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溫度與日射量對紫色葉菜甘藷生長性狀及植體元素之影響

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摘要

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本研究以農業部農業試驗所嘉義農業試驗分所育成紫葉品系的葉菜甘藷 CYY84-67 作為試驗材料，並於 2016–2018 年在農業部農業試驗所農場進行試驗調查，藉由每季定植 1 次連續採收 3 次，2 年期間共計蒐集 24 個不同採收期的調查數據與氣象資料。研究目的係釐清溫度與日射量對紫色葉菜甘藷生長性狀與植體元素之影響，以期瞭解紫色葉菜甘藷之最適栽培時期，闡明溫度與日射量對植體元素之消長變化。本研究利用典型相關分析，探討 2 組變數間相互關係最大的線性組合，並計算 2 組變數在線性關係最大化之權重，結果顯示紫色葉菜甘藷 CYY84-67 於春秋兩季的單位面積產量最高，利用典型相關分析顯示生育度日數、累加日射量及累加日夜溫差，是影響紫色葉菜甘藷其葉面積、葉乾重及莖乾重的氣象參數，其中又以累加日射量影響權重最大。此外，生育度日數、累加日射量及累加日夜溫差，也會影響紫色葉菜甘藷 CYY84-67 其葉片與莖部植體元素含量的變化，其中生育度日數對葉片的鈣影響權重較大，而累加日射量對莖部的磷影響權重較高。

關鍵詞：紫色葉菜甘藷、溫度、日射量、生長性狀、植體元素。

前言

葉菜甘藷 (*Ipomoea batatas* L.)，英名為 leafy sweet potato，別名為地瓜葉與過溝菜，屬於旋花科甘藷屬之一年或多年生蔓生植物。甘藷原產於熱帶美洲 (Cooley 1951)，為熱帶與亞熱帶地區重要的飼料、糧食作物及工業原料，具匍匐地面生長特性且全年四季皆可生產。再加上栽培管理容易不須多施農藥且可連續採收，因此生產成本較低，故葉菜甘藷成為國產大宗蔬菜之一。葉菜甘藷的形態含有多種葉色與葉片形狀，葉色有黃、淺綠、深綠及紫紅色，而葉片則有卵形、心形及羽狀深裂等形狀。另葉菜甘藷含有多種營養成分，其維生素 A 與 C 含量高，且含豐富蛋白質、葉酸、礦物元素 (鉀、鈣及鎂) 及膳食纖維 (Lai *et al*. 2000; Tang *et al*. 2021)。往昔文獻顯示葉菜甘藷可抑制糖尿病、白血病、病毒、結腸癌細胞及胃癌細胞的增生等 (Yoshimoto *et al*. 2002; Kurata *et al*. 2007; Ludvik *et al*. 2008)。紫色葉菜甘藷 (purple leafy sweet potato) 主要營養成分與葉菜甘藷相似，其富含酚類化合物、類黃酮及花青素等機能性成分，被視為現代物美價廉的健康蔬菜 (Chu *et al*. 2000; Rumbaoa *et al*. 2009; Gunathilake & Ranaweera 2016; Li *et al*. 2019)。

葉菜甘藷適合熱帶與亞熱帶地區栽培，在溫暖濕潤條件下生長快速，全臺栽培面積約 100 ha，栽培地區則以雲林縣西螺鎮為主，可週年採收又以 4–9 月為盛產期。此外，葉菜甘藷喜全日照、高溫環境、耐旱及耐熱，但不耐寒與長時間淹水，其生長適溫範圍為 20–30℃，在 10℃以下易發生寒害，10–15℃其生長呈休眠狀態，15℃以上可發根與發芽，

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35℃以上則有高溫障礙與生長衰退情形 (Lai & Huang 2012)。葉菜甘藷定植後至第一次採收需 40–50 d，在夏季 7–14 d 採收 1 次，冬季低溫生長緩慢約 20–25 d 才採收 1 次 (Lai & Huang 2012)。

已知溫度、日射量及養分為影響作物生長與產量的主要因子，如溫度會影響作物光合作用、礦物元素吸收及植體形態，高溫或低溫則會抑制作物生長表現 (Wurr & Fellows 1991; Yan & Hunt 1999; Kong *et al*. 2023)。太陽輻射量乃是提供作物進行光合作用的能量來源，而作物的乾物質是經由光合作用所形成，藉由作物累積截獲的光合有效輻射與利用效率所決定 (Andersen *et al*. 1996; Fochesatto *et al*. 2016)。除此，植物對養分吸收的方式可透過質流、根截取及滲透作用，且植物蒸散作用亦會影響養分吸收效率，而溫度、光照、濕度及風速等環境因子則會影響蒸散作用速率，進而改變植物對養分的吸收 (Chen 2009)。文獻研究顯示，葉菜類蔬菜的礦物質含量會隨生長階段、收穫時間、環境及栽培條件不同而有所差異 (Khader & Rama 1998; Wang *et al*. 2008; Waterland *et al*. 2017)，而葉片氮濃度則會影響葉面積光合作用與相對生長速率 (Reich *et al*. 1998)。此外，鈣離子是植物生長與發育的重要元素，可維持細胞壁結構完整性、調節氣孔、花粉管生長及根毛延伸等生理反應，而低溫則會誘導鈣離子訊息傳遞，以調節植物耐冷性基因的表現 (Sanders *et al*. 2002; White & Broadley 2003; Dodd *et al*. 2010; Iqbal *et al*. 2022)。

本研究目的旨在釐清溫度與日射量對紫色葉菜甘藷生長性狀與植體元素之影響，期瞭解紫色葉菜甘藷之最適栽培時期，並闡明溫度與日射量對植體元素之消長變化，以作為蔬菜生產之理論與應用基礎。

材料與方法

植物材料與栽培管理

本試驗以農業部農業試驗所嘉義農業試驗分所育成的心形紫葉品系 CYY84-67 作為試驗材料，並於 2016–2018 年種植在農業部農業試驗所之農場 (臺中市霧峰區)。本試驗採逢機完全區集設計 (randomized complete block design; RCBD)，田區規劃 4 重複，每畦長 5 m、寬 8 m，行距 1.2 m，共 4 畦，每重複種植 40 株扦插苗，株距固定為 0.5 m，採雙行植。田區施肥以有機質肥料新樂園 1 號 (固態粉粒狀，pH 7.7；成分為 4% N、3% P_2O_5、3% K_2O、2.1% MgO 及有機質 70%，興農股份有限公司，臺灣臺中市) 10 Mg ha^{-1}、尿素 (CH_4N_2O) 50 kg ha^{-1}、過磷酸鈣 ($Ca(H_2PO_4)_2$) 260 kg ha^{-1} 及氯化鉀 (KCl) 150 kg ha^{-1} 混合作為基肥，本試驗每定植 1 次將連續採收 3 次，每次採收後再施用尿素 (CH_4N_2O) 50 kg ha^{-1}。本研究有關葉用甘藷病蟲害防治之推薦藥劑，係參考農業部動植物防疫檢疫署農藥資訊服務網 (https://pesticide.aphia.gov.tw/information/) 所列的葉用甘藷之病蟲害防治用藥。

性狀調查與氣象資料收集

將紫色葉菜甘藷剪取約 15–20 cm 長度作為扦插苗，分別於 2016 年 3 月 7 日、6 月 7 日、8 月 30 日及 12 月 8 日定植，2017 年則在 3 月 7 日、6 月 28 日、9 月 5 日及 12 月 7 日定植，且每定植 1 次將連續採收 3 次，採收標準係以紫色葉菜甘藷覆蓋整個畦面為準 (圖 1)。另一方面，依栽植期間月份劃分栽植季節，以 3–5 月為春季 (spring)、6–8 月為夏季

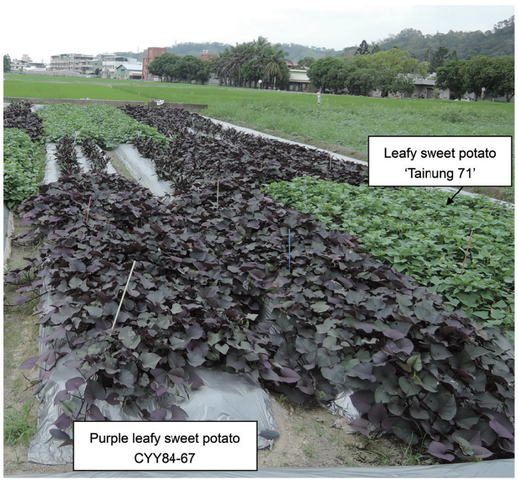

圖 1. 參試材料於試驗田區達採收標準之示意照。

Fig. 1. Photo of the test plants reaching harvesting standard in the experimental field.

(summer)、9–11 月為秋季 (autumn)，而 12 月至翌年 2 月為冬季 (winter)，因此 2016–2018 年期間合計 24 個不同採收期的試驗資料 (表 1)。本試驗取樣方式為離畦面 15–20 cm 處修平，調查部位以頂端 15 cm 長之嫩梢為主，生長性狀調查項目包含單株頂芽數 (number of terminal buds)、單枝葉片數 (number of leaves per shoot)、單枝葉面積 (leaf area per shoot, cm^2)、徑寬 (diameter of stem, mm)、單枝葉乾重 (dry weight of leaves per shoot, g)、單枝莖乾重 (dry weight of stems per shoot, g)、頂芽乾重 (dry weight of terminal buds, g) 及單位面積產量 (yield per unit area, kg m^{-2})。

紫色葉菜甘藷於 2016–2018 年栽植期間分別收集臨近試區一級農業氣象測站之氣象資料，包含 (1) 累加日均溫 (accumulated daily air temperature; ADAT,℃)，累加栽植期間每日的日均溫；(2) 累加日間最高氣溫 (accumulated maximum daytime air temperature; AMDTAT, ℃)，累加栽植期間日出至日落時間的每小時最高溫度，春季累加時間為 06:00–18:00，夏季累加時間為 05:00–19:00，秋季累加時間為 06:00–18:00，冬季累加時間為 06:00–17:00；(3) 累加夜間最低氣溫 (accumulated minimum nighttime air temperature; AMNTAT,℃)，累加栽植期間日落至日出時間的每小時最低溫度，

表 1. 紫色葉菜甘藷 CYY84-67 於 2016–2018 年期間合計 24 個採收期之定植日期、收穫日期、栽培季節及收穫天數。

Table 1. Dates of planting, harvest, crop season and days to harvest time of 24 cultivation periods of purple leafy sweet potato CYY84-67 in 2016–2018.

Date of planting	Date of harvest	Crop season	Days to harvest time
2016/3/7	2016/4/20	spring	44
	2016/5/17	spring	27
	2016/6/29	summer	43
2016/6/7	2016/7/12	summer	35
	2016/8/4	summer	23
	2016/8/24	summer	20
2016/8/30	2016/10/4	autumn	34
	2016/11/3	autumn	30
	2016/11/29	autumn	26
2016/12/8	2017/1/24	winter	47
	2017/3/1	winter	36
	2017/4/5	spring	35
2017/3/7	2017/4/20	spring	44
	2017/5/17	spring	27
	2017/6/20	summer	34
2017/6/28	2017/8/11	summer	44
	2017/9/7	summer	27
	2017/9/29	autumn	22
2017/9/5	2017/10/12	autumn	37
	2017/11/9	autumn	28
	2017/12/7	autumn	28
2017/12/7	2018/2/26	winter	81
	2018/3/30	spring	32
	2018/4/26	spring	27

春季累加時間為19:00–05:00，夏季累加時間為20:00–04:00，秋季累加時間為 19:00–05:00，冬季累加時間為 18:00–05:00；(4) 累加日夜溫差 (accumulated diurnal temperature regimes; ADTR,℃)，累加栽植期間每日的日間氣溫減去夜間氣溫之溫差；(5) 累加日射量 (accumulated daily solar radiation; ADSR, MJ m^{-2})，累加栽植期間每日的日輻射量；(6) 平均日均溫 (mean values of daily air temperature; MDAT,℃)，平均栽植期間每日的日均溫；(7) 平均日間最高氣溫 (mean values of maximum daytime air temperature; MMDTAT,℃)，平均栽植期間日出至日落時間的每小時最高溫度；(8) 平均夜間最低氣溫 (mean values of minimum nighttime air temperature; MMNTAT,℃)，平均栽植期間日落至日出時間的每小時最低溫度；(9) 平均日夜溫差 (mean values of diurnal temperature regimes; MDTR,℃)，平均栽植期間每日的日間氣溫減去夜間氣溫之溫差；(10) 平均日射量 (mean values of daily solar radiation; MDSR, MJ m^{-2})，平均栽植期間每日的日輻射量；(11) 生育度日數 (growing degree days; GDD)，為每日的日均溫減去10℃基礎溫度之總和，GDD 的計算公式如下：

$$GDD = \sum [(T_{max} + T_{min}) / 2 - T_b]$$

T_{max} 為每日最高溫，T_{min} 為每日最低溫，T_b 為基礎溫度 (León Pacheco *et al*. 2019)。當溫度低於 T_b 時，作物生長發育停止。Lai & Huang (2012) 報告顯示，葉菜甘藷在 10–15℃生長呈休眠狀態，且 Wu (2018) 碩士論文調查發現甘藷地上部基礎溫度約為 10℃，因此本試驗基礎溫度設為 10℃。

植體元素分析

本試驗參考 Zarcinas *et al*. (1987) 之方法經修飾後進行，將採收後的紫色葉菜甘藷分別秤取葉片與莖部各 400 g 鮮重，以自來水與去離子水清洗植株，並將植株置入烘箱以 70℃烘乾 48 h。烘乾後植體以鈦刀磨粉機粉碎後進行植體元素分析，氮 (nitrogen, N) 與碳 (carbon, C) 以元素分析儀 (2400 Series II, Perkin Elmer, Waltham, MA, USA) 測定，而磷 (phosphorus, P)、硫 (sulfur, S)、鈉 (sodium, Na)、鉀 (potassium, K)、鈣 (calcium, Ca) 及鎂 (magnesium, Mg) 等元素分析係採用二酸分解法，分別以硝酸 - 過氯酸 (5 : 1，v/v) 與鹽酸進行酸分解，分解液定量並以濾紙 (No.2, Whatman, Little Chalfont, UK) 過濾後，接著以感應耦合電漿原子發射光譜分析儀 (ULTIMA 2C, HORIBA Jobin Yvon, Irvine, CA, USA) 測定，單位以 % 表示。鐵 (iron, Fe)、錳 (manganese, Mn)、硼 (boron, B)、銅 (copper, Cu) 及鋅 (zinc, Zn) 等元素則是利用感應耦合電漿質譜儀 (7500C ICP–MS, Agilent, Santa Clara, CA, USA) 進行測定，單位以 mg kg^{-1} 表示。

統計分析

本研究係採用典型相關分析 (canonical correlation analysis; CCA) (Härdle & Simar 2015)，其為多變量統計的分析方法且係屬交叉共變數矩陣的一種，其目的是探討 2 組變數間相互關係最大的線性組合，並計算 2 組變數在線性關係最大化下的權重。本試驗分析變數包含 24 個不同採收期之氣象資料、8 組生長性狀參數及 14 組植體元素參數。統計分析工具係利用 R 語言，分析過程已初步排除同組變數間所存在的多元共線性現象。

結果與討論

不同採收期對紫色葉菜甘藷生長性狀之影響

本研究於 2016–2018 年利用不同季節定植紫色葉菜甘藷，並獲取 24 個不同採收期的試驗與氣象資料 (表 1 與表 2)。由表 1 結果發現，每季定植後至第一次採收的時間會相較於第二、三次時間較長，可能是扦插苗根系尚未生長所產生的生育延遲現象。再者，隨著採收次數增加則採收所需的天數會逐漸縮短，惟 2016 年 6 月 29 日與 2017 年 6 月 20 日之第三次採收時間相對較長，可能是受 6 月梅雨季節

降雨天數增加，進而影響採收時間點。此外，本研究發現 2017 年 12 月 7 日扦插至第一次採收所需的生育日數長達 81 d，其原因可能是在此生育期間，氣溫低於 15℃的天數約有 21 d，而低溫影響植株根系生長，導致紫色葉菜甘藷生育緩慢。

甘藷原產於熱帶美洲 (Cooley 1951)，其生長適溫為 20–30℃，且在 15℃時以上才開始發根與發芽，若溫度在 10–15℃時生長呈休眠狀態，而 10℃以下易發生寒害，35℃以上則會造成高溫障礙生長衰退，因此甘藷係屬一種暖季作物 (Lai & Huang 2012)。Lee *et al*. (1998) 研究指出，露天栽培之葉菜甘藷由扦插至第一次採收，所需生育日數長短與鮮重生長速度，均顯著受氣象因子影響，而影響生育日數長短的主要限制因子，乃冬季低溫與夏季扦插後，植株生長勢未恢復時的高降雨量。

本研究進一步調查紫色葉菜甘藷 CYY84-67 於 2016–2018 年不同採收期生長性狀，由結果顯示 2017 年 4 月 5 日、9 月 29 日與 2018 年 3 月 30 日、4 月 26 日採收期具有較高的單位面積產量，而上述採收期所栽培的季節主要為春秋兩季 (表 3 與表 4)。為釐清不同採收期氣象資料對紫色葉菜甘藷生長性狀之影響，本試驗分析變數包含 24 個不同採收期之氣象資料與 8 組生長性狀參數。由於變數量較多，本研究係採用典型相關分析 (CCA)，以探討此兩組變數間相關性較大的組合。由表 5 結果發現，生育度日數 (GDD)、累加日射量 (ADSR) 及累加日夜溫差 (ADTR) 可能為影響生長性狀的主要氣象參數，其中第一典型相關變數，以 GDD 與 ADSR 對單枝葉乾重與單枝葉面積的影響權重較大且呈正相關 (r = 0.735)，而在第二典型相關變數，則以 ADSR 與 ADTR 對單枝葉面積與單枝莖乾重的影響權重較高且呈正相關 (r = 0.608)。 已知作物生長與產量會受溫度與太陽輻射量所影響，而作物生育溫度大多以基溫表示，其溫度量化以生育度日數作為估算方法，可用來評估作物生育階段與採收期，以利作物栽培管理 (León Pacheco *et al*. 2019)。本研究利用典型相關分析發現，GDD、ADSR 及 ADTR 可能為影響紫色葉菜甘藷之單枝葉面積、單枝葉乾重及單枝莖乾重的氣象參數，其中又以累加日射量影響權重最大 (表 5)。Wu (2018) 論文顯示，甘藷地上部之基礎溫度約為 10℃，最適生長溫度約為 32℃，且不同品種與採收部位所需的生育度日數也會有所差異。再者，生物量為作物冠層截獲太陽輻射的產物，而作物產量與太陽輻射呈正相關，且增加氮肥含量可提高青花菜與春季油菜之光輻射利用效率，其透過增加葉面積與葉面積指數，以獲得較多的光輻射截獲量，進而提高生物量累積 (VÅgen *et al*. 2004; Fochesatto *et al*. 2016)。此外，日夜溫差的幅度大小也會影響蔬菜的生長、形態及產量 (Myster & Moe 1995; Inthichack *et al*. 2012)。

不同採收期對紫色葉菜甘藷植體元素之消長變化

將 2017–2018 年不同採收期的紫色葉菜甘藷，分別秤取葉片與莖部各 400 g 鮮重進行元素分析，共計 14 種植體元素。在不同採收期葉片的氮含量為 3.1–5.3%、碳含量為 41.7–44.4%、碳氮比 8.4–13.3、磷含量為 0.36–0.57%、硫含量為 0.31–0.42%、鈉含量為 0.10–0.83%、鉀含量為 2.3–4.3%、鈣含量為 1.0–1.9% 及鎂含量為 0.40–0.64% (表 6)，而莖部的氮含量為 0.67–2.29%、碳含量為 38.1–40.9%、碳氮比 17.3–61.4、磷含量為 0.28–0.50%、硫含量為 0.13–0.21%、鈉含量為 0.01–0.35%、鉀含量為 3.8–5.8%、鈣含量為 0.71–1.41% 及鎂含量為 0.22–0.40% (表 7)。另一方面，在不同採收期葉片的鐵含量為 164.4–586.9 mg kg^{-1}、錳含量為 45.3–95.5 mg kg^{-1}、硼含量為 25.4–65.9 mg kg^{-1}、銅含量為 8.2–14.7 mg kg^{-1} 及鋅含量為 18.2–32.0 mg kg^{-1} (表 6)，而莖部的鐵含量為 59.3–347.5 mg kg^{-1}、錳含量為 10.2–18.0 mg kg^{-1}、硼含量為 10.4–27.6 mg kg^{-1}、銅含量為 7.3–13.7 mg kg^{-1} 及鋅含量為 11.7–23.1 mg kg^{-1} (表 7)。

表 2.　紫色葉菜甘藷 CYY84-67 於 2016–2018 年期間 24 個採收期之氣象資料。

Table 2.　Meteorological data calculated from 24 cultivation periods of purple leafy sweet potato CYY84-67 in 2016–2018.

Date of transplanting	Date of harvest	ADAT[z]	AMDTAT	AMNTAT	GDD	ADTR	ADSR	MDAT	MMDTAT	MMNTAT	MDTR	MDSR
2016/3/7	2016/4/20	915.1	997.3	844.6	475.1	152.7	500.2	20.8	22.7	19.2	3.5	11.4
	2016/5/17	715.8	770.3	661.2	445.8	109.1	455.0	26.5	28.5	24.5	4.0	16.9
	2016/6/29	1,202.8	1,284.8	1,118.7	772.8	166.1	745.6	28.0	29.9	26.0	3.9	17.3
2016/6/7	2016/7/12	989.5	1,061.6	910.5	639.5	151.1	628.7	28.3	30.3	26.0	4.3	18.0
	2016/8/4	682.0	730.5	627.1	452.0	103.5	482.2	29.7	31.8	27.3	4.5	21.0
	2016/8/24	574.8	611.7	535.7	374.8	76.1	343.7	28.7	30.6	26.8	3.8	17.2
2016/8/30	2016/10/4	963.0	1,038.2	895.4	613.0	142.8	509.6	27.5	29.7	25.6	4.1	14.6
	2016/11/3	807.5	889.4	741.0	507.5	148.5	440.5	26.9	29.6	24.7	4.9	14.7
	2016/11/29	606.6	669.6	556.9	346.6	112.7	305.2	23.3	25.8	21.4	4.3	11.7
2016/12/8	2017/1/24	903.4	1,041.5	798.9	433.4	242.6	569.8	19.2	22.2	17.0	5.2	12.1
	2017/3/1	643.7	753.5	560.3	283.7	193.1	466.6	17.9	20.9	15.6	5.4	13.0
	2017/4/5	702.1	790.5	626.9	352.1	163.6	523.6	20.1	22.6	17.9	4.7	15.0
2017/3/7	2017/4/20	958.7	1,068.0	867.9	518.7	200.1	658.8	21.8	24.3	19.7	4.5	15.0
	2017/5/17	680.9	743.9	620.5	410.9	123.3	434.4	25.2	27.6	23.0	4.6	16.1
	2017/6/20	911.1	973.7	851.5	571.1	122.2	474.2	26.8	28.6	25.0	3.6	13.9
2017/6/28	2017/8/11	1,263.6	1,352.1	1,165.2	823.6	188.4	811.9	28.7	30.7	26.5	4.3	18.5
	2017/9/7	785.8	835.8	733.2	515.8	102.5	490.4	29.1	31.0	27.2	3.8	18.2
	2017/9/29	639.5	693.5	589.5	419.5	104.0	423.9	29.1	31.5	26.8	4.7	19.3
2017/9/5	2017/10/12	1,078.6	1,169.0	996.1	708.6	172.9	676.7	29.2	31.6	26.9	4.7	18.3
	2017/11/9	678.2	744.1	618.1	398.2	126.1	417.3	24.2	26.6	22.1	4.5	14.9
	2017/12/7	628.1	689.2	578.5	348.1	110.7	322.3	22.4	24.6	20.7	4.0	11.5
2017/12/7	2018/2/26	1,379.7	1,567.0	1,236.1	571.0	330.9	869.4	17.0	19.3	15.3	4.1	10.7
	2018/3/30	648.6	730.4	575.5	328.6	154.9	533.0	20.3	22.8	18.0	4.8	16.7
	2018/4/26	639.9	705.9	581.1	369.9	124.8	463.2	23.7	26.1	21.5	4.6	17.2

[z] ADAT: accumulated daily air temperature; AMDTAT: accumulated maximum daytime air temperature; AMNTAT: accumulated minimum nighttime air temperature; GDD: growing degree days (base temperature 10℃); ADTR: accumulated diurnal temperature regimes; ADSR: accumulated daily solar radiation; MDAT: mean values of daily air temperature; MMDTAT: mean values of maximum daytime air temperature; MMNTAT: mean values of minimum nighttime air temperature; MDTR: mean values of diurnal temperature regimes; and MDSR: mean values of daily solar radiation.

表 3. 紫色葉菜甘藷 CYY84-67 於 2016 年定植之不同採收期生長性狀。

Table 3. Comparison of plant growth traits of purple leafy sweet potato CYY84-67 planted in different cultivation periods in 2016.

Date of harvest	Number of terminal buds	Number of leaves per shoot	Leaf area per shoot (cm^2)	Diameter of stem (mm)	Leaf dry weight per shoot (g)	Stem dry weight per shoot (g)	Dry weight of terminal buds (g)	Yield per unit area ($kg\ m^{-2}$)
2016/4/20	4.7 ± 0.5 g[z]	21.5 ± 2.1 e	741.0 ± 87.3 g	4.91 ± 0.08 ef	2.7 ± 0.2 g	1.8 ± 0.1 f	4.5 ± 0.2 f	0.4 ± 0.1 f
2016/5/17	6.8 ± 0.8 fg	28.7 ± 3.7 de	777.9 ± 123.0 g	4.78 ± 0.24 ef	3.3 ± 0.7 g	2.6 ± 0.8 ef	5.9 ± 1.4 ef	0.9 ± 0.3 ef
2016/6/29	8.6 ± 0.4 ef	31.5 ± 1.3 d	869.9 ± 39.2 g	5.22 ± 0.05 abc	3.6 ± 0.2 fg	3.3 ± 0.2 de	7.0 ± 0.3 de	1.4 ± 0.1 def
2016/7/12	9.9 ± 0.3 de	35.5 ± 1.2 d	1,303.9 ± 60.4 ef	5.36 ± 0.14 a	4.8 ± 0.1 cde	4.2 ± 0.2 cd	9.0 ± 0.3 c	2.0 ± 0.1 cde
2016/8/4	9.8 ± 0.2 de	35.1 ± 1.0 d	944.1 ± 26.5 g	5.42 ± 0.08 a	4.3 ± 0.1 ef	3.7 ± 0.2 cd	8.0 ± 0.3 cd	1.9 ± 0.1 def
2016/8/24	11.7 ± 0.8 bcd	42.8 ± 2.6 c	1,440.3 ± 80.5 def	5.21 ± 0.11 abcd	5.0 ± 0.5 cde	3.8 ± 0.4 cd	8.8 ± 0.8 cd	2.6 ± 0.4 bcd
2016/10/4	13.4 ± 1.1 b	52.7 ± 3.9 b	1,615.0 ± 136.1 cd	4.75 ± 0.01 ef	5.3 ± 0.3 cd	4.4 ± 0.3 bc	9.7 ± 0.5 c	3.6 ± 0.5 b
2016/11/3	10.3 ± 1.1 cde	34.3 ± 3.3 d	1,491.5 ± 84.4 cde	5.00 ± 0.10 bcde	5.1 ± 0.5 cde	4.2 ± 0.5 cd	9.2 ± 1.0 c	2.5 ± 0.6 bcd
2016/11/29	12.8 ± 0.2 b	47.1 ± 2.6 bc	1,943.4 ± 116.7 b	4.64 ± 0.04 f	5.4 ± 0.4 c	3.6 ± 0.2 cd	9.0 ± 0.7 c	3.4 ± 0.2 bc
2017/1/24	9.1 ± 0.4 e	31.3 ± 1.0 d	1,212.7 ± 44.3 f	4.92 ± 0.08 def	4.4 ± 0.2 def	3.7 ± 0.2 cd	8.1 ± 0.4 cd	1.7 ± 0.2 def
2017/3/1	12.3 ± 0.7 bc	48.7 ± 1.9 bc	1,709.6 ± 59.8 bc	5.27 ± 0.06 ab	6.5 ± 0.2 b	5.3 ± 0.2 b	11.8 ± 0.4 b	3.6 ± 0.4 b
2017/4/5	20.6 ± 1.6 a	76.7 ± 3.3 a	2,630.6 ± 102.2 a	4.93 ± 0.06 cdef	9.8 ± 0.4 a	8.5 ± 0.4 a	18.2 ± 0.7 a	10.0 ± 1.4 a

[z] Data are mean ± *SE* of flour replicates. Different letters mean significant differences at $P < 0.05$ level by LSD test.

表 4. 紫色葉菜甘藷 CYY84-67 於 2017 年定植之不同採收期生長性狀。

Table 4. Comparison of plant growth traits of purple leafy sweet potato CYY84-67 planted in different cultivation periods in 2017.

Date of harvest	Number of terminal buds	Number of leaves per shoot	Leaf area per shoot (cm^2)	Diameter of stem (mm)	Leaf dry weight per shoot (g)	Stem dry weight per shoot (g)	Dry weight of terminal buds (g)	Yield per unit area ($kg\ m^{-2}$)
2017/4/20	13.3 ± 0.7 de[z]	46.6 ± 3.9 d	1,753.7 ± 140.6 bc	5.26 ± 0.13 bcd	6.1 ± 0.5 de	5.4 ± 0.3 c	11.5 ± 0.8 c	4.0 ± 0.4 bc
2017/5/17	12.4 ± 0.4 de	36.2 ± 0.7 ef	1,381.2 ± 71.3 cd	5.22 ± 0.04 cd	5.1 ± 0.1 ef	5.1 ± 0.1 cd	10.1 ± 0.1 cd	3.2 ± 0.2 c
2017/6/20	11.4 ± 0.1 e	31.4 ± 0.6 f	1,295.1 ± 68.7 de	5.42 ± 0.11 bc	4.6 ± 0.2 fg	4.3 ± 0.2 d	8.8 ± 0.4 de	2.8 ± 0.1 c
2017/8/11	7.1 ± 0.5 f	24.2 ± 1.2 g	908.1 ± 66.9 f	5.59 ± 0.12 ab	3.5 ± 0.1 gh	4.1 ± 0.2 d	7.6 ± 0.3 ef	1.2 ± 0.2 d
2017/9/7	11.7 ± 0.6 e	39.2 ± 2.5 e	1,768.1 ± 208.0 b	5.51 ± 0.13 bc	5.3 ± 0.5 ef	5.7 ± 0.5 bc	11.1 ± 1.0 c	3.4 ± 0.5 c
2017/9/29	17.4 ± 1.0 a	55.5 ± 3.6 bc	2,396.7 ± 137.3 a	5.40 ± 0.07 bc	7.5 ± 0.5 bc	7.1 ± 0.6 a	14.6 ± 1.1 b	6.4 ± 0.7 a
2017/10/12	7.0 ± 0.4 f	20.9 ± 1.9 g	928.9 ± 76.6 ef	5.85 ± 0.06 a	2.9 ± 0.3 h	2.9 ± 0.3 e	5.9 ± 0.5 f	1.1 ± 0.1 d
2017/11/9	14.1 ± 0.3 cd	47.9 ± 0.4 d	1,942.3 ± 179.3 b	5.01 ± 0.14 d	5.7 ± 0.5 ef	4.9 ± 0.3 cd	10.6 ± 0.8 cd	4.1 ± 0.3 bc
2017/12/7	n.d.[y]	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2018/2/26	14.2 ± 1.0 cd	73.5 ± 3.7 a	2,366.0 ± 137.9 a	4.46 ± 0.11 e	9.3 ± 0.5 a	7.5 ± 0.5 a	16.8 ± 0.9 a	5.3 ± 0.8 ab
2018/3/30	15.5 ± 1.0 bc	61.2 ± 3.3 b	2,323.2 ± 145.4 a	5.20 ± 0.16 cd	8.5 ± 0.5 ab	6.7 ± 0.3 ab	15.2 ± 0.8 ab	5.5 ± 0.6 a
2018/4/26	17.2 ± 0.5 ab	50.9 ± 1.6 cd	2,096.9 ± 129.8 ab	5.01 ± 0.15 d	6.9 ± 0.4 cd	6.7 ± 0.2 ab	13.6 ± 0.5 b	5.9 ± 0.4 a

[z] Data are mean ± *SE* of flour replicates. Different letters mean significant differences at $P < 0.05$ level by LSD test.
[y] n.d. = no data.

表 5. 紫色葉菜甘藷 CYY84-67 生長性狀與氣象參數之典型相關分析。

Table 5. The canonical correlation analysis for plant growth traits of purple leafy sweet potato CYY84-67 with meteorological variables.

Variable	Canonical loading	
	1st	2nd
Climatic factors (x vectors)		
GDD[z]	1.531	0.155
ADSR	-1.569	-1.667
ADTR	0.206	0.939
Growth indices (y vectors)		
Leaf area per single bud	1.121	1.756
Leaf dry weight per single bud	-2.262	0.282
Stem dry weight per single bud	0.064	-2.295
Yield per unit area	0.295	0.542
Canonical correlation (*r*)	0.735	0.608

[z] GDD: growing degree days; ADSR: accumulated daily solar radiation; ADTR: accumulated diurnal temperature regimes.

本試驗分析變數包含 24 個不同採收期之氣象資料與 14 組植體元素參數，並利用典型相關分析 (CCA)，探討不同採收期氣象參數與紫色葉菜甘藷植體元素之相關性組合。由 CCA 結果顯示，GDD、ADSR 及 ADTR 可能為影響葉片植體元素的氣象參數，而葉片植體元素鈣、鎂、鈉、鐵及硫等，可能是受氣象參數所影響的元素；其中第一典型相關變數，以 GDD 對鈣的影響權重較大且呈正相關 (r = 0.856)，在第二典型相關變數，則以 ADSR 對鈉的影響權重較高且呈正相關 (r = 0.704)。另一方面，平均日均溫 (MDAT)、ADSR、ADTR 及 GDD，可能為影響莖部植體元素的氣象參數，其中又以 ADSR 影響權重較大，而莖部植體元素磷、鋅、硫、鐵、錳及鎂等，可能是受氣象參數所影響的元素，在第一典型相關變數之 ADSR、MDAT 及 ADTR 對磷、鋅及硫呈正相關 (r = 0.915)，第二典型相關變數之 ADSR 與 ADTR 對磷、錳及鎂呈正相關 (r = 0.648) (表 8)。

上述研究發現，生育度日數 (GDD)、累加日射量 (ADSR) 及累加日夜溫差 (ADTR) 可能為影響紫色葉菜甘藷植體元素的氣象參數 (表 8)。已知影響植體元素含量變化的因素相當多，除了遺傳特性與肥料施用外，栽植環境的光照、溫度、採收時間及季節等皆是造成植體元素含量波動的原因 (Samuolienė *et al*. 2011; Li *et al*. 2013)。Fallovo *et al*. (2009) 研究指出，高光強度會促進植物對氮、鉀及鎂的吸收，因此夏季採收葉萵苣的氮、鉀及鎂含量會顯著高於春季。另一方面，植物對礦物質的吸收需透過根系呼吸進行主動運輸，而低溫會減少萵苣蒸散量與磷、鉀及硝酸鹽的吸收，若提高根溫則會促進礦物質的吸收量 (Lee *et al*. 2014; Albornoz & Lieth 2015)。

本研究顯示紫色葉菜甘藷 CYY84-67 在春秋兩季會有最高的單位面積產量，利用典型相關分析發現，生育度日數、累加日射量及累加日夜溫差，可能是影響紫色葉菜甘藷之單枝葉面積、單枝葉乾重、單枝莖乾重及植體元素之氣象參數。由於葉菜甘藷生長快速且栽培容易，再加上耐旱耐濕與抗病蟲害等特性，以及農藥施用較少屬於健康蔬菜，尤其適合機械收穫可大面積栽培，惟 CYY84-67 紫葉品系由於適口性不佳，故作為蔬菜供消費者食用的接受度不高。本研究後續將進一步分析不同採收期對紫色葉菜甘藷 CYY84-67 之機能性與抗氧化能力影響變化，據以篩檢出機能性成分含量較高之栽培時期，藉此推廣機能性蔬菜之多元利用性與附加價值，並提供消費者之營養保健參考。

表 6. 紫色葉菜甘藷 CYY84-67 於 2017–2018 年不同採收期之葉片植體元素含量分析。

Table 6. Analysis of plant element contents from the leaves of purple leafy sweet potato CYY84-67 grown in different cultivation periods in 2017–2018.

Date of harvest	Nitrogen (N)	Carbon (C)	C/N ratio	Phosphorus (P)	Sulfur (S)	Sodium (Na)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)
	%					%			
2017/1/24	5.2 ± 0.1 a[z]	44.4 ± 0.6 a	8.5 ± 0.2 g	0.46 ± 0.01 bc	0.41 ± 0.01 ab	0.20 ± 0.02 fg	3.6 ± 0.2 abcd	1.7 ± 0.1 c	0.48 ± 0.02 efg
2017/3/1	4.5 ± 0.1 b	44.1 ± 0.1 ab	9.9 ± 0.3 f	0.47 ± 0.01 bc	0.40 ± 0.02 abc	0.36 ± 0.04 cde	3.4 ± 0.1 bcd	1.8 ± 0.1 abc	0.52 ± 0.02 cde
2017/4/5	4.5 ± 0.2 b	43.6 ± 0.1 abc	9.7 ± 0.3 f	0.45 ± 0.01 bc	0.40 ± 0.03 abc	0.45 ± 0.03 bc	3.5 ± 0.0 bcd	1.9 ± 0.0 a	0.54 ± 0.02 cd
2017/4/20	5.3 ± 0.2 a	44.2 ± 0.2 a	8.4 ± 0.3 g	0.39 ± 0.01 cd	0.41 ± 0.01 ab	0.48 ± 0.07 b	3.0 ± 0.3 cde	1.7 ± 0.0 bc	0.59 ± 0.03 b
2017/5/17	4.2 ± 0.2 bc	42.8 ± 0.2 cde	10.4 ± 0.4 def	0.42 ± 0.02 cd	0.38 ± 0.01 abcd	0.83 ± 0.02 a	2.3 ± 0.1 e	1.8 ± 0.0 abc	0.64 ± 0.02 a
2017/6/20	4.2 ± 0.1 bc	44.4 ± 0.1 a	10.5 ± 0.3 def	0.45 ± 0.01 bc	0.35 ± 0.02 cde	0.38 ± 0.04 bcd	3.0 ± 0.2 de	1.0 ± 0.1 g	0.40 ± 0.01 i
2017/8/11	3.1 ± 0.1 e	41.7 ± 0.4 e	13.3 ± 0.6 a	0.41 ± 0.05 cd	0.31 ± 0.01 e	0.10 ± 0.02 g	3.9 ± 0.1 ab	1.2 ± 0.0 f	0.46 ±0.01 fg
2017/9/7	3.7 ± 0.1 d	44.2 ± 0.3 a	12.1 ± 0.2 bc	0.44 ± 0.01 c	0.34 ± 0.00 de	0.15 ± 0.01 g	3.6 ± 0.1 abcd	1.2 ± 0.1 f	0.41 ± 0.01 hi
2017/9/29	3.9 ± 0.1 cd	42.8 ± 0.8 cde	11.1 ± 0.5 cde	0.55 ± 0.03 a	0.37 ± 0.01 abcde	0.42 ± 0.07 bc	3.5 ± 0.1 bcd	1.4 ± 0.1 e	0.48 ± 0.01 efg
2017/10/12	4.2 ± 0.1 bc	42.1 ± 0.7 de	10.1 ± 0.2 ef	0.45 ± 0.01 bc	0.32 ± 0.04 de	0.28 ± 0.03 ef	4.3 ± 0.1 a	1.2 ± 0.1 f	0.45 ± 0.01 gh
2017/11/9	4.1 ± 0.1 bc	44.3 ± 0.3 a	10.7 ± 0.3 def	0.56 ± 0.04 a	0.38 ± 0.01 abcd	0.45 ± 0.01 bc	3.5 ± 0.2 bcd	1.9 ± 0.1 ab	0.55 ± 0.01 bc
2017/12/7	4.3 ± 0.2 b	42.8 ± 0.2 bcde	10.1 ± 0.6 ef	0.57 ± 0.05 a	0.38 ± 0.03 abcd	0.46 ± 0.03 bc	3.0 ± 0.1 de	1.5 ± 0.1 de	0.47 ± 0.02 efg
2018/2/26	3.5 ± 0.1 de	44.0 ± 0.8 abc	12.5 ± 0.5 ab	0.36 ± 0.01 d	0.35 ± 0.01 cde	0.20 ± 0.03 fg	3.6 ± 0.1 abcd	1.9 ± 0.1 a	0.46 ± 0.01 fg
2018/3/30	3.5 ± 0.2 de	42.1 ± 0.7 de	12.2 ± 0.4 bc	0.45 ± 0.02 bc	0.35 ± 0.02 bcde	0.29 ± 0.00 def	3.8 ± 0.1 abc	1.7 ± 0.1 cd	0.48 ± 0.01 efg
2018/4/26	3.9 ± 0.2 cd	43.1 ± 0.2 abcd	11.3 ± 0.6 cd	0.52 ± 0.04 ab	0.42 ± 0.05 a	0.45 ± 0.03 bc	3.5 ± 0.2 bcd	1.6 ± 0.0 cd	0.50 ± 0.01 def

表 6. 紫色葉菜甘藷 CYY84-67 於 2017–2018 年不同採收期之葉片植體元素含量分析。(續)

Table 6. Analysis of plant element contents from the leaves of purple leafy sweet potato CYY84-67 grown in different cultivation periods in 2017–2018. (Continued)

	Iron (Fe)	Manganese (Mn)	Boron (B)	Copper (Cu)	Zinc (Zn)
Date of harvest			mg kg^{-1}		
2017/1/24	246.3 ± 13.1 efg	45.3 ± 0.6 f	25.8 ± 2.3 f	14.7 ± 0.5 a	32.0 ± 1.0 a
2017/3/1	384.1 ± 21.8 cd	84.2 ± 9.0 ab	53.9 ± 1.5 abc	12.5 ± 0.2 cde	23.8 ± 0.9 defg
2017/4/5	293.8 ± 21.8 def	76.1 ± 7.2 abc	54.9 ± 4.1 abc	12.6 ± 0.8 cde	21.5 ± 1.4 gh
2017/4/20	443.3 ± 60.9 bc	48.8 ± 3.0 ef	40.4 ± 1.4 de	14.6 ± 0.6 ab	29.2 ± 0.4 ab
2017/5/17	586.9 ± 55.5 a	82.0 ± 5.3 ab	48.2 ± 4.4 bcde	12.6 ± 0.3 cde	26.0 ± 0.5 bcdef
2017/6/20	541.5 ± 33.9 ab	47.0 ± 3.3 f	56.6 ± 7.9 ab	11.9 ± 0.5 de	25.2 ± 0.7 cdef
2017/8/11	546.7 ± 92.8 ab	74.2 ± 13.9 bcd	25.4 ± 2.6 f	8.2 ± 0.3 f	18.2 ± 0.4 h
2017/9/7	351.0 ± 32.0 cde	48.2 ± 4.2 f	54.2 ± 2.1 abc	11.0 ± 0.4 e	22.4 ± 1.1 fg
2017/9/29	383.8 ± 43.4 cd	64.9 ± 3.8 bcdef	59.0 ± 4.0 ab	13.9 ± 0.6 abc	28.5 ± 1.2 abc
2017/10/12	289.8 ± 72.7 defg	55.1 ± 11.7 def	39.9 ± 6.4 e	12.9 ± 0.8 bcd	24.3 ± 2.2 defg
2017/11/9	164.4 ± 3.6 g	61.1 ± 7.4 cdef	59.5 ± 4.0 ab	12.5 ± 0.3 cde	27.1 ± 0.8 bcd
2017/12/7	179.5 ± 19.8 fg	47.3 ± 1.4 f	48.5 ± 3.4 bcde	14.1 ± 0.6 abc	26.7 ± 0.9 bcde
2018/2/26	223.9 ± 32.8 fg	68.1 ± 9.8 bcde	44.1 ± 1.8 cde	9.2 ± 0.3 f	23.3 ± 1.4 efg
2018/3/30	278.6 ± 36.1 defg	95.5 ± 5.9 a	52.5 ± 4.5 bcd	11.2 ± 0.7 de	24.1 ± 1.8 defg
2018/4/26	230.9 ± 26.8 efg	72.6 ± 1.6 bcd	65.9 ± 7.1 a	11.5 ± 1.4 de	23.6 ± 2.4 defg

[z] Data are mean ± *SE* of flour replicates. Different letters mean significant differences at $P < 0.05$ level by LSD test.

表 7. 紫色葉菜甘藷 CYY84-67 於 2017–2018 年不同採期之莖部植體元素含量分析。

Table 7. Analysis of plant element contents from the stems of purple leafy sweet potato CYY84-67 grown in different cultivation periods in 2017–2018.

Date of harvest	Nitrogen (N)	Carbon (C)	C/N ratio	Phosphorus (P)	Sulfur (S)	Sodium (Na)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)
	%			%					
2017/1/24	1.95 ± 0.14 b[z]	40.0 ± 0.4 abc	20.8 ± 1.5 gh	0.35 ± 0.01 defg	0.17 ± 0.01 def	0.08 ± 0.01 fghi	4.7 ± 0.2 bcd	1.33 ± 0.12 ab	0.34 ± 0.02 bc
2017/3/1	1.44 ± 0.18 cd	39.6 ± 0.2 abcd	28.6 ± 3.0 efg	0.35 ± 0.01 efg	0.21 ± 0.01 a	0.12 ± 0.01 def	5.8 ± 0.2 a	1.27 ± 0.06 abc	0.33 ± 0.01 bc
2017/4/5	1.71 ± 0.06 bc	40.6 ± 0.3 ab	23.9 ± 0.9 fgh	0.38 ± 0.03 cde	0.20 ± 0.01 abc	0.14 ± 0.01 cde	5.3 ± 0.2 ab	1.41 ± 0.11 a	0.33 ± 0.01 bc
2017/4/20	2.29 ± 0.15 a	39.1 ± 0.2 cde	17.3 ± 1.3 h	0.28 ± 0.01 g	0.15 ± 0.00 fgh	0.16 ± 0.03 bcd	4.7 ± 0.4 bcde	1.21 ± 0.06 bc	0.37 ± 0.02 ab
2017/5/17	1.21 ± 0.11 def	40.9 ± 0.4 a	34.4 ± 2.9 de	0.38 ± 0.02 cde	0.17 ± 0.01 de	0.35 ± 0.03 a	3.9 ± 0.2 f	1.10 ± 0.06 cde	0.40 ± 0.02 a
2017/6/20	1.33 ± 0.04 de	39.5 ± 0.1 abcd	29.8 ± 1.0 efg	0.46 ± 0.03 ab	0.20 ± 0.01 ab	0.18 ± 0.03 bc	4.7 ± 0.3 bcde	1.00 ± 0.03 de	0.32 ± 0.01 c
2017/8/11	0.87 ± 0.03 gh	40.0 ± 0.2 abc	46.4 ± 1.9 b	0.40 ± 0.04 bcde	0.15 ± 0.01 efg	0.01 ± 0.00 j	4.7 ± 0.1 bcde	0.76 ± 0.03 fg	0.23 ± 0.01 de
2017/9/7	0.67 ± 0.07 h	39.9 ± 0.4 abcd	61.4 ± 7.0 a	0.37 ± 0.01 def	0.14 ± 0.00 gh	0.04 ± 0.00 ij	4.3 ± 0.2 cdef	0.73 ± 0.06 fg	0.22 ± 0.01 e
2017/9/29	0.93 ± 0.05 fgh	39.2 ± 0.3 bcde	42.5 ± 1.8 bcd	0.50 ± 0.03 a	0.19 ± 0.00 abc	0.09 ± 0.01 fgh	5.0 ± 0.2 abc	0.91 ± 0.06 ef	0.32 ± 0.01 c
2017/10/12	0.94 ± 0.04 fgh	39.1 ± 0.4 cde	42.0 ± 2.0 bcd	0.33 ± 0.02 efg	0.13 ± 0.01 h	0.08 ± 0.00 fghi	3.8 ± 0.3 f	0.90 ± 0.11 efg	0.32 ± 0.02 c
2017/11/9	1.01 ± 0.14 efg	40.8 ± 0.8 a	43.0 ± 6.0 bcd	0.41 ± 0.02 bcd	0.18 ± 0.01 bcd	0.15 ± 0.01 cde	4.1 ± 0.4 def	1.12 ± 0.07 bcd	0.32 ± 0.03 c
2017/12/7	1.35 ± 0.23 d	38.5 ± 0.7 de	31.3 ± 5.7 ef	0.36 ± 0.04 def	0.21 ± 0.01 a	0.20 ± 0.03 b	4.8 ± 0.3 bcd	1.16 ± 0.07 bcd	0.33 ± 0.01 bc
2018/2/26	0.92 ± 0.05 fgh	38.1 ± 1.1 e	41.8 ± 2.4 bcd	0.31 ± 0.01 fg	0.17 ± 0.00 cde	0.06 ± 0.01 ghi	3.8 ± 0.2 f	1.30 ± 0.08 ab	0.26 ± 0.01 d
2018/3/30	0.91 ± 0.03 fgh	40.5 ± 0.3 abc	44.6 ± 1.4 bc	0.35 ± 0.01 def	0.14 ± 0.00 gh	0.04 ± 0.00 hij	3.9 ± 0.2 ef	0.75 ± 0.01 fg	0.25 ± 0.00 de
2018/4/26	1.19 ± 0.16 defg	39.5 ± 0.5 abcd	34.9 ± 4.2 cde	0.45 ± 0.02 abc	0.20 ± 0.01 ab	0.11 ± 0.01 efg	5.1 ± 0.5 ab	0.71 ± 0.01 g	0.26 ± 0.01 de

表 7. 紫色葉菜甘藷 CYY84-67 於 2017–2018 年不同採期之莖部植體元素含量分析。(續)

Table 7. Analysis of plant element contents from the stems of purple leafy sweet potato CYY84-67 grown in different cultivation periods in 2017–2018. (Continued)

Date of harvest	Iron (Fe)	Manganese (Mn)	Boron (B)	Copper (Cu)	Zinc (Zn)
			mg kg^{-1}		
2017/1/24	85.1 ± 7.7 ef	15.1 ± 1.6 abcd	17.9 ± 1.6 cd	13.7 ± 0.7 a	23.1 ± 2.0 a
2017/3/1	116.8 ± 4.4 def	18.0 ± 1.8 a	11.1 ± 1.4 e	11.1 ± 0.5 bcd	18.9 ± 0.6 b
2017/4/5	161.0 ± 5.7 cde	14.7 ± 0.9 abcd	12.2 ± 2.0 de	13.4 ± 0.7 a	16.9 ± 1.0 b
2017/4/20	190.5 ± 40.2 cd	15.2 ± 1.0 abcd	11.6 ± 0.9 de	11.5 ± 0.1 bc	16.4 ± 0.3 bc
2017/5/17	347.5 ± 87.9 a	16.0 ± 1.9 abc	19.6 ± 2.9 bc	12.3 ± 0.6 ab	17.7 ± 1.2 b
2017/6/20	252.4 ± 40.7 abc	17.4 ± 1.5 ab	27.6 ± 6.2 a	9.8 ± 0.9 cd	12.9 ± 0.8 d
2017/8/11	247.3 ± 39.5 bc	13.0 ± 1.8 cde	19.4 ± 2.8 bc	7.3 ± 0.5 e	11.7 ± 0.6 d
2017/9/7	301.5 ± 63.6 ab	12.5 ± 0.8 cde	15.3 ± 0.7 cde	9.7 ± 0.9 cd	14.0 ± 0.9 cd
2017/9/29	240.8 ± 14.7 bc	13.2 ± 0.8 cde	15.6 ± 1.3 cde	10.4 ± 0.8 cd	17.3 ± 1.3 b
2017/10/12	127.0 ± 19.6 def	12.8 ± 1.3 cde	10.4 ± 1.5 e	9.5 ± 0.5 d	12.2 ± 0.5 d
2017/11/9	59.3 ± 12.7 f	12.0 ± 1.8 de	25.4 ± 1.8 ab	11.0 ± 0.6 bcd	17.4 ± 1.0 b
2017/12/7	69.0 ± 7.3 ef	10.2 ± 1.1 e	20.7 ± 1.5 bc	10.8 ± 0.4 bcd	18.2 ± 0.9 b
2018/2/26	71.1 ± 7.4 ef	13.8 ± 1.6 bcde	17.0 ± 0.6 cde	10.8 ± 0.5 bcd	16.6 ± 1.0 bc
2018/3/30	105.1 ± 13.2 def	15.1 ± 0.5 abcd	12.2 ± 0.7 de	9.7 ± 0.1 d	19.2 ± 0.6 b
2018/4/26	63.7 ± 9.2 ef	11.7 ± 0.6 de	16.0 ± 2.5 cde	9.3 ± 0.6 d	17.0 ± 0.8 b

[z] Data are mean ± *SE* of flour replicates. Different letters mean significant differences at $P < 0.05$ level by LSD test.

表 8. 紫色葉菜甘藷 CYY84-67 不同部位植體元素與氣象參數之典型相關分析。

Table 8. The canonical correlation analysis for plant elements from the leaves and stems of purple leafy sweet potato CYY84-67 with meteorological variables.

Variables	Canonical loadings 1st	Canonical loadings 2nd
The leaves of CYY84-67		
Climatic factors (x vectors)		
GDD[z]	1.148	0.072
ADSR	-0.593	-1.259
ADTR	-0.418	0.274
Nutrition elements (y vectors)		
Calcium (Ca)	-1.238	-0.302
Magnesium (Mg)	0.446	-0.476
Sodium (Na)	0.063	1.135
Sulfur (S)	-0.038	0.441
Iron (Fe)	-0.027	-0.434
Canonical correlation (*r*)	0.856	0.704
The stems of CYY84-67		
Climatic factors (x vectors)		
ADSR	0.847	1.816
MDAT	0.687	-0.894
ADTR	-0.664	-1.255
GDD	-0.124	-0.022
Nutrition elements (y vectors)		
Phosphorus (P)	0.589	-0.586
Zinc (Zn)	-0.554	-0.151
Sulfur (S)	-0.532	-0.175
Iron (Fe)	0.242	-0.229
Manganese (Mn)	-0.165	0.497
Magnesium (Mg)	0.078	-0.662
Canonical correlation (*r*)	0.915	0.648

[z] GDD: growing degree days; ADSR: accumulated daily solar radiation; ADTR: accumulated diurnal temperature regimes; MDAT: mean values of daily air temperature.

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Effects of Temperature and Solar Radiation on Growth Traits and Plant Elements in Purple Leafy Sweet Potato

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Abstract

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In this study, the purple leafy sweet potato strain CYY84-67 bred by the Chiayi Agricultural Experiment Branch was used in the field experiment from 2016 to 2018 at Taiwan Agricultural Research Institute. A total of 24 different experimental and meteorological data were collected from 3 consecutive harvests in each cultivation period within two years. The objective of this study was to study the effects of temperature and solar radiation on the growth traits and plant elements of purple leafy sweet potato to summarize the optimal cultivation periods for purple leafy sweet potato as well as to clarify the rise and fall of temperature and solar radiation on plant elements. The canonical correlation analysis was adopted to explore the linear relationship between two groups of variables, and the weight of maximizing the correlation between the two sets of variables was calculated. The results of this study showed that purple leafy sweet potato CYY84-67 had the highest yield per unit area in both spring and autumn. The growing degree days (GDD), accumulated daily solar radiation (ADSR), and accumulated diurnal temperature regimes (ADTR) were the major meteorological variables affecting leaf area, dry weight of leaves and stems in purple leafy sweet potato, and ADSR had the greatest weight. In addition, GDD, ADSR, and ADTR also affected plant element contents from the leaves and stems of purple leafy sweet potato CYY84-67. Among these meteorological variables, GDD had the greatest weight on the calcium of the leave, while ADSR had the highest weight on the phosphorus of the stem.

Key words: Purple leafy sweet potato, Temperature, Solar radiation, Growth trait, Plant element.

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