, ** and *** represent significant differences between treatments at $P \leq 0.05$, ≤ 0.01 and ≤ 0.001.

[y]R: Total runner length; L: leaf area; H: Harvest days; Y: Yield; N: Number of fruits per plant; W: Mean fruit weight; B: Total soluble solids (°Brix).

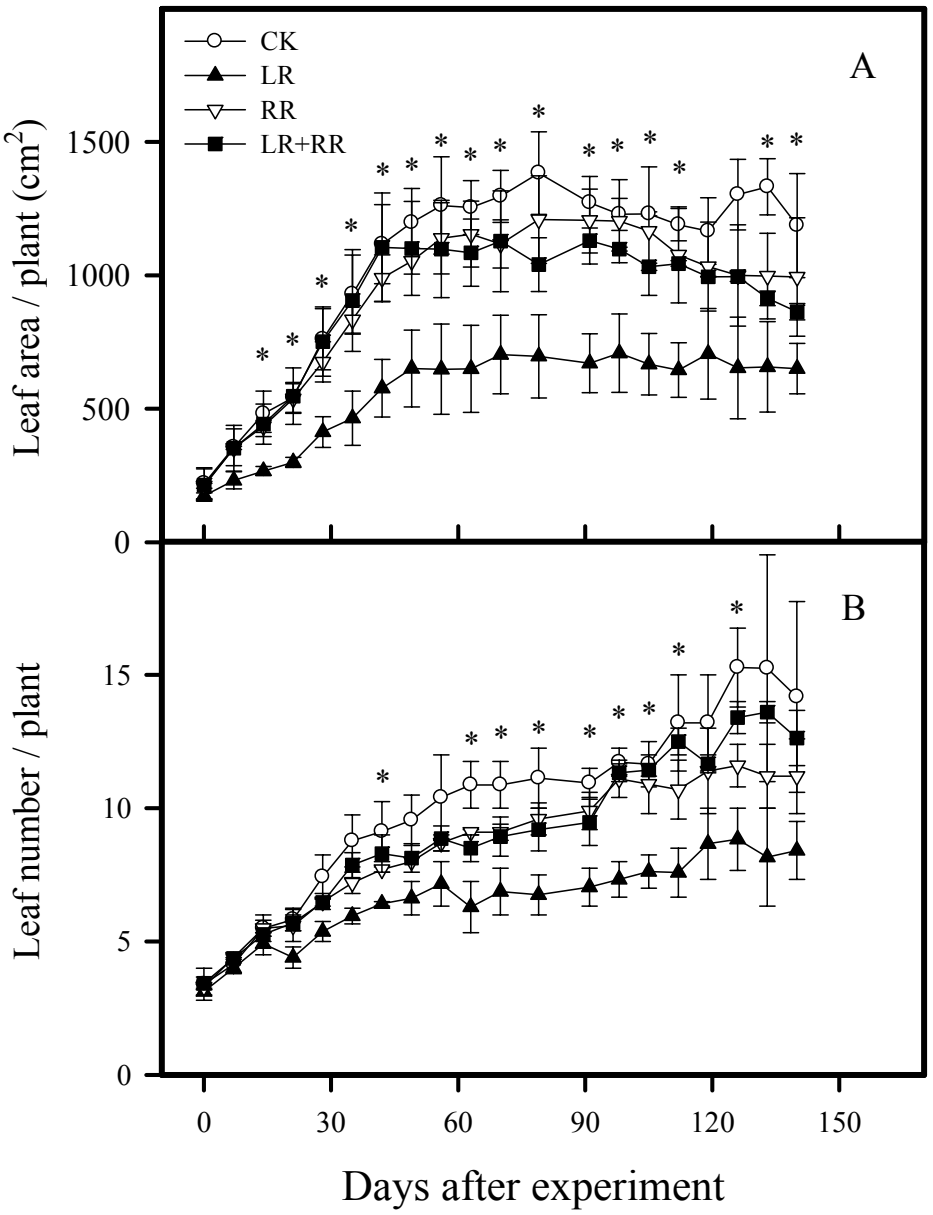

圖 2.1. 摘除老葉與摘除走莖對‘豐香’草莓植株全季葉面積與葉片數變化之影響。

Fig. 2.1. Effect of defoliation and runner removal on canopy and leaf development in winter ‘Toyonoka’ strawberry production in subtropical Taiwan. The experiment was carried out at the field, situated in Miaoli, Taiwan. ‘Toyonoka’ strawberry plants were planted on hill row in the field on 11 October 2007 and treated on 16 November 2007. Canopy leaf area development was measured from mid-November until 5 April 2008. Vertical bars indicate least significant difference (L.S.D.s) and asterisks denote significant difference among the four treatments at $P \leq 0.05$. *represent significant differences between treatments at $P \leq 0.05$.

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第三章　摘除老葉與走莖對‘豐香’草莓植株葉片光合作用能力與根系生長之影響

摘要

為探討摘除老葉與走莖等田間栽培慣行作業，對草莓植株葉片光合作用能力與根系生長之影響。本試驗在臺灣冬季以相對短日型‘豐香’草莓（桃園一號，*Fragaria* ×*ananassa* Duch. cv. ‘Toyonoka’）為試驗材料，以保麗龍為栽培容器，分別對植物定期進行摘除老葉（leaf removal, LR）、摘除走莖（runner removal, RR）、摘除老葉加上摘除走莖（leaf and runner removal, LR + RR）與對照（control, CK）等 4 處理。處理始於 2008 月 11 月 11 日結束於 2009 年 3 月 23 日，試驗期間調查及測量植株總葉面積、第二片展開葉之光合作用能力及根系生長。處理後 21 至 82 日之間，CK 與 RR 的葉面積約為 1250 平方公分高於其他兩處理 450 平方公分；處理後 105 日至試驗結束日，CK、LR、RR 與 LR + RR 處理的葉面積分別為 1200、850、120 與 1050 平方公分，而 CK 與 RR 顯著高於 LR 但與 LR + RR 無顯著差異。處理前一小時，各處理間葉片光合作用能力無顯著差異；處理後 1 日，摘除老葉會使葉片光合作用能力上升，而隔天（處理後 2 日）又回復到與處理前一小時（BT）相似之狀況。處理後 10 日，CK 及 RR 的根系密度相對生長速率與處理前 6 日相比下增加 50%，顯著高於 LR 及 LR + RR 的 3%與 9%。試驗結束後測得植株鮮重與乾重，摘除老葉降低植株總鮮重、地下部鮮重、總乾重、地上部乾重與地下部乾重，而摘除走莖則無影響。摘除老葉降低植株生長勢，進而減少產量，因此推測老葉仍然具有供給植株光合產物之功用。摘除走莖對植株生長勢影響不大，但可使發育中的果實獲得更多養分，提昇果實單果重及產量。

關鍵字：草莓、摘除老葉、摘除走莖、光合作用、根系生長、鮮乾重、產量

一、前言

臺灣地區冬季利用高畦栽培系統（hill row system）生產草莓，栽培種為相對短日型‘豐香’草莓（桃園一號，*Fragaria* ×*ananassa* Duch. cv. ‘Toyonoka’）（李, 1993）。栽培初期，植株具有同時發育新葉、走莖生長、花芽分化與開花結果等特性，摘除走莖與葉片管理為田間栽培中的兩項重要工作。走莖生長限制植株葉面積生長與根系生長（Buckley and Moore, 1982; Darrow,1936; Savini *et al*, 2008; Schaffter *et al*, 1986），摘除或抑制走莖生長可以使植株地上部與地下部內皆有較高的碳水化合物進而提昇果實產量（Black, 2004; Nishizawa, 1993; Sachs and Iszak, 1975）。葉片生長與植株生長勢、走莖生長、根系生物量和果實產量等皆皆呈正相關（Albregts et al, 1992; Chandler et al, 1988; Mohamed, 2002; Savini, et al, 2008），葉片葉齡與其葉片光合作用能力之關係，葉齡 10 天的葉片始測得淨光合作用，葉齡 17 至 27 天淨光合作用率達最高峰，葉齡 30 天後淨光合作用率急速下降，葉齡 40 天淨光合作用率僅為最大值的 40%。當葉片自然老化過程中，葉片顏色會出現明顯的變化（Jurik *et al*., 1979）。然而尚無報告有關於‘豐香’在栽培期間持續性的摘除走莖與不同葉齡之葉片對葉片光合作用能力與根系生長之影響。因此本試驗目的，即為透過盆栽持續性的進行摘除老葉與走莖等處理，連續性的觀察根系生長與測量成熟葉片之葉片光合作用能力。

二、材料與方法

（一）試驗地點與材料

本試驗於臺灣大學農業試驗園藝分場進行，試驗期間溫度如附錄一圖附 1-3.。試驗植株為‘豐香’（桃園一號，*Fragaria* × *ananassa* Duch. cv. ‘Toyonoka’） 穴植管苗。植株於 2008 年 9 月 21 日定植於長 40 公分、寬 34 公分、高 28 公分的保麗龍盆中，土壤介質為泥炭、田土與牛糞以等體積混合。試驗期間按照一般田間管理隨時摘除老化之葉片（葉齡約 60 至 65 天，如附錄三圖附 3. C 及 D）。肥培、灌溉與病蟲害防治按栽培生產模式進行。

試驗處理始於 2008 年 11 月 11 日（定植後 51 日後）並隨即進行測量及調查至 2009 年 3 月 31 日止。本試驗採用完全逢機區集設計（randomized complete block design, RCBD），生長勢一致之受試植株計 16 株，試驗區共分為 4 區集。各區集中每植株為 1 實驗單位，每重複 1 植株。試驗處理分別為摘除老葉（leaf removal, LR）：每次處理摘除葉齡超過 45 天之葉片（葉緣出現褐化之葉片，附錄三圖附 3. A 及 B）。除走莖 （runner removal, RR）：每次處理摘除所有新生之走莖；葉片按照一般傳統田間管理。摘除老葉加上摘除走莖處理（leaf and runner removal, LR + RR）：每次處理摘除葉齡超過 45 天之葉片及所有新生之走莖；對照組（CK）則不進行上述之摘除老葉及摘除走莖處理。

（二）植株生長

1. 葉面積生長

在試驗前及試驗期間每次處理記錄受試植株之葉片數並測量所有葉片之中軸長度以估算生育期間全株葉面積變化。全株葉面積以葉片樣本中軸長度與葉面積之迴歸方程式估算之。於試驗期間每週自試區旁相鄰草莓植株隨機採集不同大小之葉片，測量葉片中軸長度並以葉面積儀（LI-3100, LI-COR, Lincoln, Nebr. USA）測量葉面積後進行回歸分析，得如下方程（附錄二圖附 2-2.）：

$LA = 2.4067L^{1.9321}$

其中：

LA： 葉面積（cm^2）

L：葉片中軸長度（cm）

藉此關係式（$r^2 = 0.974$）與實際測得之葉片長度即可估算植株上所有葉片之葉面積而推估全株葉面積。

2. 光合作用測定

於試驗期間每次處理前標定受試植株的第二片展開葉（葉齡約 25 至 30 天），分別在處理前 1 小時（BT）、處理後一天（DAT1）與處理後兩天（DAT2），測定葉片之光合作用能力，連續三日的測定為 1 個組合共有 9 個組合。測定光合作用能力的儀器為可攜式光合作用測定儀（含人工光源 6400-02B Blue/Red LED source）（LI-6400, LI-COR, Lincolin, Nebraska, USA），測量標定葉片之光合作用

速率，而測定的時間在早晨 9 時至 11 時之間（測量設定條件: 光度以人工光源 6400-02B Blue/Red LED source 設定為 1,000 μE $m^{-2}·s^{-1}$、相對溼度為 50%、二氧化碳濃度以 LI-6400 注射器及二氧化碳鋼瓶設定為 375 ppm、測定葉面積為 6 cm^2）。

3. 根系生長

根系之生長由植株盆器壁上根窗記錄之。根窗由一長 26 公分、寬 12 公分與厚 0.55 公分之玻璃片製成，根窗外覆一長 32 公分、寬 20 公分之厚紙板以避免光照。每一根窗由格線劃分為長寬各 1 公分之記錄單位，計共 312 格。分別在試驗前 6 日、試驗後 10、20、29、41、55、66、77、87、97、110、124 及 135 日觀測記錄各小格內之根數目，累加各小格之根數目記為該受試植株根系生長量，根系之生長以相對生長速率表示：

$G = [(R_x - R_0) / R_0] \times 100\%$，其中

G：根系生長之相對生長速率

R_x：分別為試驗後 10、20、29、41、55、66、77、87、97、110、124 及 135 日所觀測之植株根系生長量

R_0：試驗前 6 日所觀測之植株根系生長量

4. 果實產量與品質

果實採收以果實已均勻轉色為標準，採收後之果實以外觀及鮮重初分為合格品及格外品，畸形果或每個果實鮮重小於 5 公克 為格外品且不予加入產量之計算及後續之品質分析。試驗期間各植株之產量逐週記錄之。合格品果實以糖度計（Hand refractometer, N-1, Atago, Tokyo, Japan）測量果汁之可溶性固形物含量（°Brix）。

5. 植株鮮重與乾物重

2009 年 3 月 20 日為試驗結束日，將受試植株以清水沖洗乾淨再以布拭乾後，分為地下部與地下部分別秤其重量；植株體以烘箱 70 ℃烘乾 120 小時後秤重測得植株體乾物重。

（三）統計分析

本試驗為複因子完全逢機區集設計（randomized complete block design,

RCBD），共分為 4 區集，各區集中每植株為 1 實驗單位，每重複 1 植株。試驗所得之數據皆以便方分析（A nalysis of variance, ANOVA）比較，變異分析同時期各處理間之差異是否達顯著水準（$P \leq 0.05$）。葉片光合作用能力值，皆與同區集中 CK 處理比較以相對值呈現，數值先以開方根轉換再進行變異分析，確定處理間之差異達顯著水準（$P \leq 0.05$），再進一步以最小顯著性差異（Least Significant Difference $LSD_{0.05}$,CoStat 6.2, CoHort Software, USA）判定各處理彼此間之差異。植株總葉面積及走莖生長與處理至開花日數、採收日數、果實產量、品質等之關係以複回歸分析（Multiple linear regression），計算 Correlation Coefficient 與 P value。植株鮮重及乾物重以摘除老葉處理與摘除走莖處理為變方，再進行雙因子變異分析（Two way analysis of variance (ANOVA)）以比較除葉與除走莖對其影響（$P \leq 0.05$）。

三、結果

（一）植株葉面積變化

各試驗植株於 2007 年 11 月 5 日（處理前 6 日），平均葉面積為 2100 平方公分。處理後 21 至 82 日，植株經歷第一期開花、結果、採收、與第二期開花及結果。此段期間各植株葉面積變化不大，大至可以分為兩個群組，CK 與 RR 的葉面積約為 1250 平方公分高於 LR 與 LR + RR 450 平方公分。處理後 105 日至試驗結束日（處理後 141 日）為第二期結果與採收階段，CK、LR、RR 與 LR + RR 處理的葉面積分別為 1200、850、120 與 1050 平方公分，而 CK 與 RR 顯著高於 LR 但與 LR + RR 無顯著差異（圖 3.1）。

（二）葉片之光合作用能力

此試驗中葉片之光合作用能力測定，在 9 個時間點連續三日測定第二片展開葉之光合作用能力，連續三日的測定可稱為一個組合：分別為摘除走莖與摘除老葉處理前一小時（BT）、後一天（DAT1）與後兩天（DAT2）。無論在哪一組合的 BT，各處理間葉片光合作用能力與 CK 相較都介於正負 10%之間且無達到顯著差異。在 1 DAT，LR 與 RR + LR 的葉片光合作用能力皆高於 CK 10%至 30%之間，

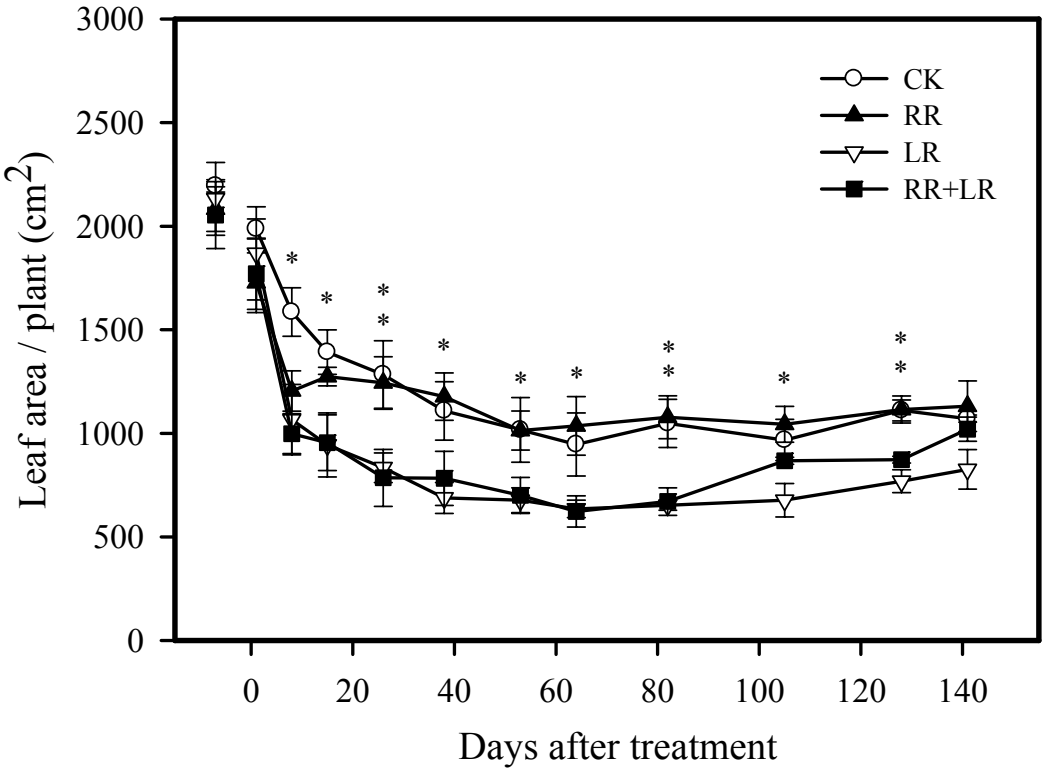

圖 3.1. 摘除老葉與摘除走莖對‘豐香’草莓植株葉面積生長之影響。

Fig. 3.1. Runner removal and defoliation affects leaf areas development in ‘Toyonoka’ strawberries for winter production in Taiwan. The experiment was carried out at the field, situated in Horticulture Research, Experimental Farm, College of Bio-Resources and Agriculture of National Taiwan University. ‘Toyonoka’ strawberry plants were planted on hill row in the field on 21 September 2008 and treated on 11 November 2008. Canopy leaf area development was measured from 5 November until 20 March 2009. Vertical bars indicate least significant difference (L.S.D.s) and asterisks denote significant difference among the four treatments at $P \leq 0.05$. * and ** represent significant differences between treatments at $P \leq 0.05$ and 0.001.

而 RR 與 CK 則是無顯著差異且在 B、C、H 組合中與 LR 及 RR + LR 為無顯著差異，但在其他組合（A、D、E、F、G、I）中皆低於 LR 及 RR + LR 5%至 25%。在 2 DAT 與 BT 有類似現象，RR、LR 及 RR + LR 的葉片光合作用能力與 CK 相較也是皆介於正負 10%之間且無達到顯著差異。綜合以上，整體而言在摘除走莖與摘除老葉處理前一小時（BT），各處理間葉片光合作用能力無顯著差異。處理後 1 日，摘除老葉會使葉片光合作用能力上升，而隔天（處理後 2 日）又回復到與處理前一小時（BT）相似之狀況（圖 3.3）。

（三）根系生長

進行處理後 10 日，CK 及 RR 的根系密度相對生長速率與處理前 6 日相比下增加 50%，顯著高於 LR 及 LR + RR 的 3%與 9%。處理後 20 日至試驗結束日（處理後 145 日），CK 及 RR 的皆維持在 50%以上，而 LR 及 LR + RR 皆未超過 50%，但未達到顯著差異水準（圖 3.2）。

（四）果實產量與品質

植株總葉面積與可銷售產量（$r^2 = 0.752$）及可銷售果實單果重（$r^2 = 0.664$）呈正相關；走莖生長是呈負相關。植株總葉面積及走莖生長皆不影響可銷售果實數與可銷售果實可溶性固形物。隨著植株總葉面積增加可以提昇可銷售產量（$p < 0.001$）、可銷售果實單果重（$p = 0.038$）；摘除走莖減少植株分配至走莖以提供其生長所需之養分，亦可提昇可銷售產量（$p = 0.042$）、可銷售果實單果重（$p = 0.027$）（表 3.2）。

（五）植株鮮重與乾重

摘除走莖與摘除老葉皆不影響地上部鮮重，但摘除老葉降低植株總鮮重與地下部鮮重。植株乾重，摘除老葉使植株總乾重、地上部乾重與地下部乾重下降，而摘除走莖對植株總乾重、地上部乾重與地下部乾重皆無影響（表 3.1）。

四、討論

在處理後 1 日，摘除老葉會暫時提高葉片光合作用能力 15%至 30%（圖 3.3）。

表 3.1. 摘除老葉與摘除走莖對‘豐香’草莓植株鮮重及乾重之影響

Table 3.1. Effect of runner removal and defoliation on aboveground fresh weight, aboveground dry weight, underground fresh weight, underground dry weight , Total fresh weight and total dry weight of plant at the end of the experiment[z].

Partial defoliation	Runner removal	Aboveground fresh weight	Aboveground dry weight	Underground fresh weight	underground dry weight	Total fresh weight	Total dry weight
−[y]	−	96.53	23.16	89.36	19.64	185.90	42.80
+	−	84.66	19.28	126.38	28.61	211.04	47.89
−	+	86.55	18.77	81.22	17.79	167.77	36.56
+	+	72.91	15.95	79.23	16.66	152.15	32.61
P-value							
LR		0.190	0.037**[x]	0.008**	0.019*	0.009**	0.006**
RR		0.131	0.063	0.061	0.141	0.689	0.854
LR×RR		0.911	0.743	0.041*	0.067	0.111	0.171

[z]The experiment was situated in Horticulture Research, Experimental Farm, College of Bio-Resources and Agriculture of National Taiwan University. ‘Toyonoka’ strawberry plants were planted on hill row in the field on 21 September 2008 and treated on 11 November 2008. The trial was a randomized complete block design with four treatments: 1) LR: partial defoliation; 2) RR: runner removed; 3) LR + RR; 4) CK: controls. At the end of the experiment, the fresh weight of the aboveground and underground of plant was measured, and then both tops were dried in an oven for 120 hours at 70 ℃ and their dry weights were measured.

[y]−: no treatment; +: had treatment; LR: partial defoliation; RR: runner removed.

[x]Statistical analyses were conducted using two way analysis of variance (CoStat 6.2, CoHort Software, USA) and the means compared with the significance degree $\alpha = 0.05$. *, ** and *** represent significant differences between treatments at $P \leq 0.05$, ≤ 0.01 and ≤ 0.001.

表 3.2. 摘除老葉與摘除走莖對‘豐香’草莓植株全季果實生產之影響

Table 3.2. The effect of defoliation and runner removal on berry yield and berry quality in winter ‘Toyonoka’ strawberry production in subtropical Taiwan[z].

Parameters	Equation	Correlation coefficient	R[y] *P*-value	L *P*-value
Yield (kg per plant)	Y = -0.150R+0.122L-27.425	0.752	0.042*	<0.001***
Number of fruits per plant	N = 0.00009R+0.005L+1.885	0.220	0.892	0.133
Mean fruit weight (g)	W = -0.029R+0.009L+6.140	0.664	0.027*	0.038*
Total soluble solids (°Brix)	B = 0.005R+0.0009L+7.535	0.246	0.061	0.209

[z]The experiment was carried out at the field, situated in Miaoli, Taiwan. ‘Toyonoka’ strawberry plants were planted on hill rows on 21 September 2008 and treated on 11 November 2008. Berry production began on 10 January 2009 and ended on 27 March 2009. Only marketable fruit (greater than 5 gram, no blemishes and misshaped) were weighed, measured total soluble solids content and included in yield. Relationships between leaf area, total runner length and other (yield, number of fruits per plant, mean fruit weight and total soluble solids) by the multiple linear regression analysis. *, ** and *** represent significant differences between treatments at $P \leq 0.05$, ≤ 0.01 and ≤ 0.001.

[y]R: Total runner length; L: leaf area; Y: Yield; N: Number of fruits per plant; W: Mean fruit weight; B: Total soluble solids (°Brix).

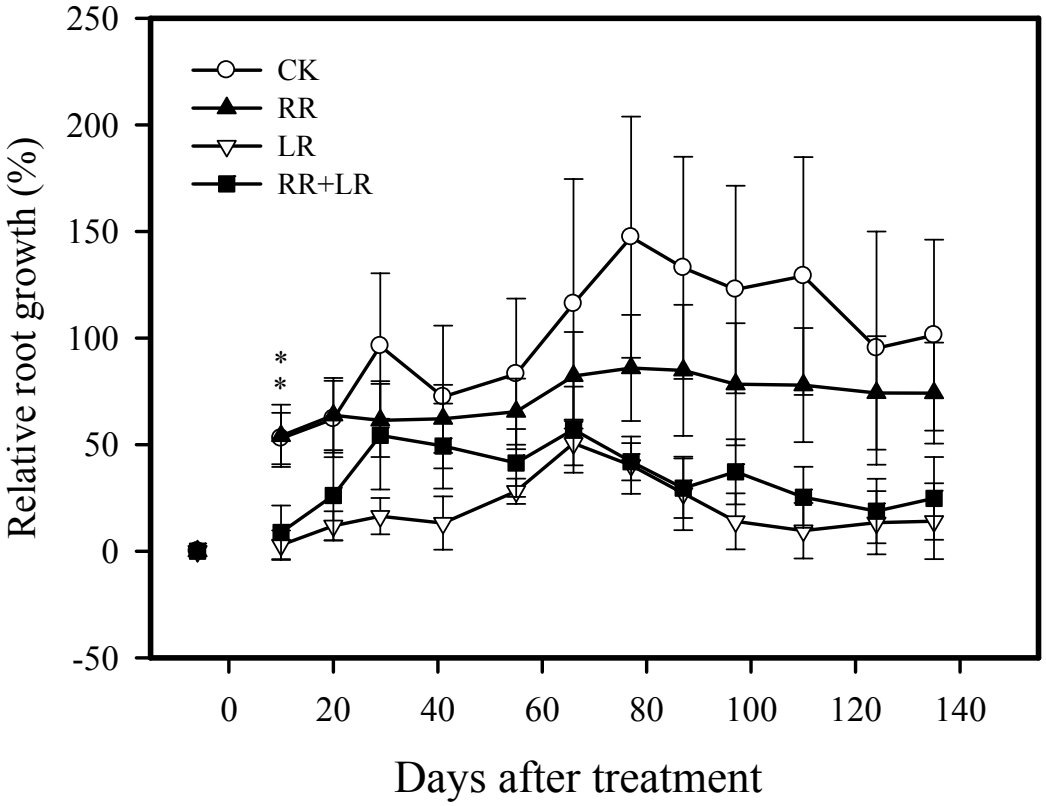

圖 3.2. 摘除老葉與摘除走莖對‘豐香’草莓植株根系生長之影響。

Fig. 3.2. Runner removal and defoliation affects Root Zone development in ‘Toyonoka’ strawberries for winter production in Taiwan. The experiment was carried out at the field, situated in Horticulture Research, Experimental Farm, College of Bio-Resources and Agriculture of National Taiwan University. ‘Toyonoka’ strawberry plants were planted on hill row in the field on 21 September 2008 and treated on 11 November 2008. Root Zone development was measured from 5 November until 20 March 2009. Vertical bars indicate least significant difference (L.S.D.s) and asterisks denote significant difference among the four treatments at $P \leq 0.05$. * and ** represent significant differences between treatments at $P \leq 0.05$ and 0.001.

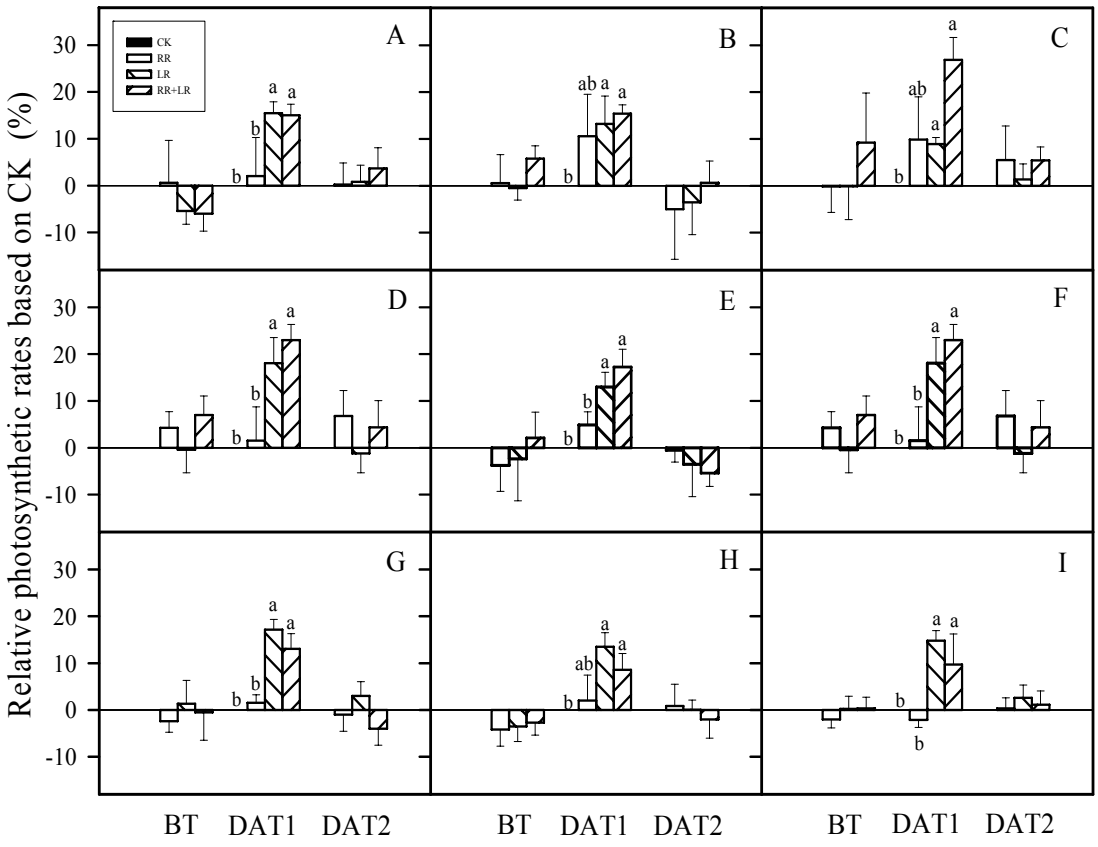

圖 3.3. 摘除老葉與摘除走莖對'豐香'草莓植株葉片光合作用能力之影響。

Fig. 3.3. Runner removal and defoliation affects photosynthesis in 'Toyonoka' strawberries for winter production in Taiwan.The experiment was carried out at the field, situated in Horticulture Research, Experimental Farm, College of Bio-Resources and Agriculture of National Taiwan University. 'Toyonoka' strawberry plants were planted on hill row in the field on 21 September 2008 and treated on 11 November 2008. Photosynthesis rates were was measured nine grope (A) 19 November to 21 November (B) 25 November to 27 November (C) 6 December to 8 December (D) 17 December to 19 December (E) 2 January to 4January (F) 13 January to 15 January (G) 31 January to 2 February (H) 23 February to 25 February (I) 10 March to 13 March from 19 November until 13 March 2009. One grope had three measures: 1) BT: 1hr before treatment; 2) DAT1: 1 day treatment; 3) DAT2: 2 day treatment. Photosynthesis rates were determined with obtained photosynthesis rate values between 9 and 11 h. Vertical bars indicate least significant difference (L.S.D.s) and letters denote significant difference among the four treatments at $P \leq 0.05$ (n = 4).

Poni 等人（2006）利用 *Vitis vinifera* L.為試驗材料，在結果期間進行枝條修剪（修剪之枝條包含成熟葉），修剪後 2 天成熟葉之光合作用能力亦上升。而 Meyer（1998）以 *Solidago altissima* 為試驗材料進行除葉處理，處理後植株葉片之光合作用能力亦有上升之趨勢。當光合產物充足時抑制光合作用能力，若修剪或是摘除仍具供源能力之葉片減少光合產物供應，便激發其他葉片便提高光合作用效率（Iglesias *et al*., 2002）。本試驗在處理後 2 日，摘除老葉處理之葉片光合作用效率便回復到處理前之狀態（圖 3.3）。推測摘除老葉雖仍具供源之能力，但可能處於供源轉為積儲之臨界點，其光合作用能力對植株貢獻不大（Jurik *et al*., 1979）。

本試驗結果顯示，摘除老葉減少植株葉面積，而摘除走莖對葉面積則不顯著（圖 3.1）。前人研究提及在栽培前期、中期及後期摘除老葉皆會減少植株葉面積（Mohamed, 2002; Carlen *et al*., 2007; Reekie *et al*., 2007），而對本試驗而言摘除之老葉（葉齡約 45 天）可能仍為供源可以提供植株光合產物，摘除後植株光合產物來源減少，因而減少植株葉面積。此結果可與第二章試驗結果驗證，摘除老葉（葉齡約 45 天）僅能短暫提昇成熟葉片之光合作用能力，提昇光合作用能力所產生光合產物，不一定能補足遭摘除老葉所產生光合產物，且老葉（葉齡約 45 天）可能仍為供源能力，因此摘除老葉後便減少提供植株之光合產物，進而降低果實產量。

Reekie 等人（2007）利用 Prohexadione-calcium 抑制草莓植株走莖發生，並促進根系生長。但本試驗摘除走莖對根系生長影響不顯著（圖 3.2），Prohexadione-calcium 為激勃素（gibberellin, GA）生合成抑制劑，施用在草莓植株除了抑制走莖發生，亦增加葉片淨光合作用速率與影響植株其他生化反應（Reekie and Hicklenton, 2002），因而促進根系生長。本試驗結果顯示，摘除老葉減少植株根系生長（圖 3.2）。Reekie 等人（2007）在草莓植株開花結果時摘除仍是積貯（sink）之新葉使其他器官獲得更多養分且促進根系生長。而本試驗摘除仍具供源（source）能力之葉片減少光合產量之供應，因而減少根系生長。

摘除老葉減少植株葉面積，而葉面積大小與植株鮮乾重有極高的相關性，較大的植株葉面積有較佳的植株鮮乾重（Mohamed, 2002; Reekie *et al*., 2005; Reekie *et al*., 2007）。本試驗亦有相同之趨勢（表 3.1），但在地上部鮮重方面各處理間無顯著差異，推測可能本試驗將 CK 及 LR 等處理受試植株，發生之走莖與其節點形

表 3.1. 摘除老葉與摘除走莖對‘豐香’草莓植株鮮重及乾重之影響

Table 3.1. Effect of runner removal and defoliation on aboveground fresh weight, aboveground dry weight, underground fresh weight, underground dry weight , Total fresh weight and total dry weight of plant at the end of the experiment[z].

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P-value							
LR		0.190	0.037**[x]	0.008**	0.019*	0.009**	0.006**
RR		0.131	0.063	0.061	0.141	0.689	0.854
LR×RR		0.911	0.743	0.041*	0.067	0.111	0.171

[z]The experiment was situated in Horticulture Research, Experimental Farm, College of Bio-Resources and Agriculture of National Taiwan University. ‘Toyonoka’ strawberry plants were planted on hill row in the field on 21 September 2008 and treated on 11 November 2008. The trial was a randomized complete block design with four treatments: 1) LR: partial defoliation; 2) RR: runner removed; 3) LR + RR; 4) CK: controls. At the end of the experiment, the fresh weight of the aboveground and underground of plant was measured, and then both tops were dried in an oven for 120 hours at 70 ℃ and their dry weights were measured.

[y]−: no treatment; +: had treatment; LR: partial defoliation; RR: runner removed.

[x]Statistical analyses were conducted using two way analysis of variance (CoStat 6.2, CoHort Software, USA) and the means compared with the significance degree $\alpha = 0.05$. *, ** and *** represent significant differences between treatments at $P \leq 0.05$, ≤ 0.01 and ≤ 0.001.

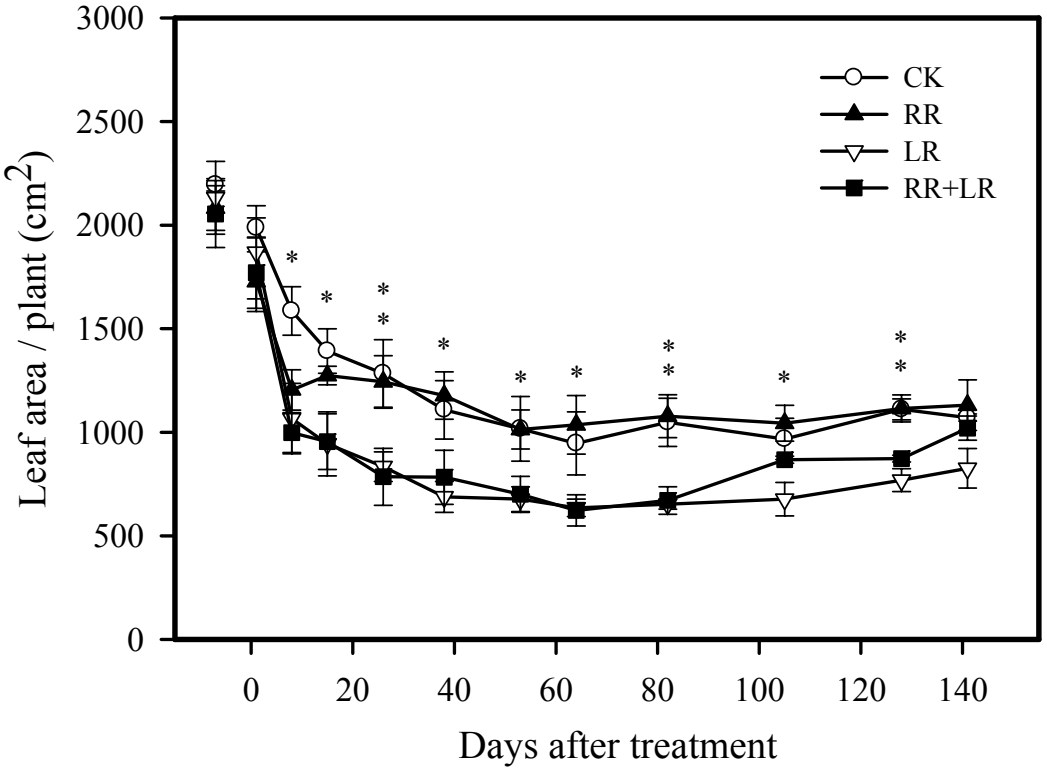

圖 3.1. 摘除老葉與摘除走莖對‘豐香’草莓植株葉面積生長之影響。

Fig. 3.1. Runner removal and defoliation affects leaf areas development in ‘Toyonoka’ strawberries for winter production in Taiwan. The experiment was carried out at the field, situated in Horticulture Research, Experimental Farm, College of Bio-Resources and Agriculture of National Taiwan University. ‘Toyonoka’ strawberry plants were planted on hill row in the field on 21 September 2008 and treated on 11 November 2008. Canopy leaf area development was measured from 5 November until 20 March 2009. Vertical bars indicate least significant difference (L.S.D.s) and asterisks denote significant difference among the four treatments at $P \leq 0.05$. * and ** represent significant differences between treatments at $P \leq 0.05$ and 0.001.

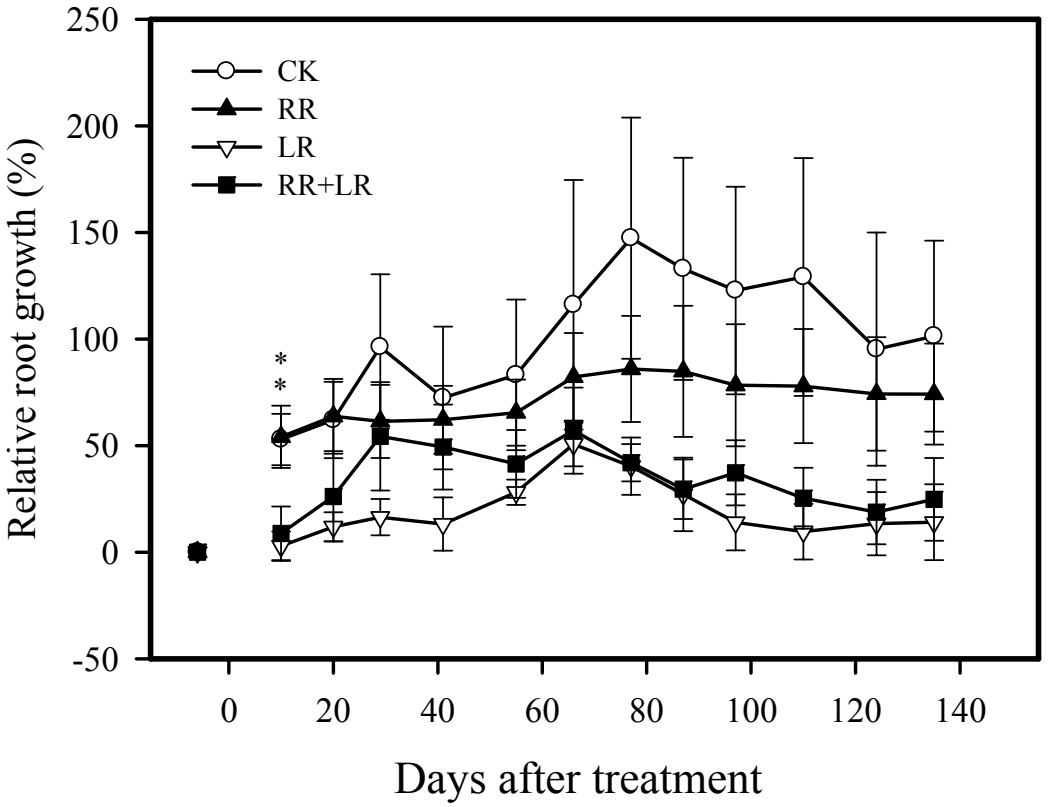

圖 3.2. 摘除老葉與摘除走莖對‘豐香’草莓植株根系生長之影響。

Fig. 3.2. Runner removal and defoliation affects Root Zone development in ‘Toyonoka’ strawberries for winter production in Taiwan. The experiment was carried out at the field, situated in Horticulture Research, Experimental Farm, College of Bio-Resources and Agriculture of National Taiwan University. ‘Toyonoka’ strawberry plants were planted on hill row in the field on 21 September 2008 and treated on 11 November 2008. Root Zone development was measured from 5 November until 20 March 2009. Vertical bars indicate least significant difference (L.S.D.s) and asterisks denote significant difference among the four treatments at $P \leq 0.05$. * and ** represent significant differences between treatments at $P \leq 0.05$ and 0.001.

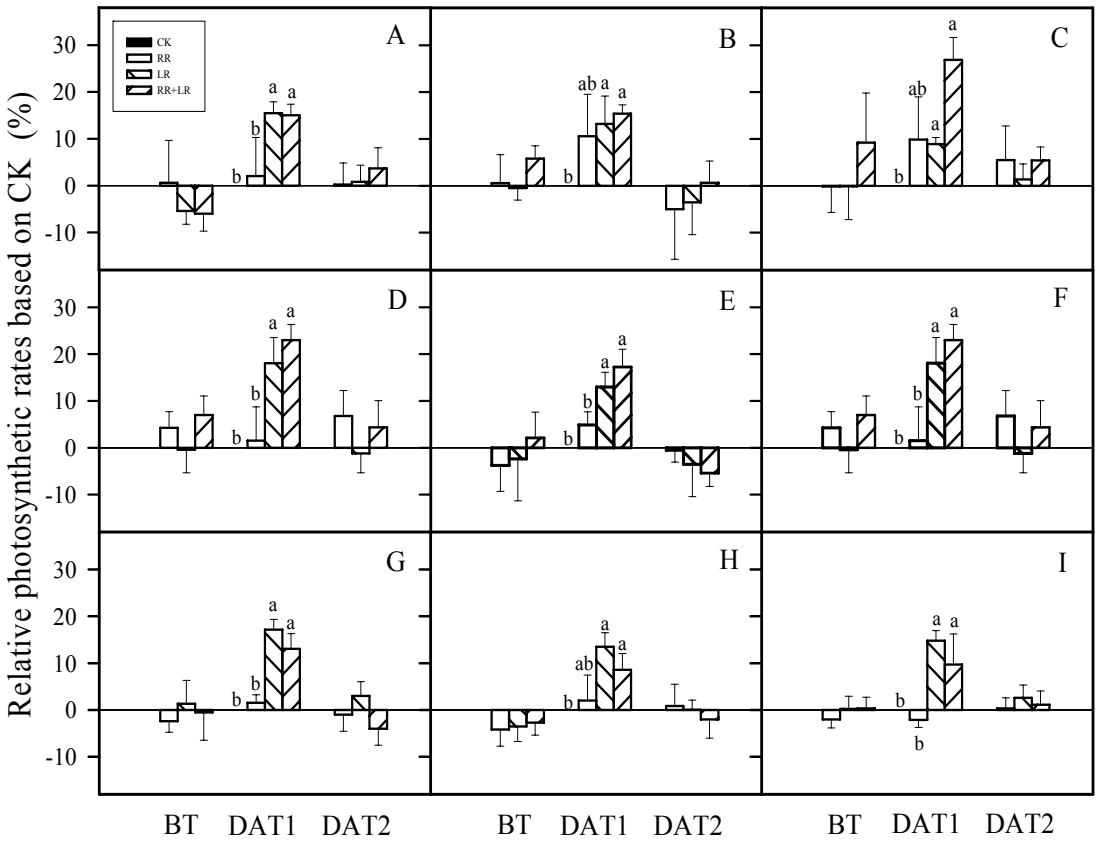

圖 3.3. 摘除老葉與摘除走莖對'豐香'草莓植株葉片光合作用能力之影響。

Fig. 3.3. Runner removal and defoliation affects photosynthesis in 'Toyonoka' strawberries for winter production in Taiwan.The experiment was carried out at the field, situated in Horticulture Research, Experimental Farm, College of Bio-Resources and Agriculture of National Taiwan University. 'Toyonoka' strawberry plants were planted on hill row in the field on 21 September 2008 and treated on 11 November 2008. Photosynthesis rates were was measured nine grope (A) 19 November to 21 November (B) 25 November to 27 November (C) 6 December to 8 December (D) 17 December to 19 December (E) 2 January to 4January (F) 13 January to 15 January (G) 31 January to 2 February (H) 23 February to 25 February (I) 10 March to 13 March from 19 November until 13 March 2009. One grope had three measures: 1) BT: 1hr before treatment; 2) DAT1: 1 day treatment; 3) DAT2: 2 day treatment. Photosynthesis rates were determined with obtained photosynthesis rate values between 9 and 11 h. Vertical bars indicate least significant difference (L.S.D.s) and letters denote significant difference among the four treatments at $P \leq 0.05$ (n = 4).

成不定芽、冠莖及葉片皆納入地上部鮮重計算，增加地上部鮮重，可能因此而影響地上部鮮重。

試驗期間植株總葉面積變化趨勢，試驗前期植株葉面積較後期多，此現象與第二章試驗結果相反。推測可能有下列幾項原因，第一項為兩試驗受試植株之種苗不同，第二章試驗受試植株為裸根苗，而本章試驗受試植株為穴植管苗，其品質應較裸根苗佳，且在定植時不易使根系受傷，定植後能較快速增加生長勢（李, 1995）。第二項為定植時間不同，本章試驗於於 9 月 21 日定植，而第二章試驗則於 10 月 13 日定植，較早面臨低於 20℃之栽培環境。前人指出‘Chandler’、‘Sweet Charlie’、‘Earliglow’及‘Kent’等草莓品種，在平均溫度低於 20℃的栽培環境下，其葉片生長較於 23℃至 28℃環境下栽培者差（Kadir and Sidhu, 2006；Wang and Camp, 2000）。第三項為兩試驗處理時間點不同，本章試驗於定植後 50 日開始進行摘除老葉及摘除走莖處理，而第二章試驗則是在定植後 35 日便開始進行摘除老葉及摘除走莖處理，兩者處理時間點相差 15 日應會影響生長勢。

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第四章　疏花疏果對臺灣地區冬季草莓生產之影響

摘要

本試驗目的為探討草莓植株藉由疏花疏果，生產少量但果形大及品質較好之果實，摘除花序上後開之小花應有助於養分集中於先開之花朵及果實。試驗臺灣苗栗地區，以相對短日型'豐香'草莓（桃園一號，*Fragaria* ×*ananassa* Duch. cv. 'Toyonoka'）為試驗材料，栽培採高畦雙行栽培，分別為摘除每期第一級花或第一級果（primary flower or fruit removed, PR）、摘除每期第四級以後之花朵或果實（quaternary flower or fruit removed, QR）、摘除每期第五級以後之花朵或果實（fifth flower or fruit removed, FR）與對照組（CK）等處理採用完全逢機區集設計（randomized complete block design, RCBD）。試驗處理始於 2008 月 11 月 14 日結束於 2009 年 3 月 27 日，試驗期間每週調查及測量植株總葉面積、各期第二、三級果實生長、各期果實產量及果實可溶性固形物，進而探討疏花疏果對草莓植株之影響。試驗結果如下，各處理對植株葉面積生長影響不顯著，僅在處理後 56 日 PR 葉面積高於其他處理 150 平方公分；處理後 70 日 PR 與 QR 葉面積高於其他處理 150 平方公分。各期二、三級果實生長，疏花疏果僅對第二、三期三級果實有所影響且皆以 PR 表現較佳。疏花疏果對各期可銷售產量、可銷售總產量及第一、二期及全季可銷售果實可溶性固形物皆無差異，僅減少不合品果實數。

關鍵字：草莓、疏花疏果、產量、葉面積

一、前言

臺灣地區冬季利用高畦系統生產草莓，栽培種為‘豐香’（桃園一號，*Fragaria* × *ananassa* Duch. cv. ‘Toyonoka’ ）於低溫短日環境花芽分化，在 9 月中至 10 月初之間定植後，11 月開第一期花，12 月則為第一期果實採收期，開花至採收約為 35 日。在 11 月至翌年 3 月植株皆能感受低溫短日環境而持續開花結果，因此在 12 月至翌年 4 月初期約有 3 至 4 個產期（朱, 2007）。草莓花序為聚繖花序，花序中央的第一朵花最先開放為第一級花，再漸及於兩側分別為第二、三、四、五級花依序開花，而花朵數分別為 1、2、4、8、16，果實大小與重要亦呈現隨級數增加而減少之趨勢（Galletta and Himelrick, 1990）。同一植株可能同時具有不同時間發育之花序，而開花具有次序性加上開花後至採收約 35 天，同一植株上同時存在不同果齡之果實互相競爭養分，植株持續處於生殖生長狀態可能使生長勢衰落，因此適當摘除花或果實可能達到植物體累積養分、增加葉果比、植株生長勢、下一期產量、果實糖度與單果重等效果（李, 2001; Carlen *et al*., 2007; Daugarrd, 1999; Khanizadeh *et al*., 1993; Pritts and Worden , 1988）。在臺灣現行的栽培制度下，第一級果實常為畸形果，花序後開之小花所發育之果實小果率高，以上現象皆會降低商品價值造成栽培者損失。因此本試驗目的，即為透過摘除第一級花或果實、摘除每期第四級以後之花朵或果實以及摘除每期第五級以後之花朵或果實等處理，探討留果數較適宜現行的栽培方式，希望能達到方便管理與在維持或減少產量的前提下提高單果重增加商品價值。

二、材料與方法

（一）試驗地點與材料

本試驗於臺灣苗栗縣大湖鄉（東經 120.51°、北緯 24.25°）進行。試驗園之海拔高度約 260 公尺，2008 年 10 月至 2004 年 4 月之溫度如附錄一圖附 1-2.。園區採南北向高畦雙行栽培，每畦長 12 公尺、寬 0.9 公尺、高 30 公分、行株距為 30 公分。試驗植株為利用走莖在傳統育苗圃自行繁殖之‘豐香’（桃園一號，*Fragaria* ×*ananassa* Duch. cv. ‘Toyonoka’, ‘Taoyuan. No. 1’）裸根苗。植株於 2008 年 10 月 6

日定植於試驗田中，定植前每一植穴中同時混 25 公克的複合肥料（N: P_2O_5: K_2O: MgO = 12 12: 17: 2，獅馬三號藍肥）作為基肥。試驗期間肥培、灌溉與病蟲害防治按當地栽培生產模式進行。

試驗處理始於 2008 年 11 月 14 日並隨即進行測量及調查至 2009 年 4 月初止。本試驗採用完全逢機區集設計（randomized complete block design, RCBD），生長勢一致之受試植株計 40 株選自同一畦之同一行，試驗區依方位分為左右 2 區集。各區集中每植株為 1 實驗單位，每處理重複於 5 植株。試驗處理分別為摘除每期的第一級花或第一級果（primary flower or fruit removed, PR）；摘除每期第四級以後之花朵或果實（quaternary flower or fruit removed, QR）；摘除每期第五級以後之花朵或果實（fifth flower or fruit removed, FR）；對照組（CK）則不進行上述之疏花疏果處理。

（二）植株生長及果實發育調查

1. 營養生長

試驗期間逐週記錄受試植株之葉片數，並測量所有葉片之中軸長度，以估算生育期間全株葉面積變化。全株葉面積以葉片樣本中軸長度與葉面積之迴歸方程式估算之。於試驗期間每週自試區旁相鄰草莓植株隨機採集不同大小之葉片，測量葉片中軸長度並以葉面積儀（LI-3100, LI-COR, Lincoln, Nebr. USA）測量葉面積後進行回歸分析，得如下方程式（附錄二圖附 2-3.）：

$LA = 1.7754L^{2.0498}$

其中：

LA：葉面積 (cm^2)

L：葉片中軸長度 (cm)

藉此關係式（$r^2 = 0.97$）與實際測得之葉片長度，即可估算植株上所有葉片之葉面積而推估全株葉面積。

2. 果實生長發育

隨機標定每處理受試植株中各期花二級果共 8 顆及三級果共 15 顆，每週測量果實縱徑與橫徑至該果採收時。第一期二級果於 2008 年 11 月 22 日標定開花後 10

天之果實；三級果於 2008 年 12 月 5 日標定開花後 10 天之果實。第二期二級果於 2009 年 1 月 22 日標定開花後 8 天之果實；三級果於 2009 年 2 月 6 日標定開花後 8 天之果實。第三期二級果於 2009 年 2 月 20 日標定開花後 10 天之果實；三級果於 2009 年 2 月 26 日標定開花後 9 天之果實。

3. 果實產量與品質

各果實採收期以果實已均勻轉色為標準，採收後之果實以外觀及鮮重初分為合格品及格外品，畸形果或每個果實鮮重小於 5 公克為格外品且不予加入產量之計算及後續之品質分析。試驗期間各植株之產量逐週記錄之。合格品果實以糖度計（Hand refractometer, N-1, Atago, Tokyo, Japan）測量果汁之可溶性固形物含量（°Brix）。

（三）統計分析

本試驗為完全逢機區集設計（Randomized Complete Block Design, RCBD），共分為 2 區集，各區集中每植株為 1 實驗單位，每處理 5 重複。試驗結果，不同處理各期果及全季之不合格果實數、可銷售果實數、可銷售果實單果重、可銷售果實產量與可銷售果實品質進行變異分析（Two way analysis of variance, ANOVA），確定處理間之差異達顯著水準（$P \leq 0.05$），再進一步以最小顯著性差異（Least Significant Difference $LSD_{0.05}$,CoStat 6.2,CoHort Software, USA）判定各處理彼此間之差異。試驗期間內各處理連續全株葉面積及葉片數變化，以 SigmaPlot 10.0（SPSS Inc., USAS）進行繪圖並顯示標準差（stand error）並以變異分析同時期各處理彼此間之差異（CoStat 6.2, CoHort Software, USA）。各處理標定之果實其連續生長狀況，以 SigmaPlot 10.0（SPSS Inc., USAS）進行繪圖並顯示標準差（stand error）並以 ANOVA 變方統計分析同時期各處理彼此間之差異，確定處理間之差異達顯著水準（$P \leq 0.05$），再進一步以最小顯著性差異（Least Significant Difference $LSD_{0.05}$,CoStat 6.2, CoHort Software, USA）判定各處理彼此間之差異。

三、結果

（一）葉面積與葉片數變化

2008 年 11 月 14 日各試驗植株為第一期花開花階段，進行疏花疏果處理前葉片數為 4 片葉，葉面積為 400 平方公分。處理後 21 日至 49 日為第一期果實大量生產期，各處理葉片數與葉面積分別為 6 片葉及 650 平方公分且各處理間無顯著差異。處理後 56 日至 70 日為第一期果實採收後期與第二期果開花期，處理後 56 日 PR 葉面積為 850 平方公分高於其他處理 150 平方公分；處理後 70 日 PR 與 QR 葉面積為 800 平方公分高於其他處理 150 平方公分，此期各受試植株葉片數為 7 片葉且各處理間無顯著差異。處理後 77 日至 98 日為第二期果實大量生產期，CK、PR、QR 與 FR 等處理葉面積分別為 850、1050、950 與 850 平方公分；葉片數介於 9 至 11 片葉之間，各處理間葉面積與葉片數無顯著差異。處理後 105 日至 126 日為第二期果實採收後期與第三期果採收期，處理後 105 日各處理植株葉面積與葉片數均為全季之最大值分別介於 900 至 1200 平方公分及 11 至 14 片葉，但各處理間無顯著差異（圖 4.1）。各處理植株整季葉面積與葉片數變化皆呈現相似的趨勢，疏花疏果處理對整季葉面積與葉片數影響不大。

（二）果實生長

摘除不同級花對第一期二級果及三級果、第二期二級果與第三期二級果等果實生長皆無顯著差異（圖 4.2、圖 4.3、圖 4.4、圖 4.6），但對第二期三級果及第三期三級果而言各處理間達顯著差異（圖 4.5、圖 4.7）。在第二期三級果實生長過程中僅在花後 22 日與 29 日有顯著差異。花後 22 日的果實，PR 果實橫徑為 21 公釐與 QR 無差異，大於其他處理 2 至 3 公釐（$p= 0.03$）；PR 果實縱徑為 27 公釐大於 CK 及 FR 處理 4 公釐但與 FR 無顯著差異（$p= 0.003$）。在花後 29 日，PR 果實橫徑及縱徑生長分別為 30 公釐（$p= 0.04$）及 39 公釐（$p= 0.0003$），皆大於其他處理（圖 4.5）。第三期三級果實生長過程中僅在花後 22 日與 29 日有顯著差異，花後 22 日之 PR 果實不論在橫徑（20 公釐）（$p= 0.003$）與縱徑（26 公釐）（$p= 0.008$）皆大於 CK 與 FR，但與 QR 沒顯著差異；而花後 29 日之果實與花後 22 日有相似的情形，唯在縱徑不同，PR 果實為 32 公釐大於 FR 處理 6 公釐（$p= 0.03$），與

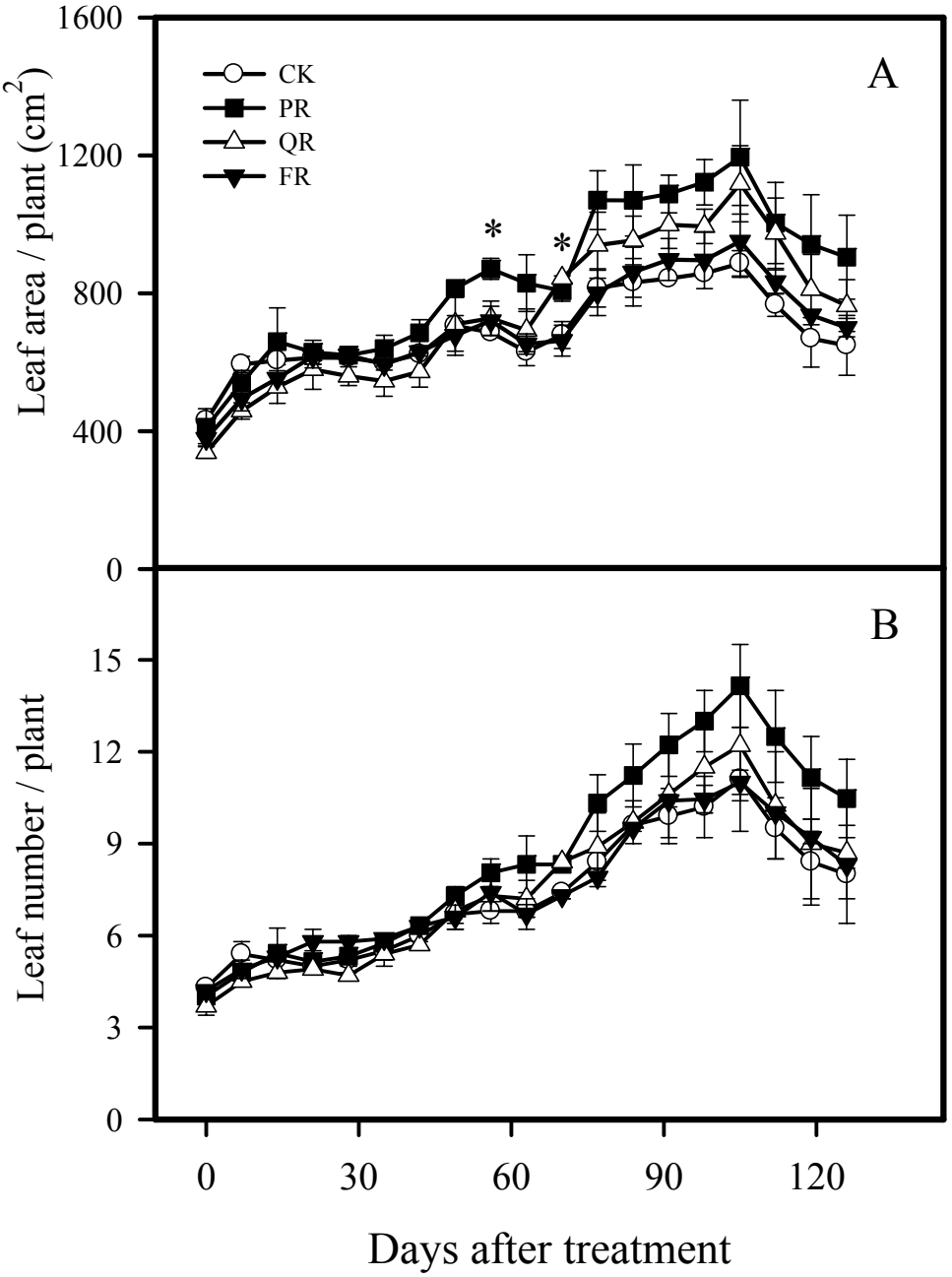

圖 4.1. 疏花疏果處理對‘豐香’草莓植株葉片生長與葉面積之影響。

Fig. 4.1. Effect of flower or fruit thinning on leaf and canopy development in winter ‘Toyonoka’ strawberry production in subtropical Taiwan. The experiment was carried out at the field, situated in Miaoli, Taiwan. ‘Toyonoka’ strawberry plants were planted on hill row in the field on 6 October 2008 and treated on 14 November 2008. Canopy leaf area development was measured from mid-November until 20 March 2009. Vertical bars indicate least significant difference (L.S.D.s) and asterisks denote significant difference among the four treatments at $P \leq 0.05$.*represent significant differences between treatments at $P \leq 0.05$.

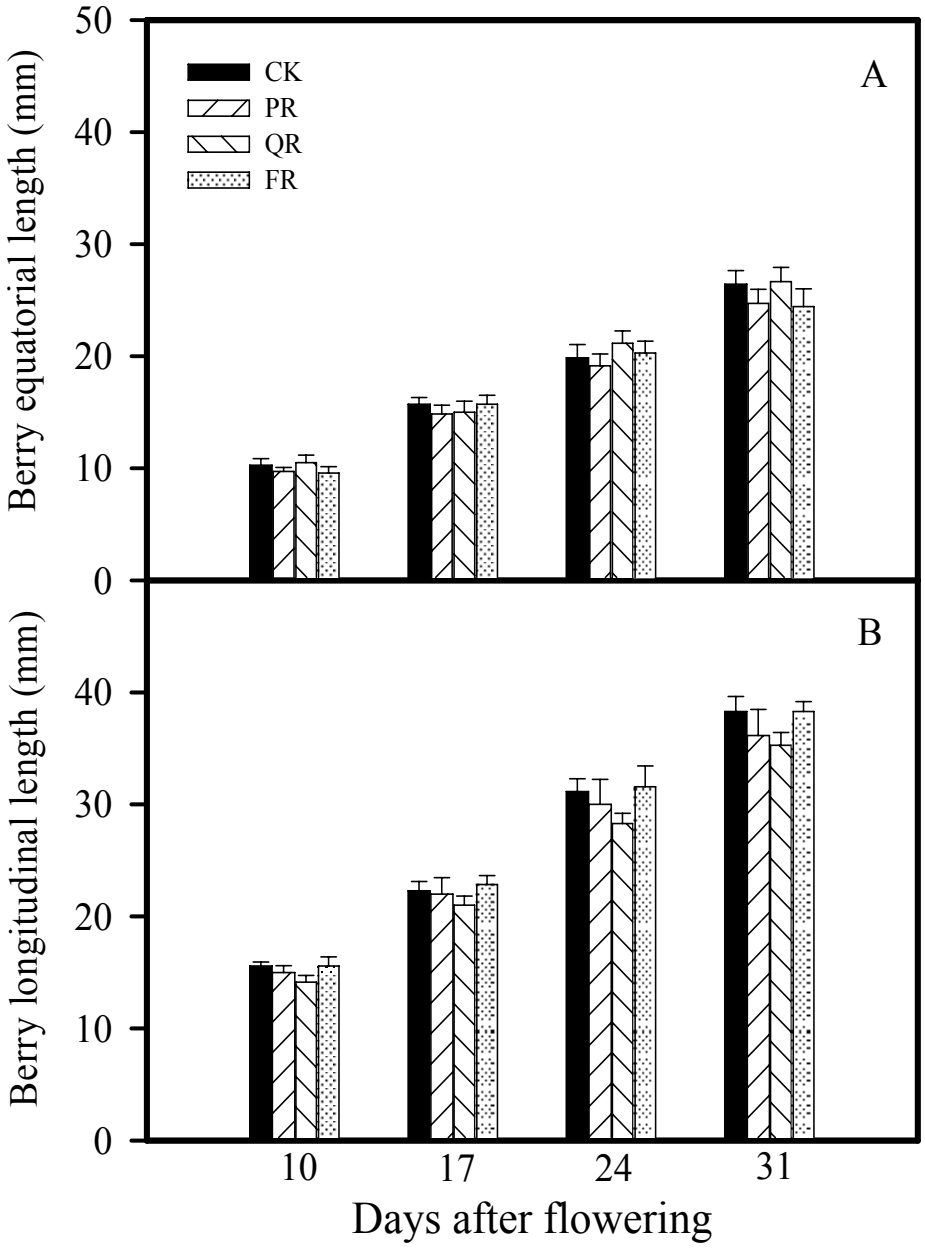

圖 4.2. 疏花疏果處理對‘豐香’草莓第一期二級果實生長之影響。

Fig. 4.2. Effect of flower or fruit thinning on secondary berry development of first crop in winter ‘Toyonoka’ strawberry production in subtropical Taiwan. The experiment was carried out at the field, situated in Miaoli, Taiwan. ‘Toyonoka’ strawberry plants were planted on hill row in the field on 6 October 2008 and treated on 22 November 2008. Berry development was measured weekly from 22 November until 21 December 2008.

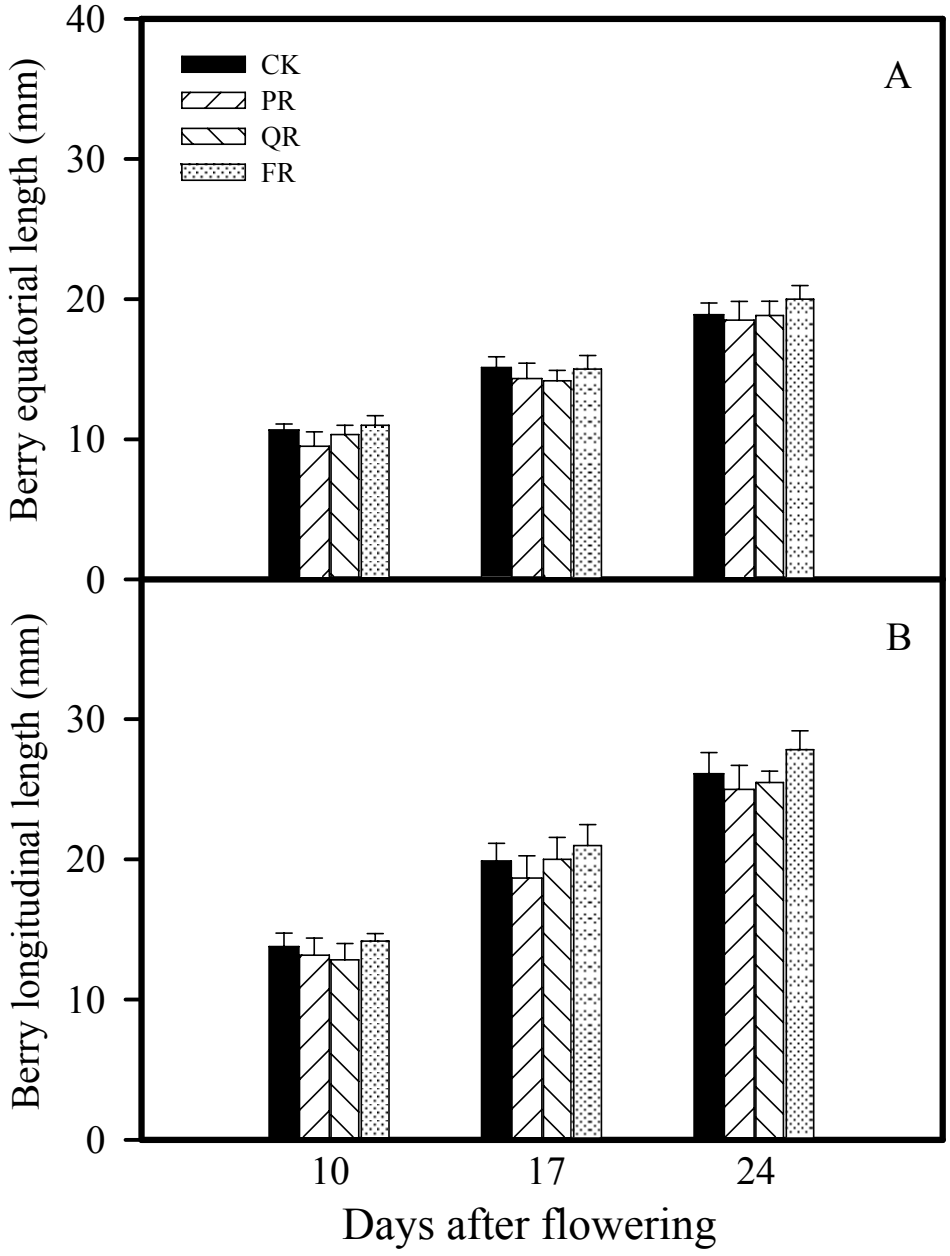

圖 4.3. 疏花疏果處理對'豐香'草莓第一期三級果實生長之影響。

Fig. 4.3. Effect of flower or fruit thinning on third berry development of first crop in winter 'Toyonoka' strawberry production in subtropical Taiwan. The experiment was carried out at the field, situated in Miaoli, Taiwan. 'Toyonoka' strawberry plants were planted on hill row in the field on 6 October 2008 and treated on 22 November 2008. Berry development was measured weekly from 5 December until 19 December 2008.

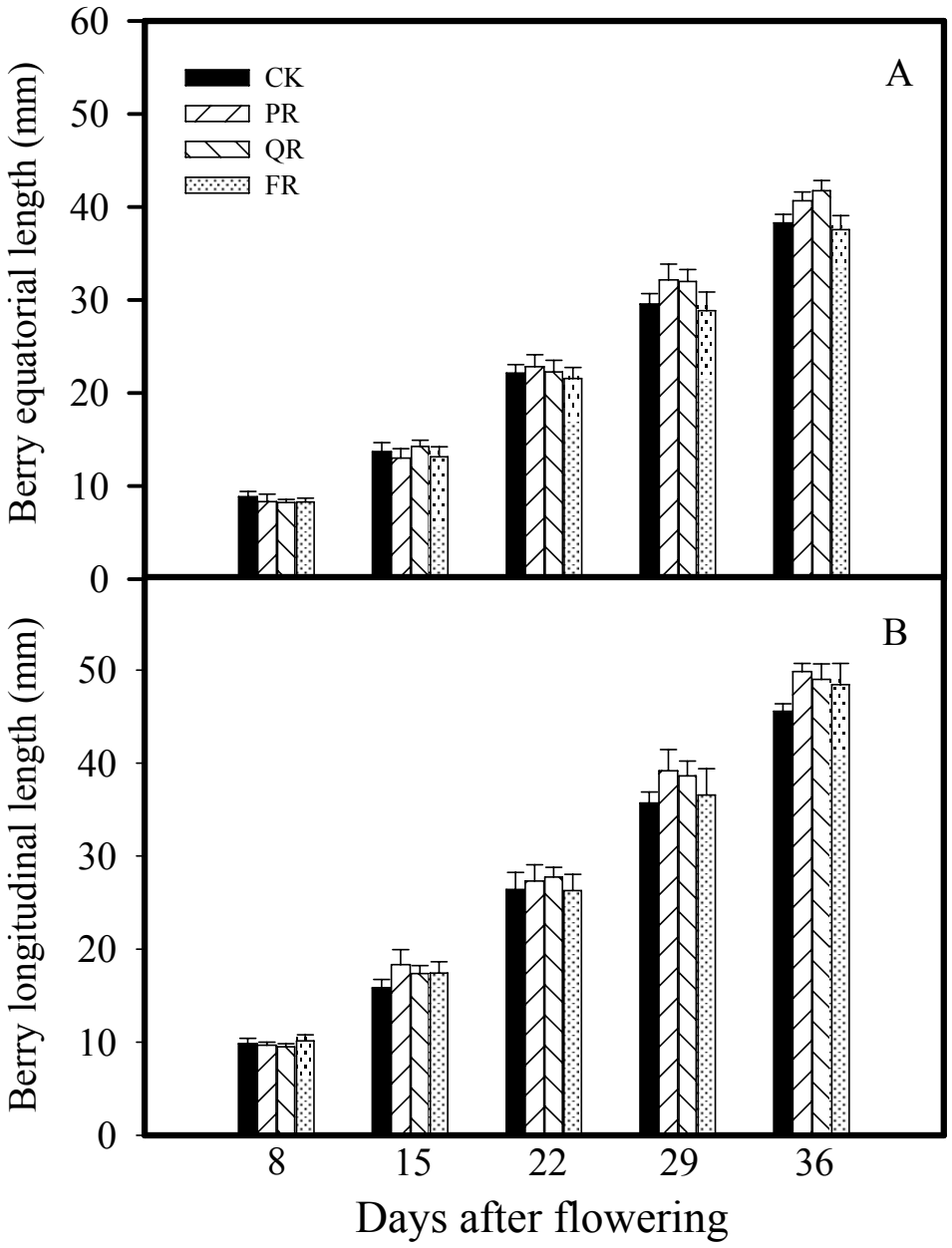

圖 4.4. 疏花疏果處理對‘豐香’草莓第二期二級果實生長之影響。

Fig. 4.4. Effect of flower or fruit thinning on secondary berry development of second crop in winter ‘Toyonoka’ strawberry production in subtropical Taiwan. The experiment was carried out at the field, situated in Miaoli, Taiwan. ‘Toyonoka’ strawberry plants were planted on hill row in the field on 6 October 2008 and treated on 22 November 2008. Berry development was measured weekly from 22 January 2009 until 20 February 2009.

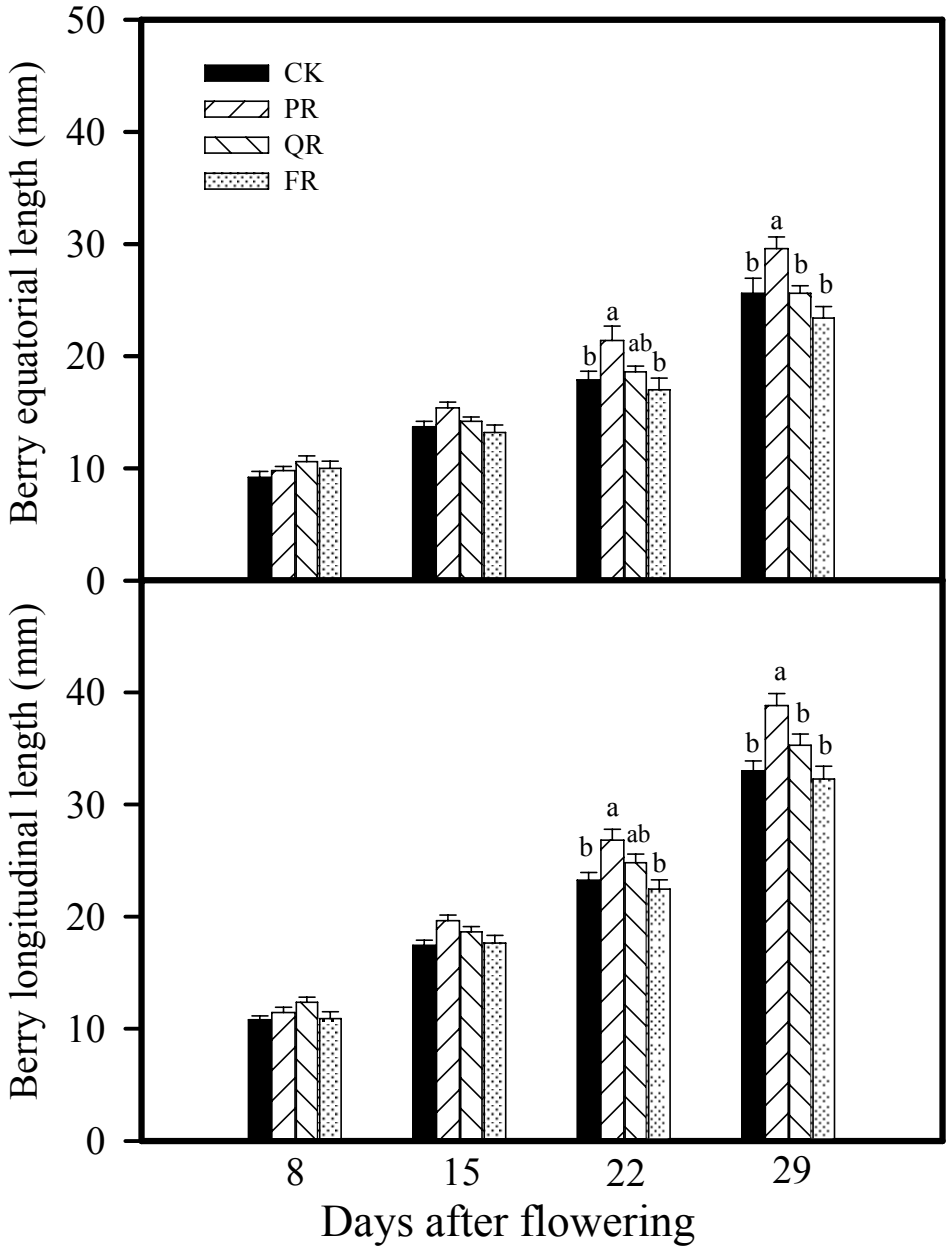

圖 4.5. 疏花疏果處理對‘豐香’草莓第二期三級果實生長之影響。

Fig. 4.5. Effect of flower or fruit thinning on third berry development of second crop in winter ‘Toyonoka’ strawberry production in subtropical Taiwan. The experiment was carried out at the field, situated in Miaoli, Taiwan. ‘Toyonoka’ strawberry plants were planted on hill row in the field on 6 October 2008 and treated on 22 November 2008. Berry development was measured weekly from 6 February 2009 until 27 February 2009. Vertical bars indicate least significant difference (L.S.D.s) and letters denote significant difference among the three treatments at $P \leq 0.05$ (n = 15).

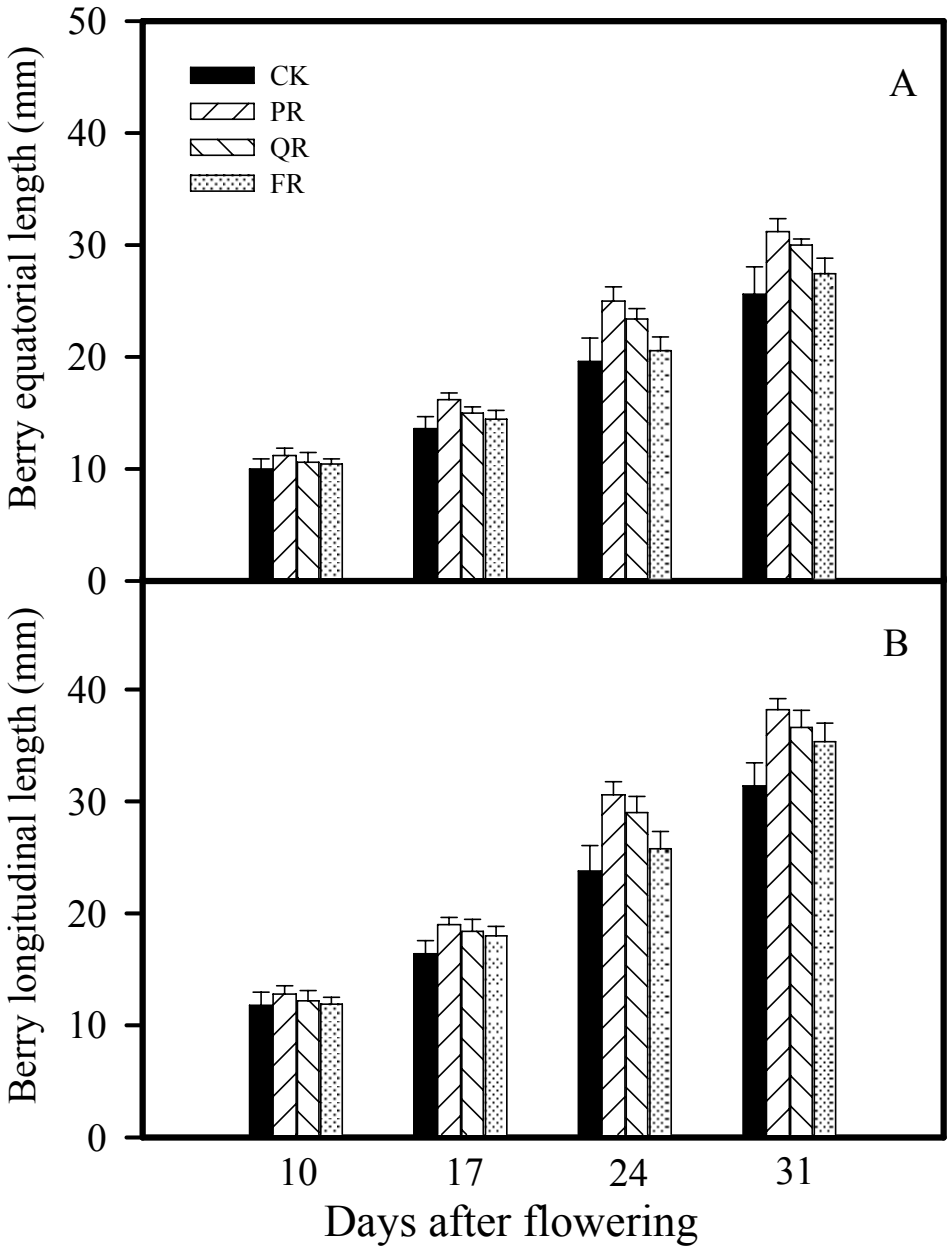

圖 4.6. 疏花疏果處理對'豐香'草莓第三期二級果生長之影響。

Fig. 4.6. Effect of flower or fruit thinning on secondary berry development of third crop in winter 'Toyonoka' strawberry production in subtropical Taiwan. The experiment was carried out at the field, situated in Miaoli, Taiwan. 'Toyonoka' strawberry plants were planted on hill row in the field on 6 October 2008 and treated on 22 November 2008. Berry development was measured weekly from 20 February 2009 until 13 March 2009.

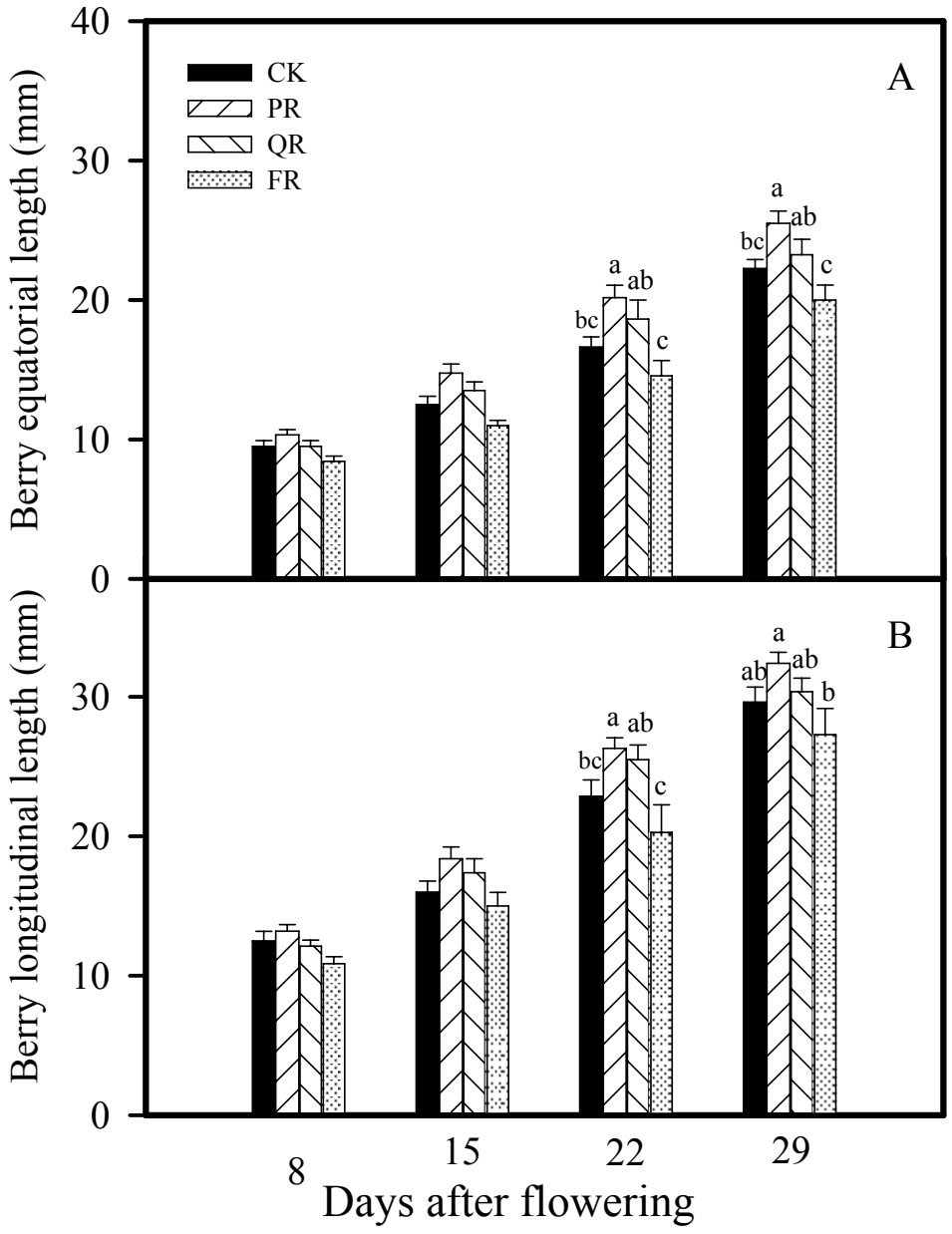

圖 4.7. 疏花疏果處理對‘豐香’草莓第三期三級果生長之影響。

Fig. 4.7. Effect of flower or fruit thinning on third berry development of thirdcrop in winter ‘Toyonoka’ strawberry production in subtropical Taiwan. The experiment was carried out at the field, situated in Miaoli, Taiwan. ‘Toyonoka’ strawberry plants were planted on hill row in the field on 6 October 2008 and treated on 22 November 2008. Berry development was measured weekly from 26 February 2009 until 20 February 2009. Vertical bars indicate least significant difference (L.S.D.s) and letters denote significant difference among the three treatments at $P \leq 0.05$ (n = 15).

CK 及 QR 無顯著差異（圖 4.7）。

（三）果實產量與品質

第一期果，CK、PR、QR 與 FR 等處理除了不合品果實之外，可銷售果實數、單株可銷售產量、可銷售果實單果重與可銷售果實可溶性固形物皆無顯著差異，QR 處理則是以 0.7 顆不合品果實低其他處理（表 4.1）。第二期果，QR 處理以 0.2 顆不合品果實低於其他處理。PR 處理 9.6 顆可銷售果實高於 QR 處理 6.7 顆，而 PR 與 CK 及 FR 無顯著差異；QR 與 CK 及 FR 亦無顯著差異。QR 處理可銷售果實單果重以 17.1 公克高於 CK 與 PR 處理的 12.4 公克，但與 FR 處理無顯著差異。單株產量及果實可溶性固形物，CK、PR、QR 與 FR 等處理分別為 100.6、119.3、114.4 及 116.4 公克與 9.3、8.7、8.2 及 8.5 °Brix，各處理間則是無顯著差異（表 4.2）。第三期果，PR 處理以 2.0 顆不合品果低於 CK 處理的 3.1 顆、QR 處理的 3.4 顆以及 FR 處理的 3.5 顆。PR 處理以 4.2 顆可銷售果實高於 CK 及 QR 處理，但與 FR 處理無顯著差異。單株可銷售產量各處理無顯著差異，CK、PR、QR 與 FR 等處理分別為 34.0、44.1、39.3 及 37.5 公克。CK 及 QR 處理之可銷售果實單果重，分別以 13.8 公克及 14.0 公克大於 PR 處理的 10.5 公克；CK、QR 及 PR 處理皆與 FR 處理的 11.1 公克無顯著差異。在果實可溶性固形物則是與單果重有一樣的趨勢，CK 及 QR 處理高於 PR；CK、QR 及 PR 處理與 FR 處理無顯著差異（表 4.3）。

全季果實生產，單株總產量介於 182 至 221.8 公克之間、單果重介於 10.7 至 13.1 公克之間及果實可溶性固形物則是介於 9.5 至 10.1 °Brix 之間，疏花疏果各處理間皆無顯著差異。不合品果實數達顯著差異，以 QR 處理的 4.6 顆不合品果實數低於其他處理。疏花疏果數多亦有減少單株可銷售果實數，以 QR 處理的 14.7 顆果實數低於 PR 與 FR 處理，而不進行疏花疏果處理使不合品果實數過多；亦有減少單株果實數的現象（表 4.4）。

四、討論

Hansen（1989）與 Carlen 等人（2007）分別在丹麥地區冬季利用溫室栽培一年生草莓與在瑞士夏季以露地栽培一年生草莓且進行疏花處理，結果顯示疏花處

表 4.1. 疏花疏果處理對‘豐香’草莓植株第一期果實生產之影響

Table 4.1. Effect of flower or fruit thinning on first crop berry yield and berry quality in winter ‘Toyonoka’ strawberry production in subtropical Taiwan[z].

Treatment	Unqualified[z] fruit number / plant	Marketable fruit number / plant	Marketable fruit weight / plant (g)	Marketable fruit weight / fruit (g)	Marketable total soluble solids (°Brix)
CK[y]	8.9 a[x]	4.9 a	47.4 a	9.3 a	9.3 a
PR	8.3 a	6.8 a	58.4 a	8.2 a	8.2 a
QR	0.7 b	5.1 a	41.6 a	8.4 a	8.4 a
FR	6.9 a	6.1 a	49.1 a	8.0 a	8.0 a

[z]The experiment was carried out at the field, situated in Miaoli, Taiwan. ‘Toyonoka’ strawberry plants were planted on hill row in the field on 6 October 2008 and treated on 14 November 2008. First crop berry production began on early December 2008 and ended on early February 2009. Only marketable fruit (no blemishes and misshaped) were weighed, measured total soluble solids content and included in yield.

[y]CK: control no flower buds or fruit removed; RR: primary flower bud or fruit removed; QR: quaternary and hereafter flower buds or fruit removed; fifth and hereafter flower buds or fruit removed.

[x]Statistical analyses were conducted using ANOVA (CoStat 6.2, CoHort Software, USA) and the means compared with the LSD test with a significance degree $\alpha = 0.05$.

表 4.2. 疏花疏果處理對‘豐香’草莓植株第二期果實生產之影響

Table 4.2. Effect of flower or fruit thinning on second crop berry yield and berry quality in winter ‘Toyonoka’ strawberry production in subtropical Taiwan[z].

Treatment	Unqualified[z] fruit number / plant	Marketable fruit number / plant	Marketable fruit weight / plant (g)	Marketable fruit weight / fruit (g)	Marketable total soluble solids (°Brix)
CK[y]	10.9 a[x]	8.1 ab	100.6 a	12.4 b	9.3 a
PR	9.0 b	9.6 a	119.3 a	12.4 b	8.7 a
QR	0.2 d	6.7 b	114.4 a	17.1 a	8.2 a
FR	3.9 c	9.3 ab	116.4 a	13.0 ab	8.5 a

[z]The experiment was carried out at the field, situated in Miaoli, Taiwan. ‘Toyonoka’ strawberry plants were planted on hill row in the field in 6 October 2008 and treated on 14 November 2008. Second crop berry production began on 22 January 2009 and ended on 10 March 2009. Only marketable fruit (no blemishes and misshaped) were weighed, measured total soluble solids content and included in yield.

[y]CK: control no flower buds or fruit removed; RR: primary flower bud or fruit removed; QR: quaternary and hereafter flower buds or fruit removed; fifth and hereafter flower buds or fruit removed.

[x]Statistical analyses were conducted using ANOVA(CoStat 6.2, CoHort Software, USA) and the means compared with the LSD test with a significance degree $\alpha = 0.05$.

表 4.3. 疏花疏果處理對‘豐香’草莓植株第三期果實生產之影響

Table 4.3. Effect of flower or fruit thinning on third crop berry yield and berry quality in winter ‘Toyonoka’ strawberry production in subtropical Taiwan[z].

Treatment	Unqualified[z] fruit number / plant	Marketable fruit number / plant	Marketable fruit weight / plant (g)	Marketable fruit weight / fruit (g)	Marketable total soluble solids (°Brix)
CK[y]	3.1 a[x]	2.5 b	34.0 a	13.8 a	13.8 a
PR	2.0 b	4.2 a	44.1 a	10.5 b	10.5 b
QR	3.4 a	2.8 b	39.3 a	14.0 a	14.0 a
FR	3.5 a	3.4 ab	37.4 a	11.1 ab	11.1 ab

[z]The experiment was carried out at the field, situated in Miaoli, Taiwan. ‘Toyonoka’ strawberry plants were planted on hill row in the field in 6 October 2008 and treated on 14 November 2008. Third crop berry production began on 27 February 2009 and ended on late March 2009. Only marketable fruit (no blemishes and misshaped) were weighed, measured total soluble solids content and included in yield.

[y]CK: control no flower buds or fruit removed; RR: primary flower bud or fruit removed; QR: quaternary and hereafter flower buds or fruit removed; fifth and hereafter flower buds or fruit removed.

[x]Statistical analyses were conducted using ANOVA (CoStat 6.2, CoHort Software, USA) and the means compared with the LSD test with a significance degree $\alpha = 0.05$.

表 4.4. 疏花疏果處理對‘豐香’草莓植株全季果實生產之影響

Table 4.4. Effect of flower or fruit thinning on total berry yield and berry quality in winter ‘Toyonoka’ strawberry production in subtropical Taiwan[z].

Treatment	Unqualified[z] fruit number / plant	Marketable fruit number / plant	Marketable fruit weight / plant (g)	Marketable fruit weight / fruit (g)	Marketable total soluble solids (°Brix)
CK[y]	22.8 a[x]	15.5 b	182.0 a	11.8 a	9.9 a
PR	19.5 a	20.7 a	221.8 a	10.7 a	9.9 a
QR	4.6 c	14.7 b	192.9 a	13.1 a	9.5 a
FR	14.2 b	18.8 a	203.0 a	11.0 a	10.1 a

[z]The experiment was carried out at the field, situated in Miaoli, Taiwan. ‘Toyonoka’ strawberry plants were planted on hill row in the field on 6 October 2008. The berry production began on early December 2008 and ended on late March 2009. Only marketable fruit (no blemishes and misshaped) were weighed, measured total soluble solids content and included in yield.

[y]CK: control no flower buds or fruit removed; RR: primary flower bud or fruit removed; QR: quaternary and hereafter flower buds or fruit removed; fifth and hereafter flower buds or fruit removed.

[x]Statistical analyses were conducted using ANOVA(CoStat 6.2, CoHort Software, USA) and the means compared with the LSD test with a significance degree $\alpha = 0.05$.

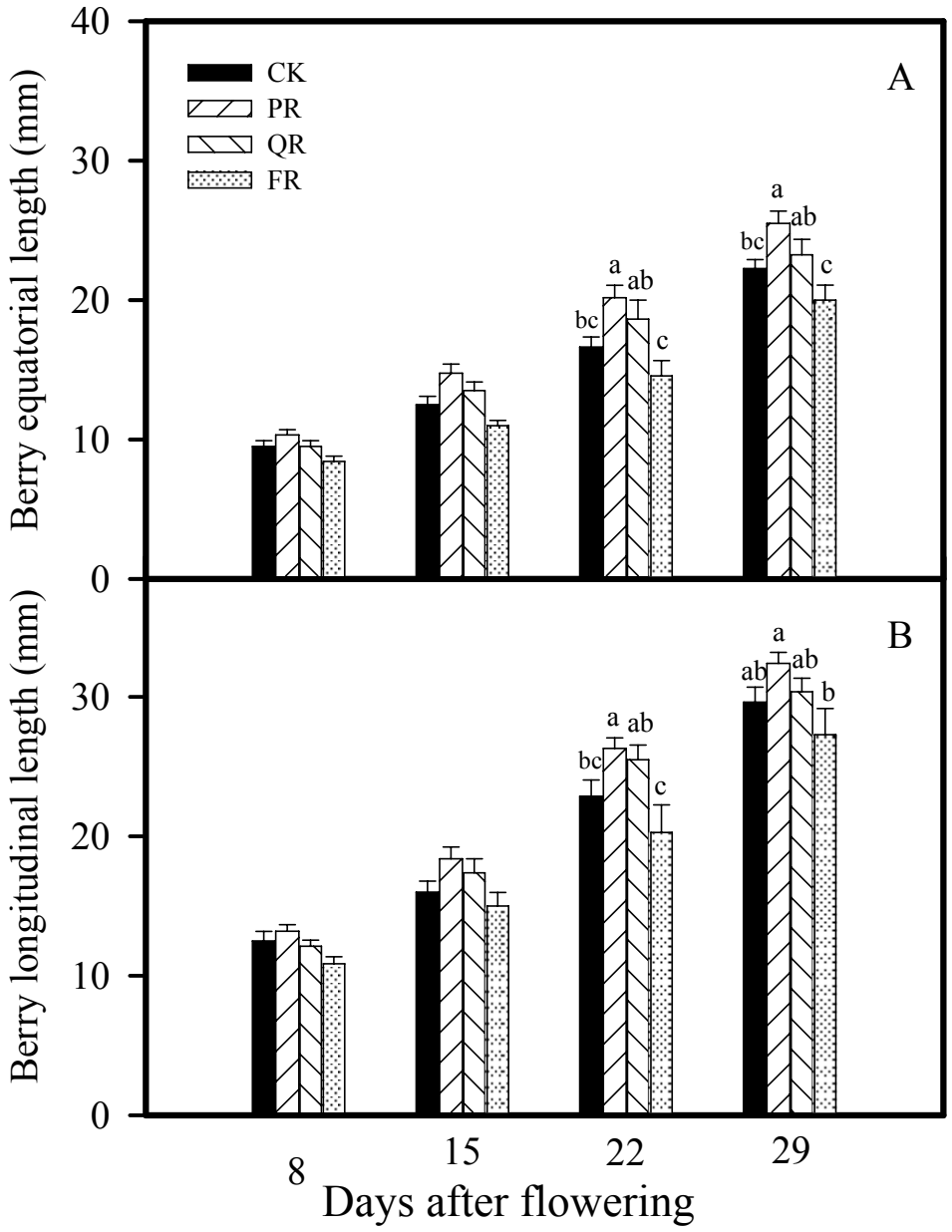

圖 4.7. 疏花疏果處理對‘豐香’草莓第三期三級果生長之影響。

Fig. 4.7. Effect of flower or fruit thinning on third berry development of thirdcrop in winter ‘Toyonoka’ strawberry production in subtropical Taiwan. The experiment was carried out at the field, situated in Miaoli, Taiwan. ‘Toyonoka’ strawberry plants were planted on hill row in the field on 6 October 2008 and treated on 22 November 2008. Berry development was measured weekly from 26 February 2009 until 20 February 2009. Vertical bars indicate least significant difference (L.S.D.s) and letters denote significant difference among the three treatments at $P \leq 0.05$ (n = 15).

理皆可以提昇植株葉面積。而本試驗與上述結果有所不同，PR 及 QR 等處理之植株葉面積雖有稍高之趨勢，僅在處理後 56 日 PR 平均葉面積為 850 平方公分高於其他處理 150 平方公分，而其他則無顯著差異（圖 4.1）。李（1993）在臺灣桃園地區以桃園三號草莓為試驗材料進行疏花試驗，結果顯示疏花對植株生長勢差異不大，這結果與本試驗結果相似。造成以上結果的不同，推測可能與開花結果次數有關。Hansen（1989）與 Carlen 等人（2007）試驗皆因栽培地區氣候環境僅有一次結果期，而本試驗與李（1993）有三次以上的結果期。當摘除第一期花的三、四級花時，此時第二期花的第一級花可能處於花芽分化或是開花階段，植株持續處於生殖生長階段，因此在營養生長方面就不顯著。

疏花處理對第一期二、三級果與產量沒有影響（表 4.1、圖 4.2、圖 4.3），可能與各處理植株葉面積及果實數在此階段無差異有關（圖 4.1），果實可獲得之光合產物應相同，可推論果實生長與產量無差異是合理的。第二期果中，在各處理植株葉面積相近前提下，果實數因摘除不同程度花而不同，因此各果實獲之養分亦有不同，以 QR 有較少的果實數因而有較大的單果重，但產量無顯著差異（表 4.2）。在第三期果方面，各處理果實數皆小於 5 顆致使產量下降（表 4.3）。2009 年 2 月中期至 3 月初期為第三期花大量開花期，此期苗栗地區有連續數日最低溫度低於 10℃，此低溫極可能減少花粉萌發及花粉活力而降低授粉受精的成功率，最終減少著果數（Risser, 1997）。2009 年 3 月初期苗栗地區有連續數日最高溫度超過 30 ℃，此高溫極可能減少該期花芽形成數、花粉活力、花序數、花朵數與果實，降低正常發育之果實數進而使產量下降（Ledesma and Sugiyama, 2005）。

疏花對第一期果、第二期果及全季果實可溶性固形物皆無顯著差異，僅在第三期果中有顯著差異（表 4.1、表 4.2、表 4.3、表 4.4）。雖然不同程度的摘疏花製造不一樣的葉片與果實之比例，但 Carlen 等人（2007）提出，草莓果實可溶性固形物可參考葉面積（平方公分）與果實重量（公克）之比例（leaf/fruit ratio, $cm^2 \cdot g^{-1}$），葉面積與果實重量之比例介於 0 至 15（$cm^2 \cdot g^{-1}$）時，果實可溶性固形物呈直線上升；而當葉面積與果實重量之比例超過 15（$cm^2 \cdot g^{-1}$），果實可溶性固形物便趨於平緩。本試驗中，各處理間之植株葉面積及總產量皆無顯著差異（圖 4.1、表 4.4），葉面積與果實重量之比例亦相近，因此推測各處理間果實可溶性固形物無顯著差異。

表 4.1. 疏花疏果處理對‘豐香’草莓植株第一期果實生產之影響

Table 4.1. Effect of flower or fruit thinning on first crop berry yield and berry quality in winter ‘Toyonoka’ strawberry production in subtropical Taiwan[z].

Treatment	Unqualified[z] fruit number / plant	Marketable fruit number / plant	Marketable fruit weight / plant (g)	Marketable fruit weight / fruit (g)	Marketable total soluble solids (°Brix)
CK[y]	8.9 a[x]	4.9 a	47.4 a	9.3 a	9.3 a
PR	8.3 a	6.8 a	58.4 a	8.2 a	8.2 a
QR	0.7 b	5.1 a	41.6 a	8.4 a	8.4 a
FR	6.9 a	6.1 a	49.1 a	8.0 a	8.0 a

[z]The experiment was carried out at the field, situated in Miaoli, Taiwan. ‘Toyonoka’ strawberry plants were planted on hill row in the field on 6 October 2008 and treated on 14 November 2008. First crop berry production began on early December 2008 and ended on early February 2009. Only marketable fruit (no blemishes and misshaped) were weighed, measured total soluble solids content and included in yield.

[y]CK: control no flower buds or fruit removed; RR: primary flower bud or fruit removed; QR: quaternary and hereafter flower buds or fruit removed; fifth and hereafter flower buds or fruit removed.

[x]Statistical analyses were conducted using ANOVA (CoStat 6.2, CoHort Software, USA) and the means compared with the LSD test with a significance degree $\alpha = 0.05$.

表 4.2. 疏花疏果處理對‘豐香’草莓植株第二期果實生產之影響

Table 4.2. Effect of flower or fruit thinning on second crop berry yield and berry quality in winter ‘Toyonoka’ strawberry production in subtropical Taiwan[z].

Treatment	Unqualified[z] fruit number / plant	Marketable fruit number / plant	Marketable fruit weight / plant (g)	Marketable fruit weight / fruit (g)	Marketable total soluble solids (°Brix)
CK[y]	10.9 a[x]	8.1 ab	100.6 a	12.4 b	9.3 a
PR	9.0 b	9.6 a	119.3 a	12.4 b	8.7 a
QR	0.2 d	6.7 b	114.4 a	17.1 a	8.2 a
FR	3.9 c	9.3 ab	116.4 a	13.0 ab	8.5 a

[z]The experiment was carried out at the field, situated in Miaoli, Taiwan. ‘Toyonoka’ strawberry plants were planted on hill row in the field in 6 October 2008 and treated on 14 November 2008. Second crop berry production began on 22 January 2009 and ended on 10 March 2009. Only marketable fruit (no blemishes and misshaped) were weighed, measured total soluble solids content and included in yield.

[y]CK: control no flower buds or fruit removed; RR: primary flower bud or fruit removed; QR: quaternary and hereafter flower buds or fruit removed; fifth and hereafter flower buds or fruit removed.

[x]Statistical analyses were conducted using ANOVA(CoStat 6.2, CoHort Software, USA) and the means compared with the LSD test with a significance degree $\alpha = 0.05$.

表 4.3. 疏花疏果處理對‘豐香’草莓植株第三期果實生產之影響

Table 4.3. Effect of flower or fruit thinning on third crop berry yield and berry quality in winter ‘Toyonoka’ strawberry production in subtropical Taiwan[z].

Treatment	Unqualified[z] fruit number / plant	Marketable fruit number / plant	Marketable fruit weight / plant (g)	Marketable fruit weight / fruit (g)	Marketable total soluble solids (°Brix)
CK[y]	3.1 a[x]	2.5 b	34.0 a	13.8 a	13.8 a
PR	2.0 b	4.2 a	44.1 a	10.5 b	10.5 b
QR	3.4 a	2.8 b	39.3 a	14.0 a	14.0 a
FR	3.5 a	3.4 ab	37.4 a	11.1 ab	11.1 ab

[z]The experiment was carried out at the field, situated in Miaoli, Taiwan. ‘Toyonoka’ strawberry plants were planted on hill row in the field in 6 October 2008 and treated on 14 November 2008. Third crop berry production began on 27 February 2009 and ended on late March 2009. Only marketable fruit (no blemishes and misshaped) were weighed, measured total soluble solids content and included in yield.

[y]CK: control no flower buds or fruit removed; RR: primary flower bud or fruit removed; QR: quaternary and hereafter flower buds or fruit removed; fifth and hereafter flower buds or fruit removed.

[x]Statistical analyses were conducted using ANOVA (CoStat 6.2, CoHort Software, USA) and the means compared with the LSD test with a significance degree $\alpha = 0.05$.

表 4.4. 疏花疏果處理對‘豐香’草莓植株全季果實生產之影響

Table 4.4. Effect of flower or fruit thinning on total berry yield and berry quality in winter ‘Toyonoka’ strawberry production in subtropical Taiwan[z].

Treatment	Unqualified[z] fruit number / plant	Marketable fruit number / plant	Marketable fruit weight / plant (g)	Marketable fruit weight / fruit (g)	Marketable total soluble solids (°Brix)
CK[y]	22.8 a[x]	15.5 b	182.0 a	11.8 a	9.9 a
PR	19.5 a	20.7 a	221.8 a	10.7 a	9.9 a
QR	4.6 c	14.7 b	192.9 a	13.1 a	9.5 a
FR	14.2 b	18.8 a	203.0 a	11.0 a	10.1 a

[z]The experiment was carried out at the field, situated in Miaoli, Taiwan. ‘Toyonoka’ strawberry plants were planted on hill row in the field on 6 October 2008. The berry production began on early December 2008 and ended on late March 2009. Only marketable fruit (no blemishes and misshaped) were weighed, measured total soluble solids content and included in yield.

[y]CK: control no flower buds or fruit removed; RR: primary flower bud or fruit removed; QR: quaternary and hereafter flower buds or fruit removed; fifth and hereafter flower buds or fruit removed.

[x]Statistical analyses were conducted using ANOVA(CoStat 6.2, CoHort Software, USA) and the means compared with the LSD test with a significance degree $\alpha = 0.05$.

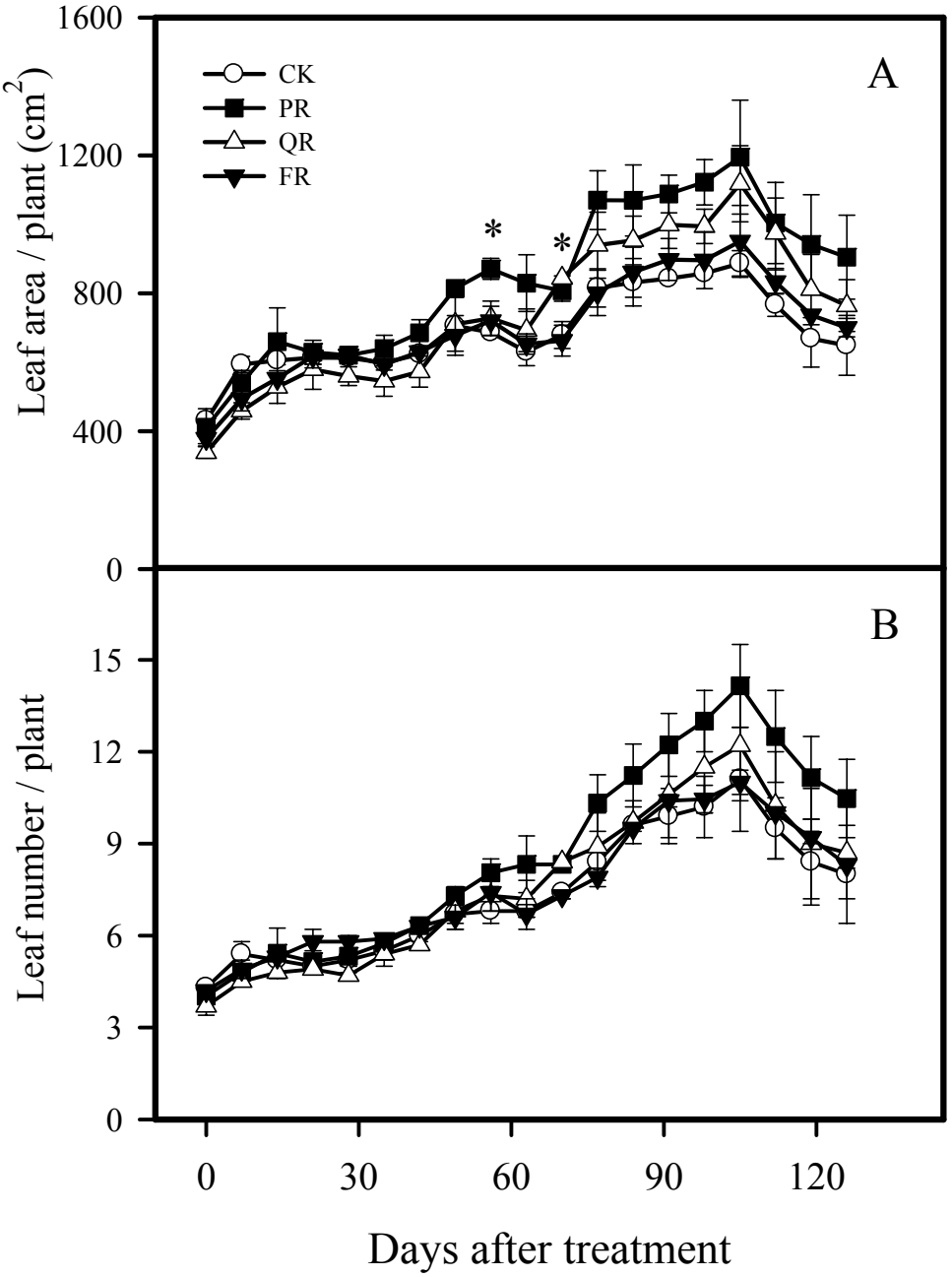

圖 4.1. 疏花疏果處理對‘豐香’草莓植株葉片生長與葉面積之影響。

Fig. 4.1. Effect of flower or fruit thinning on leaf and canopy development in winter ‘Toyonoka’ strawberry production in subtropical Taiwan. The experiment was carried out at the field, situated in Miaoli, Taiwan. ‘Toyonoka’ strawberry plants were planted on hill row in the field on 6 October 2008 and treated on 14 November 2008. Canopy leaf area development was measured from mid-November until 20 March 2009. Vertical bars indicate least significant difference (L.S.D.s) and asterisks denote significant difference among the four treatments at $P \leq 0.05$.*represent significant differences between treatments at $P \leq 0.05$.

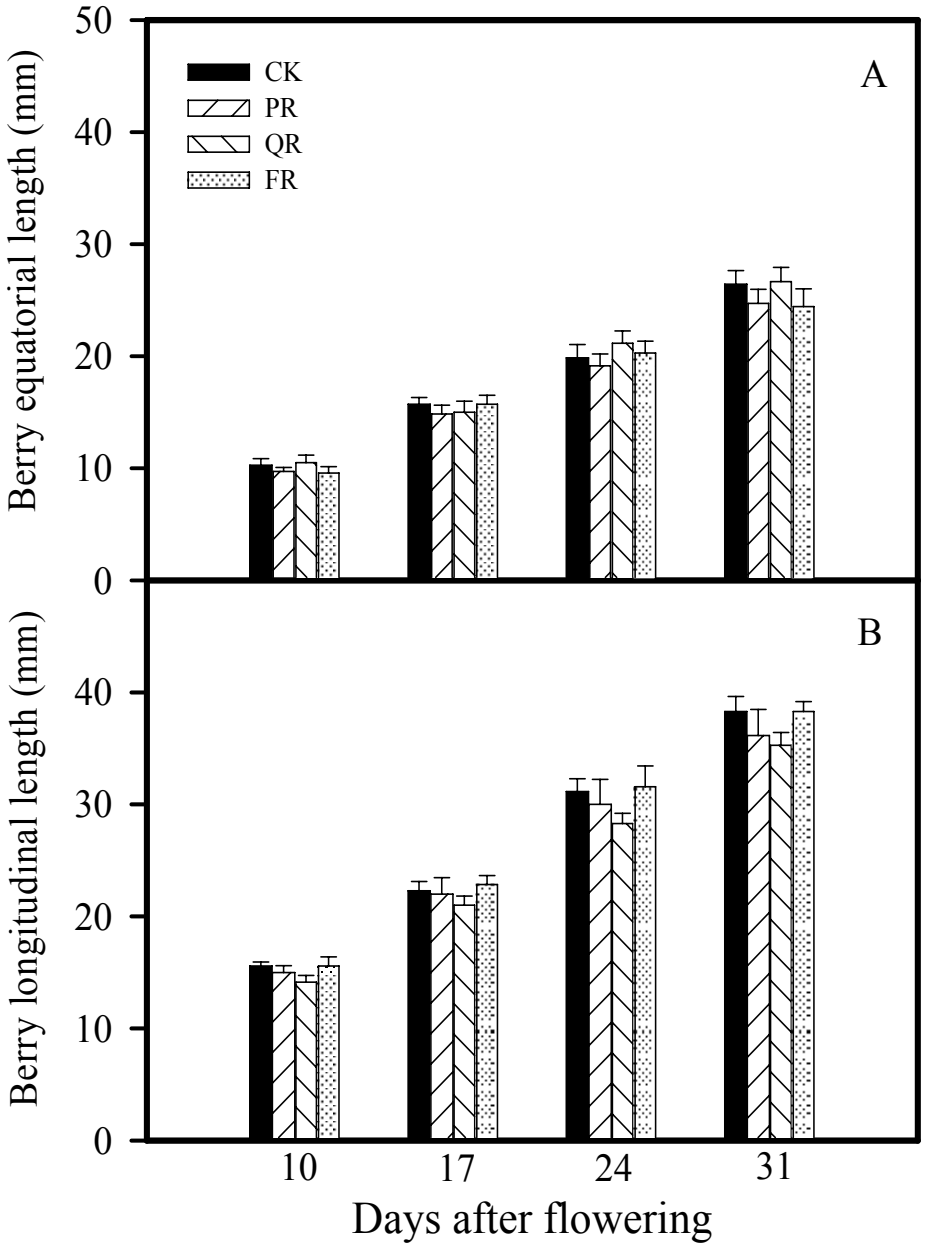

圖 4.2. 疏花疏果處理對'豐香'草莓第一期二級果實生長之影響。

Fig. 4.2. Effect of flower or fruit thinning on secondary berry development of first crop in winter 'Toyonoka' strawberry production in subtropical Taiwan. The experiment was carried out at the field, situated in Miaoli, Taiwan. 'Toyonoka' strawberry plants were planted on hill row in the field on 6 October 2008 and treated on 22 November 2008. Berry development was measured weekly from 22 November until 21 December 2008.

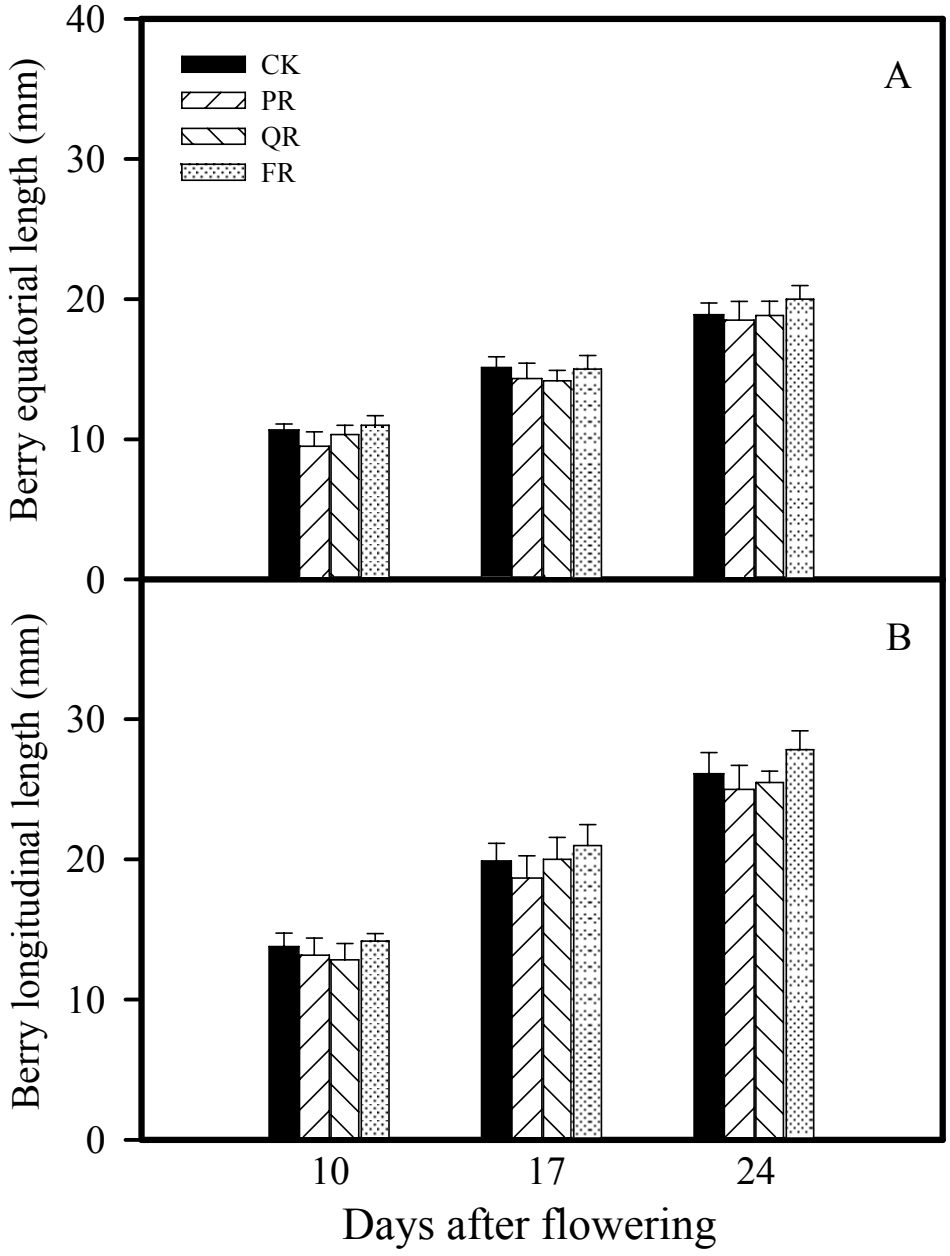

圖 4.3. 疏花疏果處理對'豐香'草莓第一期三級果實生長之影響。

Fig. 4.3. Effect of flower or fruit thinning on third berry development of first crop in winter 'Toyonoka' strawberry production in subtropical Taiwan. The experiment was carried out at the field, situated in Miaoli, Taiwan. 'Toyonoka' strawberry plants were planted on hill row in the field on 6 October 2008 and treated on 22 November 2008. Berry development was measured weekly from 5 December until 19 December 2008.

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第五章　結論與未來研究方向

一、結論

臺灣地區冬季利用高畦生產草莓，於 9 月中至 10 月初之間定植，主要的栽培品種為‘豐香’（‘Toyonoka’, ‘桃園一號’），為相對短日型（facultative short day）品種，在栽培前期及末期因日長及溫度影響，植株同時發育新葉、走莖生長、花芽分化與開花結果且植株型為披狀，增加病蟲害管理與田間操作困難。摘除走莖、老葉與疏花疏果作業遂成為草莓田間栽培的慣行作業，但這些田間操作作業對草莓植株生理與生產上的影響及帶給農民的效益尚未經詳細評估。

植株營養生長階段（進入第一期開花結果期之前）葉面積呈直線上升，進入生殖生長階段葉面積則趨於平緩。若在植株營養生長期摘除老葉減少植株葉面積、鮮乾重及根系生長，且植株葉面積與產量有極高之正相關，然摘除老葉減少植株葉面積亦減少產量，而此期果實有較高之售價且老葉仍可以提供植株光合產物，若葉片無遮蔽花或果實建議可不摘除。10 月底至 12 月初期間為大量走莖發生期，此時期亦為植株營養生長中後期與第一期開花結果期。摘除走莖應可減少植株分配至走莖提供生長之養分，可使發育中的花及生長中的果實獲得更多養分，提昇產量、果實單果重及果實可溶性固形物，使可銷售果實數增加。

草莓花序為聚繖花序，花數及果實數隨花序分枝而愈來愈多，果實大小則愈來愈小，栽培期間約可以採收二至四期果實，前後果期相互交疊且競爭養分，有疏花疏果之可行性。疏花雖不能增加植株葉面積生長，但摘除花序上後開之小花有助於養分集中於先開之花朵及果實，可降低不合品果實數及提昇單果重等效果且不影響總產量。

臺灣地區冬季生產之草莓平均售價為每公斤 100 元，前期產量（12 月至翌年 2 月）之售價最高，平均售價超過每公斤 150 元。筆者以試驗田區周圍農家之栽培工作情形進行估算摘除走莖、葉片管理及疏花等田間操作帶來之效益，由 11 月中期起至翌年 2 月底共 15 週，每週進行摘除走莖、葉片管理及疏花等田間操作，若以每公頃每週需花費 15000 元之人工成本，15 週之花費共為 225000 元。本試驗結

果顯示，RR 處理之每株第一期果產量約 210 公克高於 CK 處理 57 公克。每公頃平均栽培草莓植株為 45000 株，若以每株產量提昇 50 公克計算及售價以每公斤 150 元計算，產量共提昇 2250000 公克（2250 公斤）、收益為 337500 元，再扣除花費 225000 元（且不考慮疏花處理可不影響產量及提高單果重與售價等效益），因此每公頃淨收益可提高 112500 元。

二、未來研究方向

臺灣地區在冬季利用高畦生產草莓，產期由十二月開始至翌年四月，在三月時達到最大的產量。一般將十一月中至翌年二月的產量劃分為早期產量，此期產量較低且適逢元旦及農曆春節等節慶，因此市場價格高；翌年二月至四月的產量為後期產量，此期產量較高，但受溫度升高及春雨影響，果實品質較差，因此市場價格低（朱, 2007; 李, 1993）。故提昇草莓初期產量亦成為可進一步探討之議題。本研究發現隨著葉面積產量、果實數及單果重亦增加，而草莓植株進入生殖生長之前（營養生長階段）葉面積呈直線上升，進入生殖生長階段後葉面積則趨於平緩。因此提昇草莓植株定植後至進入生殖生長前之生長勢及葉面積應可增加初期產量。藉由冷藏苗（Tehranifar *et al*., 1998）、暗中斷（Lieten, 1997a; Lieten, 1997b）、長日處理（Konsin *et al*., 2002）、GA 處理（Tehranifar and Battey, 1997）、育苗（李, 1995）、種苗大小（Bish *et al*., 1997; Crawford *et al*., 2000）及肥培管理（吳等, 2002 ; Neuweiler, 1997）等策略提昇草莓植株定植後之葉面積，望能提昇草莓初期產量，但這些策略對草莓植株生理與生產上的影響及帶給農民的效益需進一步探討與評估。

又本研究發現摘除老葉後 1 日，第二片成熟葉片光合作用能力提昇 15%至 30%，但不知成熟葉片光合作用能力提昇，是否能補足被摘除老葉光合作用產生之光合產物，亦不知摘除老葉後對非成熟葉片光合作用能力之影響。因此可藉由測得全株總光合作用能力，在摘除老葉與摘除走莖處理之後，得知是提昇或是降低全株總光合作用能力，推論摘除老葉是否影響全株總光作用能力進而改變植株生長勢，最後可再與第二章試驗結果驗證。

第三章試驗在觀察根系生長部分，假設草莓植株根系不同方向生長應是相同

的，僅利用保麗容盆栽容器的一面作為根窗觀測根系生長，所觀測根系生長代表植株之根系生長。可利用與本試驗相似之栽培容器，但縮小其栽培容器左右端寬度約至 5 公分，迫使草莓根系向栽培容器前後端生長，再利用根窗觀測栽培容器前後端之根系生長，此方法應可提高觀測根系生長之準確度。亦可增加試驗植株之重複數，利用破壞性試驗，在試驗期間每週隨機採樣植株，測得植株根系總長度、根系鮮重及乾物重代表植株根系生長。

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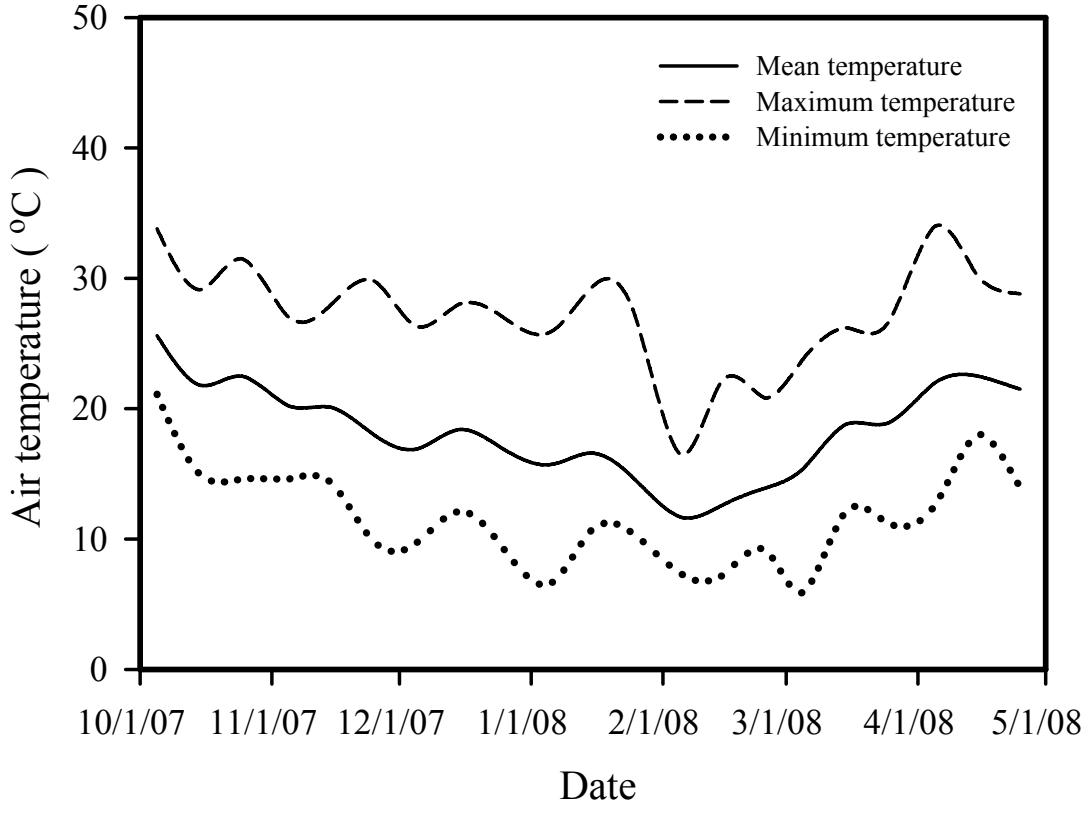
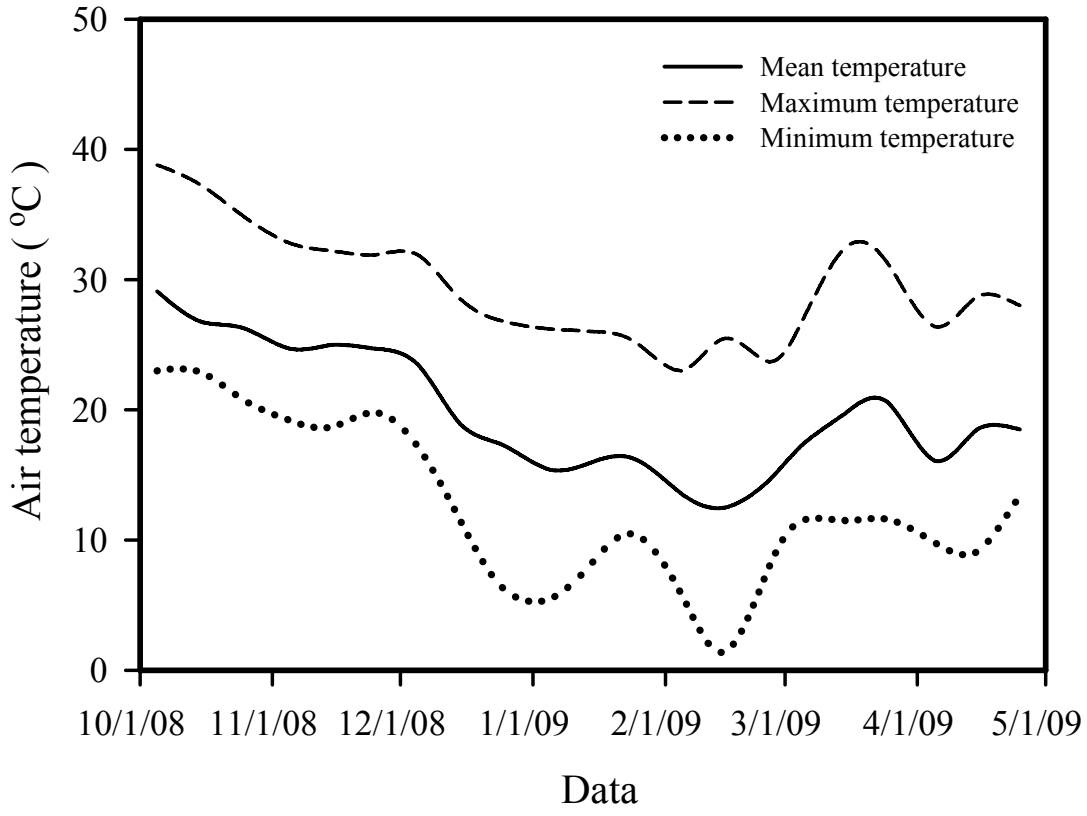
附錄

附錄一、試驗地區氣溫記錄



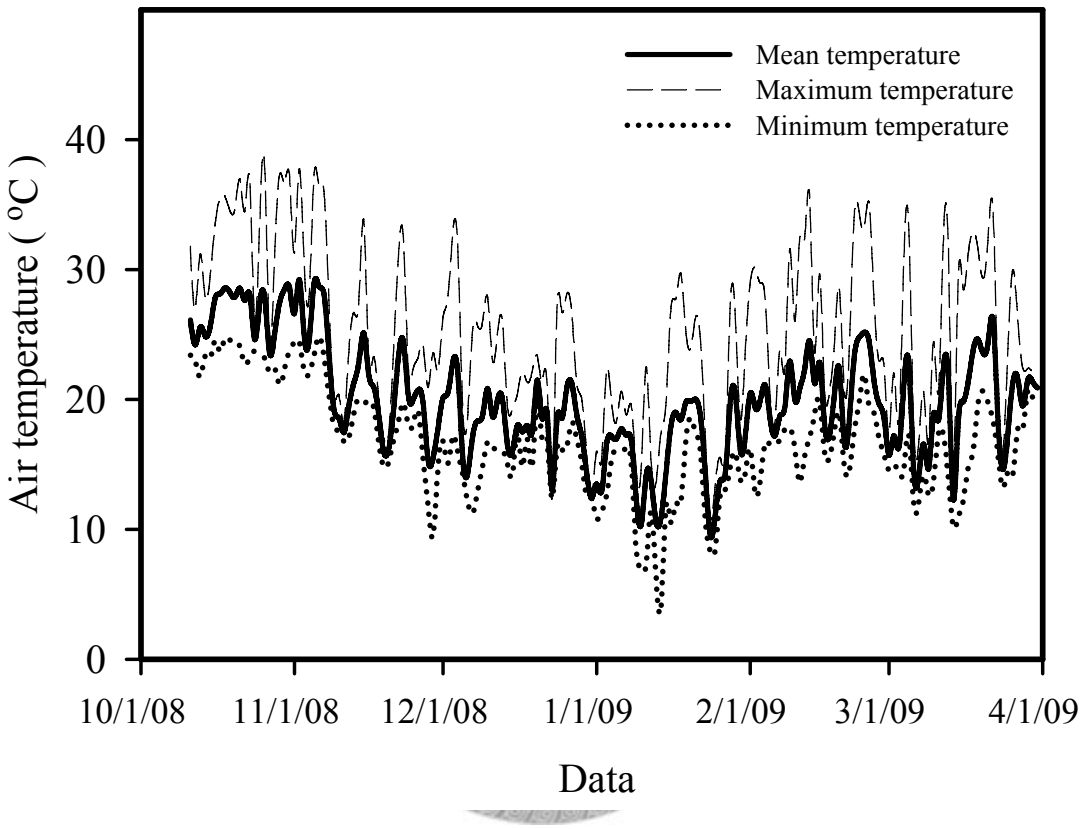
圖附 1-1. 2007 年 10 月至 2008 年 4 月苗栗地區溫度。

Appendix 1-1. The mean temperature, maximum temperature and minimum temperature in Miaoli (Oct. 2007 to Apr. 2008). The date was acquired form Miaoli District Agricultural Research and Extension Station council of Agriculture, Executive Yuan.



圖附 1-2. 2008 年 10 月至 2009 年 4 月苗栗地區溫度。

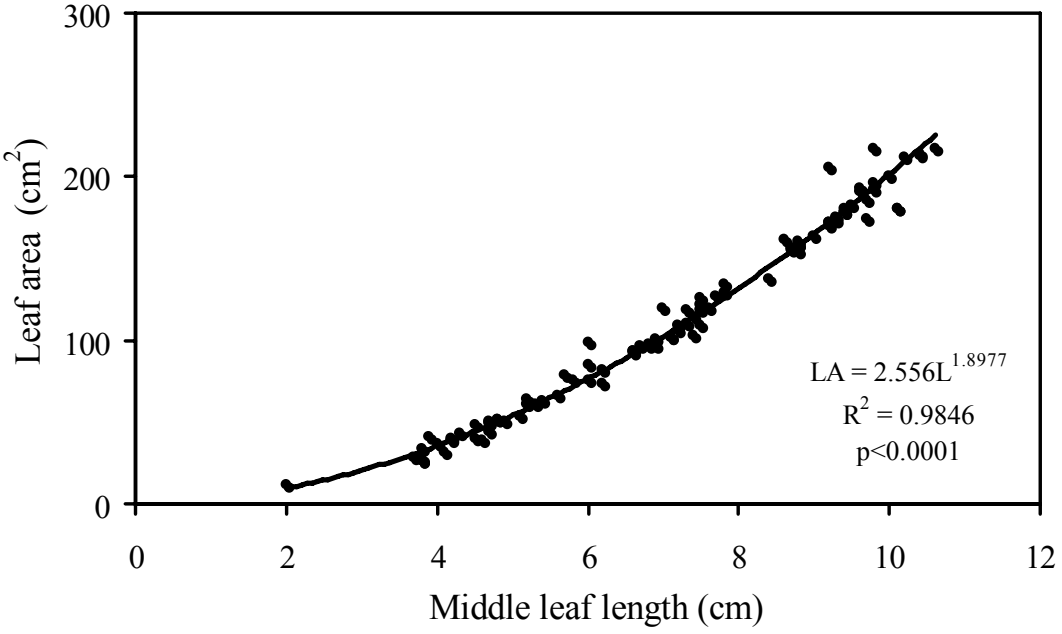
Appendix 1-2. The mean temperature, maximum temperature and minimum temperature in Miaoli (Oct. 2008 to Apr. 2009). The date was acquired form Miaoli District Agricultural Research and Extension Station council of Agriculture, Executive Yuan.



圖附 1-3. 2008 年 10 月至 2009 年 3 月臺灣大學農業試驗園藝分場溫度。

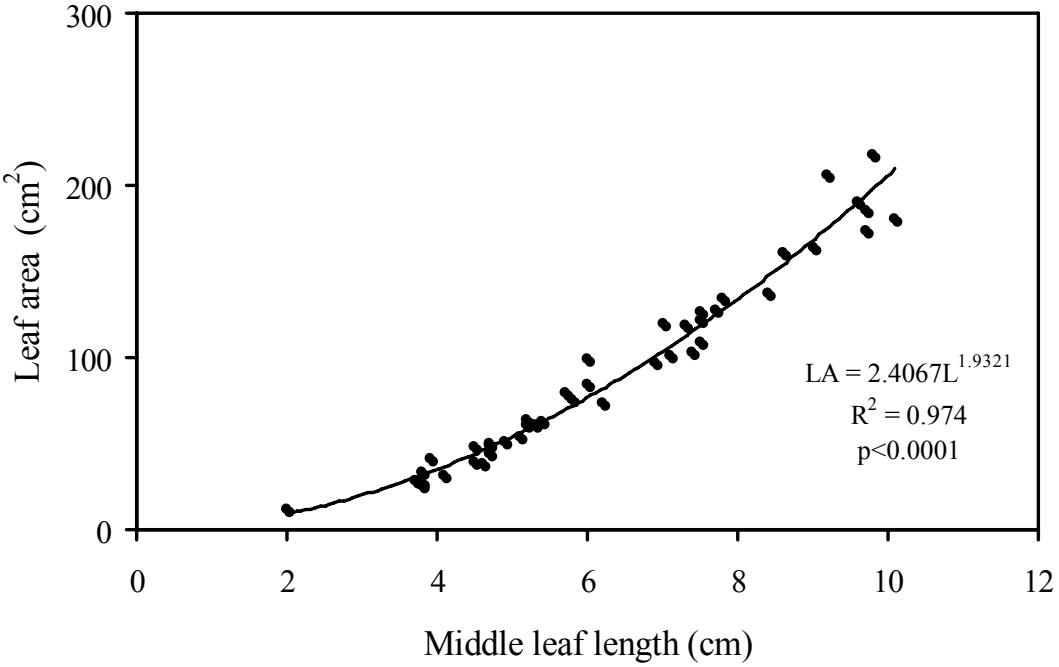
Appendix 1-3. The mean temperature, maximum temperature and minimum temperature in Horticulture Research, Experimental Farm, College of Bio-Resources and Agriculture of National Taiwan University (Oct. 2008 to Apr. 2009).

附錄二、利用葉片長度估算草莓葉面積



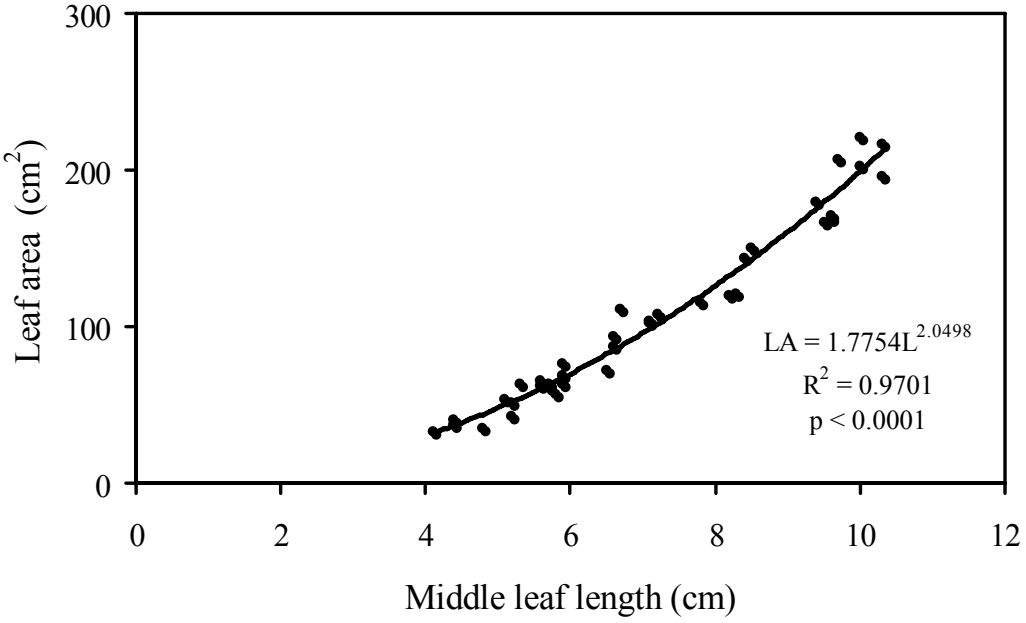
圖附 2-1.‘豐香’草莓三出複葉之頂小葉片長度與葉面積之關係(試驗於 2007 年 10 月至 2008 年 4 月，苗栗)。

Appendix 2-1. The overall relationship between middle leaf length of ternate leaf and the measurements of the actual leaf area of ‘Toyonoka’ strawberries(n = 150) (Oct. 2007 to Apr. 2008, Miaoli).



圖附 2-2.‘豐香’草莓三出複葉之頂小葉片長度與葉面積之關係（試驗於 2008 年 10 月至 2009 年 4 月，臺北）。

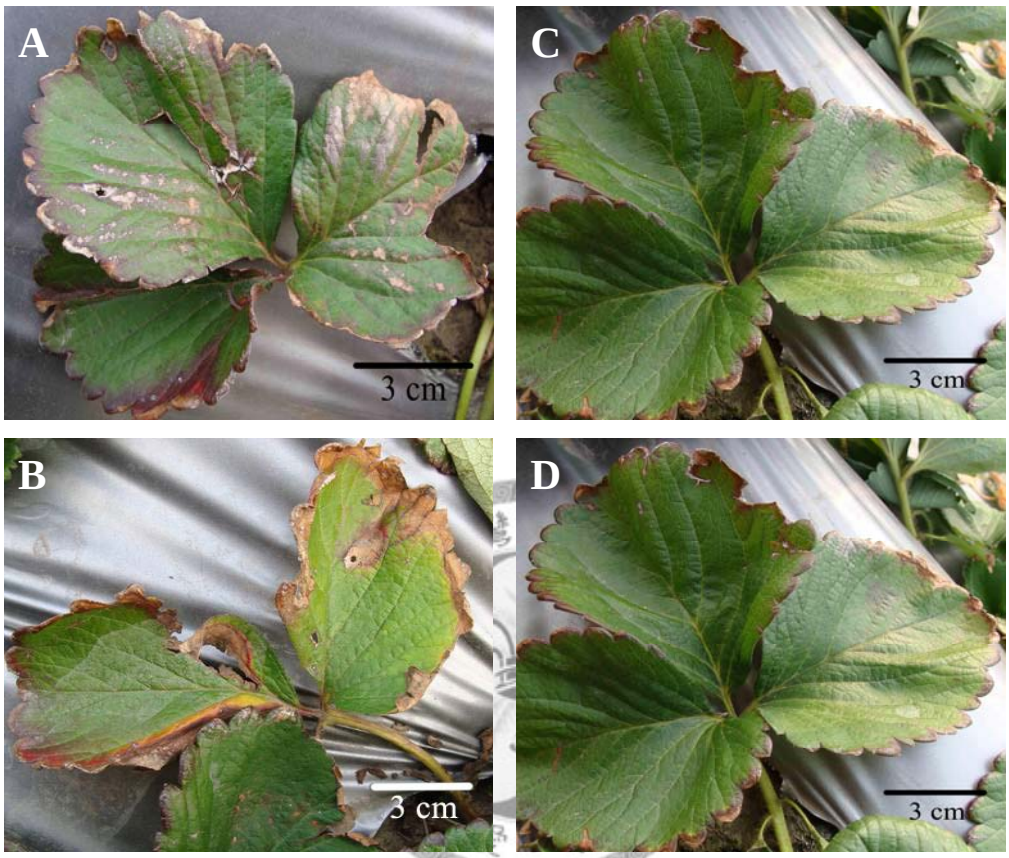
Appendix 2-2. The overall relationship between middle leaf length of ternate leaf and the measurements of the actual leaf area of ‘Toyonoka’ strawberries (n = 80) (Oct. 2008 to Apr. 2009, Taipei).



圖附 2-3.‘豐香’草莓三出複葉之頂小葉片長度與葉面積之關係（試驗於 2008 年 10 月至 2009 年 4 月，苗栗）。

Appendix 2-3. The overall relationship between middle leaf length of ternate leaf and the measurements of the actual leaf area of ‘Toyonoka’ strawberries (n = 80) (Oct. 2007 to Apr. 2008, Miaoli).

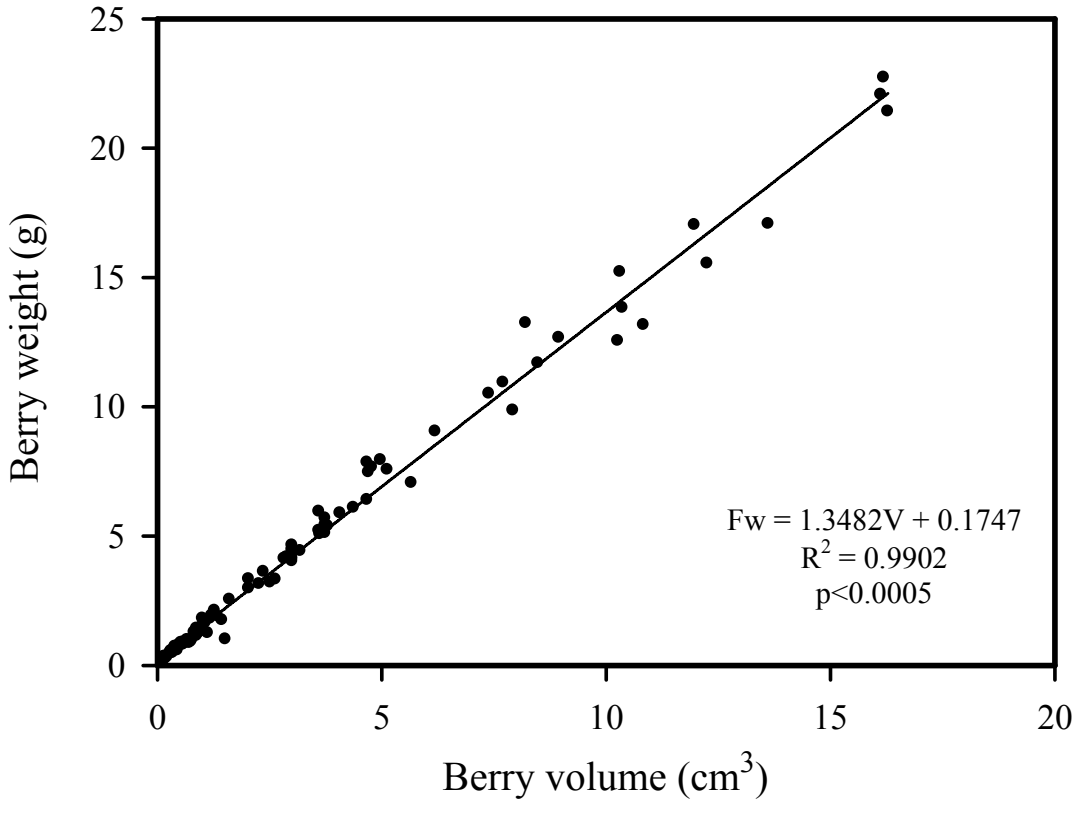
附錄三、草莓葉片葉齡 60 天與葉齡 45 天之外觀



圖附 3.‘豐香’草莓不同葉齡之葉片外觀（A）（B）葉齡超過 60 天（C）（D）葉齡超過 45 天。

Appendix 3. Leaf Morphology and Characteristics at Various Ages of ‘Toyonoka’ strawberries. (A) (B) Leaves 60-day or older. (C) (D) Leaves 45-day or older.

附錄四、果實體積與果實重量之關係



圖附 4.‘豐香’草莓果實體積與果實重量之關係（試驗於 2007 年 10 月至 2008 年 4 月，苗栗）。

Appendix 4. The overall relationship between berry volume and the measurements of the actual berry weight of ‘Toyonoka’ strawberries (n = 100) (Oct. 2007 to Apr. 2008, Miaoli).