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番茄淹水耐受性之生理研究(一)

The physiological study on tomato flooding tolerance (I)

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關鍵字：番茄、淹水耐受性

Key words：tomato, flooding tolerance.

摘要：以野生種番茄 L3683 (*Lycopersicon. hirsutum* Humb & Bongl)、L4422 (*L. pimpinellifolium*)、L1947 (*L. peruvianum* Mill)與番茄台南亞蔬 6 號(*L. esculentum*)為試驗材料，播種後兩個月淹水 0、12、48 與 120 小時。病徵依序為上偏生長、下位葉黃化、不定根生長、萎凋。根據病徵以 L3683 最耐淹水，L1947 次之，台南亞蔬 6 號最不耐淹水。淹水時間對植株鮮重、根鮮重、主根鮮重、主根乾重、葉片相對含水量與氣孔導度具顯著主效應，試驗材料對植株鮮重、植株乾重、根鮮重、地上部鮮重、主根鮮重、主根乾重、與葉綠素含量具顯著主效應，淹水時間與試驗材料之交感作用僅表現於氣孔導度。四試驗材料中，台南亞蔬 6 號之葉綠素含量最高。L1947 之全株鮮重與乾重、根鮮重與乾重最小；淹水 120 hr 期間維持穩定之葉片相對含水量；淹水 48 hr 時 Ascorbate peroxidase 活性比淹水 0hr 顯著增高；淹水 12 至 120 hr 期間氣孔導度皆比淹水 0 hr 顯著降低，且淹水 24 hr 後為四種材料中氣孔導度最低者；淹水後 12 hr 氣孔導度降低與 48 hr 之 Ascorbate peroxidase 活性增高應為 L1947 較台南亞蔬 6 號耐淹水的兩種機制。L4422 於淹水後 24 小時、台南亞蔬 6 號在 48 小時氣孔導度增高，之後下降；L4422 於淹水 120 hr 時比台南亞蔬 6 號與 L1947 有顯著較多的開花數。L3683 在淹水 48 hr 期間氣孔導度無變化，但淹水 120 hr 比 48 hr 之氣孔導度顯著較低；L3683 於淹水 120 hr 時總 Ascorbate 含量比台南亞蔬 6 號及 L1947 顯著較高；淹水 120 hr 時總 Ascorbate 含量增加與氣孔導度下降應為 L3683 較台南亞蔬 6 號耐淹水的機制之一。

前　言

番茄屬於茄科番茄屬，一年或多年生，草本或半草本灌木，原產南美安地斯山區，由西班牙人傳入歐洲。番茄果實營養豐富，可生食、煮食及加工，是具高經濟價值的世界性蔬菜，也是台灣的重要蔬果。番茄喜愛暖和、乾燥氣候，土壤過濕及高溫易發生青枯病；土壤水份過多時，根部處於缺氧(hypoxia)或無氧(anoxia)狀態，吸收礦物營養能力受抑制，根系易腐爛，影響地上部生長，下位葉易黃化，影響產量，嚴重時甚至植株死亡。台灣夏季高溫，颱風豪雨侵襲時常帶來過多的雨水，淹水逆境使夏季番茄生產遭受極大損失。

番茄屬有兩亞屬，著色果亞屬有三亞種，綠白色果亞屬有七物種，各具許多不同特性之種源，可供番茄育種時利用。目前臺灣番茄夏作及秋作品種皆不耐淹水，本計畫擬藉淹水生理研究，根據生長指標(株高、根部與地上部之鮮重及乾重、始花序節位與節間長、葉片相對含水量、葉綠素含量、葉綠素螢光反應、氣孔導度)以及生化指標(抗氧化酵素 APX 活性、抗氧化物維生素 C 與 E 含量、與根部無氧呼吸酵素活性)，了解淹水逆境下生長指標與生理機制間之關係，並期自野生種番茄找到耐淹水種源，供做番茄耐淹水育種時之材料。

本年度(93 年)比較番茄栽培品種台南亞蔬 6 號、耐水野生種 L4422 (*L. pimpinellifolium* Mill)、具多種抗病性種源之毛番茄 *L. hirsutum* Humb & Bongl、以及具耐濕與多種抗病性種源之秘魯番茄 *L. peruvianum* Mill，在淹水逆境下生長指標包括株高、根部與地上部之鮮重及乾重、始花序節位與節間長、葉片相對含水量、葉綠素含量、氣孔導度以及生化指標抗氧化酵素 APX 活性、抗氧化物 ascorbic acid 含量之差異。

前人研究

番茄屬有著色果與綠白色果兩亞屬，各有許多不同特性之種源，可供番茄育種時利用(陳, 1988)。1、著色果亞屬 Eulycopersicon 有三亞種，(1)栽培型番茄亞種(*L. esculentum* ssp. Cultum)：包括普通栽培番茄(Var. vulgare)、直立番茄(Var. validum)與大葉番茄(Var. grandifolium)。(2)半栽培型番茄亞種(*L. esculentum* ssp. Subspontaneum)：包括長圓形番茄(Var. elongatum)、多室番茄(Var. succenturiatum)、櫻桃形番茄(Var. cerasiforme)、梨形番茄(Var. pyriforme)與李形番茄(Var. pruniforme)。(3)野生型番茄亞種(*L. pimpinellifolium* Mill)：包括總狀番茄(Var. racemigerum)乾物量及糖份高、抗旱；醋栗狀番茄(Var. eupimpinellifolium)抗萎凋病。2、綠白色果亞屬 Eriopersicon (1)秘魯番茄(*L. peruvianum* Mill)：抗線虫、番茄嵌紋病毒、萎凋病、晚疫病、細菌斑點病、耐濕、高維生素 C 及高糖度(12~13%)。(2)智利番茄(*L. chilense* Dum)：抗頂葉黃化捲曲病毒病、胡瓜嵌紋病毒病。(3)多毛番茄(*L. hirsutum* Humb & Bongl)：抗胡瓜嵌紋病毒病、抗頂葉黃化捲曲病毒病、馬鈴薯 Y 型病毒病、番茄嵌紋病毒病，線虫、晚疫病、多果色。(4)潘內力番茄(*L. pennellii* Rick)：抗番茄夜蛾、具高糖度。(5)契斯曼番茄(*L. cheesmanii* Riley)。(6) *L. chmielewski*。(7) *L. parviflorum*。

作物在淹水逆境下，氣孔關閉，葉片黃化(Webb and Fletcher, 1996)。淹水降低番茄氣孔導度，抑制根部與枝條的生長；氣孔關閉是向日葵淹水時光合效率降低的主要因素，氣孔關閉亦造成氧化逆境(Schwanz *et al.*, 1996)。淹水使地下部器官如根、地下莖缺氧，有氧呼吸、電子傳遞降低，產生的能量減少，進而根部的導水力減弱，植物體內可利用的水分減少，光合作用速率迅速降低，產量受影響。當植物在逆境下，ROS 增加，造成細胞之氧化傷害(Zhang & Kirkham, 1996)。植物若能於逆境下加強 ROS 掃除系統，可有較強之逆境抗性，維持其生存、健康、生長及生產。抗氧化酵素活性及抗氧化物含量常被當做抗逆境指標(Tausz *et al*, 1997; Cho & Park, 2000)；高等植物之抗氧化系統(antioxidative system)可清除 ROS (Allen, 1995)，包括酵素 ascorbate peroxidase (APX)、 superoxide dismutase、catalase 及 glutathione reductas (Gupta *et al*, 1993)，以及抗氧化物如抗壞血酸(ascorbate, ASA)、麩胱甘肽(glutathione, GSH)、α-tocopherol 和 carotenoid (Yu & Rengel, 1999)。Biemelt 等人(1998)對小麥實生苗進行部分缺氧或完全缺氧處理，亦造成小麥根部抗氧化系統的活化。植物在淹水逆境下，其未淹水部位之抗氧化酵素活性與其耐淹水的能力有關。

農委會 90~92 年經費補助本計畫之主持人，以番茄台南亞蔬 6 號、L4422 (*L. pimpinellifolium* Mill.)、及茄子屏東長茄 EG117 和番茄根砧用品系 EG203 為試驗材料，在播種後 60 天淹水 0、3、6、12、24、48 和 72 hr，抗氧化酵素 APX 活性與抗壞血酸之總、氧化與還原態含量皆以 EG117 最高，EG203 次之，台南亞蔬 6 號最低。APX 活性隨淹水時間延長而增高。還原態 ascorbate 隨著淹水時間增加而升高，至 48 hr 達最高，之後下降。淹水處理下，EG117 具最強抗氧化系統，EG203 次之，台南亞蔬 6 號最弱；此結果符合茄子比番茄較為耐淹水、L4422 比台南亞蔬 6 號耐淹水、以及台南亞蔬 6 號不耐淹水之特性(Lin et al, 2003)。

材料與方法

以番茄(*Lycopersicon esculentum* Mill)經濟品種台南亞蔬 6 號、L4422 (*L. pimpinellifolium* Mill)、毛番茄 *L. hirsutum* Humb & Bongl 及秘魯番茄 *L. peruvianum* Mill 為試驗材料。於網室播種育苗，2003 年 8 月 24 日播種於 72 格穴盤，9 月 17 日移植。移植前以 1/1000 之獅馬葉肥每週施肥一次。移植於 5 寸素燒盆，移植後以台肥 43 號每週施肥一次。10 月 17 日番茄開第一花序時，將同一重複之盆栽放置於塑膠桶，做不同淹水時間處理：0、6、12、24 與 120 小時，採裂區設計，品種為主區，淹水時間處理為副區，完全逢機試驗(completely randomized design, CRD)，三重複。於各淹水時間分別測定生長指標包括株高、根部與地上部之鮮重及乾重、始花序節位與節間長、葉片相對含水量。3.測定生化指標：(1)葉綠素含量以 Chlorophyll Meter (Minolta, SPAD 502)測定 SPAD 值。(2)氣孔導度以 Porometer AP4 (Delta-T Devices-Cambridge-UK)測定。(3) Ascorbate peroxidase 活性(APX, 1.11.1.11)：製備酵素反應液包含 Sample 40 μL、HEPES 166 mM 760 μL、Na ascorbate 1.5 mM 100 μL、 H2O2 1.0 mM 200 μL，以 Jasco V-530 型分光光度計測量 Na-ascorbate 於單 位時間內 290 nm 之吸光度，反應 80 秒，每 2 秒取一值(Anderson et. al., 1992)。(4) ascorbic acid 含量(Cakmak et. al., 1992)：取重約 0.1 g 根磨粉，以 1 mL 之 5% m-phosphporic acid 溶液均質後，在 4℃以 13,000 g 離心 15 min，取上 清液。製備反應液：(A)總 ASA 含量之測定：Sample 100 μL、Potassium phosphate buffer (pH7.4) 150 mM 250 μL、Dithiothreitol 10 mM 50 μL、N- ethlmaleimide 0.5 M 50 μL。(B)還原態 ASA 含量之測定：反應液與總 ASA 之反應液相同，但 DTT 與 N-ethlmaleimide 以二次蒸餾水取代。於室溫中反應 10 min 後，加入呈色反應液於 40℃反應 40 分鐘。呈色反應液： 10% trichloroacetic acid 200 μL、44% o-phosphoric acid 200 μL、4% α-dipyridyl in 70% ethanol 200 μL、3% FeCl3 100 μL。以 Jasco V-530 型分光光度計測量於 525 nm 之吸光值。(C) DHA 含量之測定：以總 ASA 含量減去還原態 ASA 含量。

以分析軟體 PC SAS V8.1 針對植株各調查項目進行統計分析。

結果與討論

番茄台南亞蔬 6 號、L4422、毛番茄及秘魯番茄四種試驗材料在淹水後，外表病徵依序為上偏生長、下位葉黃化、不定根生長、萎凋；根據病徵，以 L3683 最耐淹水，L1947 次之，台南亞蔬 6 號最不耐淹水。

表 1 顯示淹水時間對植株鮮重、根鮮重、主根鮮重、主根乾重、葉片相對含水量與氣孔導度具顯著主效應，試驗材料對植株鮮重、植株乾重、根鮮重、地上部鮮重、主根鮮重、主根乾重、與葉綠素含量具顯著主效應，淹水時間與試驗材料之交感作用僅表現於氣孔導度。

表 2 為四試驗材料於淹水期間植株鮮重之變化，L1914 之植株鮮重為四試驗材料中顯著最小；台南亞蔬 6 號在淹水 48 hr 時、L3683 於淹水 24 與 48 hr 時植株鮮重顯著降低，但二者淹水 120 hr 之植株鮮重則與淹水 0 hr 無顯著差異。四試驗材料於淹水期間植株乾重之變化列於表 3，L1914 之植株乾重仍為四試驗材料中顯著最小。

淹水時間對試驗材料根鮮重之影響列於表 4，在淹水 0, 12 與 120 hr，L1914 之根鮮重皆為四 4 試驗材料中顯著最小；淹水 48 hr 時，四試驗材料之根鮮重皆顯著降低，但淹水 120 hr 時則與淹水 0 hr 無顯著差異。

表 5 為淹水時間對四試驗材料主根鮮重之影響，在淹水 12 與 24hr，L1914 之主根鮮重亦為四試驗材料中最小；淹水 48 hr 時，四試驗材料之主根鮮重亦皆顯著降低，但淹水 120 hr 時主根鮮重皆比淹水 0 hr 更大。淹水時間對四試驗材料主根乾重之影響列於表 6，L4422 之主根乾重為四試驗材料中最大；淹水 48 hr 時，台南亞蔬 6 號與 L3683 主根乾重減小，但淹水 120 hr 時則與淹水 0 hr 無顯著差異。

於淹水 120 hr，L3683 與 L1947 之葉片相對含水量比台南亞蔬 6 號顯著較低(表 7)；淹水 48 hr 時，台南亞蔬 6 號、L4422 與 L3683 之葉片相對含水量皆顯著降低，但 120 hr 時復升高至與淹水 0 hr 無顯著差異。

表 8 顯示四試驗材料各生長指標間之相關係數，除了主根乾重與各生長指標間、相對含水量與地上部鮮重及主根乾重間、主根鮮重與地上部鮮重間無相關性之外，其他生長指標間皆具顯著相關性。

由表 9 得知，L4422 在淹水後 24 小時、台南亞蔬 6 號在 48 小時氣孔導度增高，但之後下降；L3683 在淹水 48 hr 氣孔導度無變化，但淹水 120 hr 比 48 hr 之氣孔導度顯著較低；L1947 在淹水 12 hr 後，其氣孔導度皆比淹水 0 hr 顯著減小，且淹水 24 hr 後成為四種材料中氣孔導度最低者。淹水後氣孔導度降低應為 L1947 耐淹水機制之一，而可於淹水 120 hr 期間維持其葉片相對含水量。

四試驗材料台南亞蔬 6 號之葉綠素含量最高(表 10)。淹水 120 hr 時，L4422 之開花數比台南亞蔬 6 號與 L1947 顯著較多(表 11)。淹水 120 hr 時，四試驗材料之花苞數皆比淹水 0 hr 顯著增加(表 12)。淹水期間四試驗材料之始花節間長無顯著差異(表 13)。

淹水 48 hr 時 Ascorbate peroxidase 活性比淹水 0hr 顯著增高(表 14)。L3683 於淹水

120 hr 時總 Ascorbate 含量比台南亞蔬 6 號及 L1947 顯著較高(表 15)。

結 論

L1947 之全株鮮重與乾重、根鮮重與乾重最小；淹水 120 hr 期間維持穩定之葉片相對含水量；淹水 48 hr 時 Ascorbate peroxidase 活性比淹水 0hr 顯著增高；在淹水 12 hr 至 120 hr，氣孔導度皆比淹水 0 hr 顯著降低，且淹水 24 hr 後為四種材料中氣孔導度最低者。淹水 12 hr 後氣孔導度降低與 48 hr 之 Ascorbate peroxidase 活性增高應為 L1947 較台南亞蔬 6 號耐淹水的兩種機制。

L3683 在淹水 48 hr 期間氣孔導度無變化，但淹水 120 hr 比 48 hr 之氣孔導度顯著較低。L3683 於淹水 120 hr 時總 Ascorbate 含量比台南亞蔬 6 號及 L1947 顯著較高。於淹水 120 hr 時有較高之總 Ascorbate 含量與氣孔導度下降應為 L3683 較台南亞蔬 6 號耐淹水的兩種機制。

L4422 於淹水後 24 小時、台南亞蔬 6 號在 48 小時氣孔導度增高，但之後下降，其可於淹水 120 hr 時比台南亞蔬 6 號與 L1947 有顯著較多的開花數。

Table 1. ANOVA of flooding time, entry and interaction (TxE) on characters of tomato.

Source of Variance	F Value						
	Whole plant		Main root		Fresh weight		Relative
	FW	DW	FW	DW	Root	Tops	water content
Flooding time	0.0116*	0.5674NS	0.0001**	0.0301*	0.0001**	0.0681NS	0.0401*
Entry	0.0001**	0.0001**	0.0002**	0.0011**	0.0002**	0.0001**	0.7585NS
TxE	0.9277NS	0.6605NS	0.7978NS	0.8795NS	0.5363NS	0.9401NS	0.9813NS

＊: n≦0.05; ＊＊: 0.001≦n≦0.01; ＊＊＊: n≦0.001; NS: non-significant difference.

Table 1 (continued). ANOVA of flooding time, entry and interaction (TxE) on characters of tomato.

Source of variance	F Value			
	Stomatal conductivity	Chlorophyll content	Ascorbate Peroxidase	Total Ascorbate content
Flooding time	0.0001 **	0.3881NS	0.2668NS	0.6560NS
Entry	0.0946NS	0.0487*	0.1403NS	0.6698NS
TxE	0.0212*	0.741NS	0.1382NS	0.6690NS

Table 2. The effect of flooding time on plant fresh weight of tomato.

Entry	Plant fresh weight (g)				
	Flooding time				
	0 hr	12 hr	24 hr	48 hr	120 hr
TNVEG 6	63.62aA	63.21aA	56.32aAB	44.78aB	59.57aAB
L4422	72.36aA	77.28aA	68.55aA	59.64aA	76.098aA
L3683	75.71aA	60.71aAB	55.71aB	53.30aB	74.81aA
L1947	35.42bA	26.44bA	34.87bA	23.66bA	38.20bA

a, b, c: Each value is the mean of three replicates of each entry (column).
A, B, C: Each value is the mean of three replicates in each flooding time (row).
Means with the same letters are not significantly different using least significant difference (LSD) test under completely randomized design.

Table 3. The effect of flooding time on plant dry weight of tomato.

Entry	Plant dry weight (g)				
	Flooding time				
	0 hr	12 hr	24 hr	48 hr	120 hr
TNVEG 6	3.26aA	4.51aA	3.34aA	3.86aA	3.34aA
L4422	4.61aA	4.82aA	4.36aA	6.06aA	5.04aA
L3683	4.77aA	3.43aA	2.99aA	3.77aA	4.61aA
L1947	2.29bA	1.30bA	2.22bA	2.34bA	2.45bA

a, b, c: Each value is the mean of three replicates of each entry (column).
A, B, C: Each value is the mean of three replicates in each flooding time (row).
Means with the same letters are not significantly different using least significant difference (LSD) test under completely randomized design.

Table 4. The effect of flooding time on root fresh weight of tomato.

Entry	Root fresh weight (g)				
	Flooding time				
	0 hr	12 hr	24 hr	48 hr	120 hr
TNVEG 6	7.0717aAB	8.025aA	5.0617abC	1.2467aD	5.955abBC
L4422	8.673aA	9.778aA	6.992aA	1.67aB	8.858aA
L3683	8.263aA	6.788abAB	4.325bBC	2.1167aC	7.08aAB
L1947	3.475bA	2.628bAB	4.547abA	0.788aB	3.635bA

a, b, c: Each value is the mean of three replicates of each entry (column).
A, B, C: Each value is the mean of three replicates in each flooding time (row).
Means with the same letters are not significantly different using least significant difference (LSD) test under completely randomized design.

Table 5. The effect of flooding time on main root fresh weight of tomato.

Entry	Main root fresh weight (g)				
	Flooding time				
	0 hr	12 hr	24 hr	48 hr	120 hr
TNVEG 6	0.62aB	0.68abB	0.73abB	0.21bC	1.22aA
L4422	0.83aB	0.93aB	0.870aB	0.41aC	1.33aA
L3683	0.77aB	0.62abB	0.59bcB	0.27abC	1.19aA
L1947	0.57aB	0.40bBC	0.43cBC	0.27abC	0.92aA

a, b, c: Each value is the mean of three replicates of each entry (column).
A, B, C: Each value is the mean of three replicates in each flooding time (row).
Means with the same letters are not significantly different using least significant difference (LSD) test under completely randomized design.

Table 6. The effect of flooding time on dry main root weight of tomato.

Entry	Main root dry weight (g)				
	Flooding time				
	0 hr	12 hr	24 hr	48 hr	120 hr
TNVEG 6	0.063bA	0.073aA	0.061bA	0.029cB	0.054bAB
L4422	0.100aA	0.073aA	0.108aA	0.067aA	0.110aA
L3683	0.087abA	0.053aB	0.058bAB	0.044abB	0.085abA
L1947	0.061bA	0.035aA	0.063bA	0.034bA	0.046bA

a, b, c: Each value is the mean of three replicates of each entry (column).
A, B, C: Each value is the mean of three replicates in each flooding time (row).
Means with the same letters are not significantly different using least significant difference (LSD) test under completely randomized design.

Table 7. The effect of flooding time on relative water content of tomato.

Entry	Relative water content (%)				
	Flooding time				
	0 hr	12 hr	24 hr	48 hr	120 hr
TNVEG 6	86.84aAB	70.96aBC	88.60aA	66.01bC	93.41aA
L4422	89.42aA	81.37aAB	89.01aA	71.75abB	88.67abA
L3683	90.92aA	81.37aA	84.81aA	70.98abB	81.49bA
L1947	83.91aA	75.98aA	77.33aA	74.53aA	80.03bA

a, b, c: Each value is the mean of three replicates of each entry (column).
A, B, C: Each value is the mean of three replicates in each flooding time (row).
Means with the same letters are not significantly different using least significant difference (LSD) test under completely randomized design.

Table 8. Correlation coefficient among characters.

r	Plant FW	Plant DW	Root FW	Tops FW	Main root FW	Main root DW
Plant DW	0.975*					
Root FW	0.981*	0.999**				
Tops FW	0.999**	0.982*	0.986*			
Main root FW	0.922NS	0.984*	0.979*	0.934NS		
Main root DW	0.822NS	0.917NS	0.895NS	0.849NS	0.947NS	
Relative water content	0.965*	0.998**	0.993**	0.975NS	0.986*	0.940NS

*: n≦0.05; **: 0.001≦n≦0.01; ***: n≦0.001; NS: non-significant difference.

Table 9. The effect of flooding time on stomatal conductivity of tomato.

Entry	Stomatal conductivity (mmol/m^2/s)				
	Flooding time				
	0 hr	12 hr	24 hr	48 hr	120 hr
TNVEG 6	99.95aBC	60.46aC	165.59abAB	204.30aA	60.38bC
L4422	97.99aB	63.93aB	234.43aA	124.57abB	78.32aB
L3683	103.48aABC	66.62aBC	140.42bAB	147.00abA	61.77abC
L1947	142.96aA	74.29aB	93.32bB	47.73bB	51.82bB

a, b, c: Each value is the mean of three replicates of each entry (column).
A, B, C: Each value is the mean of three replicates in each flooding time (row).
Means with the same letters are not significantly different using least significant difference (LSD) test under completely randomized design.

Table 10. The effect of flooding time on chlorophyll content of tomato.

Entry	Chlorophyll content (μ g/gfw)				
	Flooding time				
	0 hr	12 hr	24 hr	48 hr	120 hr
TNVEG 6	4.73aA	5.29aA	5.35aA	4.93aA	5.23aA
L4422	4.52aA	4.55aA	5.07aA	4.53aA	4.78aA
L3683	4.33aA	4.25aA	3.94aA	4.86aA	4.86aA
L1947	4.54aA	4.44aA	4.39aA	4.69aA	5.20aA

a, b, c: Each value is the mean of three replicates of each entry (column).
A, B, C: Each value is the mean of three replicates in each flooding time (row).
Means with the same letters are not significantly different using least significant difference (LSD) test under completely randomized design.

Table 11. The effect of Flower number on flower number of tomato.

Entry	Flower number Flooding time				
	0 hr	12 hr	24 hr	48 hr	120 hr
TNVEG 6	0A	0aA	0A	0A	0bA
L4422	0B	2.17aAB	0B	0AB	0aB
L3683	0A	1.33aA	0A	0A	1.33abA
L1947	0A	1.00aA	0A	0A	0.17bA

a, b, c: Each value is the mean of three replicates of each entry (column).
A, B, C: Each value is the mean of three replicates in each flooding time (row).
Means with the same letters are not significantly different using least significant difference (LSD) test under completely randomized design.

Table 12. The effect of Flower number on flower bud number of tomato.

Entry	Flower bud number Flooding time				
	0 hr	12 hr	24 hr	48 hr	120 hr
TNVEG 6	0B	5.167aA	0aB	0B	4.333aA
L4422	0B	5.5aA	0aB	0B	6.5aA
L3683	0B	5aAB	0aB	0B	9.667aA
L1947	0B	3.167aAB	1.167aB	0B	8.667aA

a, b, c: Each value is the mean of three replicates of each entry (column).
A, B, C: Each value is the mean of three replicates in each flooding time (row).
Means with the same letters are not significantly different using least significant difference (LSD) test under completely randomized design.

Table 13. The effect of Flower number on internode length of first flower of tomato.

Entry	Internode length of first flower (mm) Flooding time				
	0 hr	12 hr	24 hr	48 hr	120 hr
TNVEG 6	4.50aA	5.60aA	7.00aA	4.98aA	4.08aA
L4422	3.40aA	5.58aA	4.15abA	5.87aA	7.30aA
L3683	2.15aA	2.50aA	1.35bA	3.52aA	3.95aA
L1947	2.65aA	4.47aA	2.40abA	3.70aA	2.98aA

a, b, c: Each value is the mean of three replicates of each entry (column).
A, B, C: Each value is the mean of three replicates in each flooding time (row).
Means with the same letters are not significantly different using least significant difference (LSD) test under completely randomized design.

Table 13. The effect of Flower number on internode length of first flower of tomato.

Entry	Internode length of first flower (mm)				
	Flooding time				
	0 hr	12 hr	24 hr	48 hr	120 hr
TNVEG 6	4.50aA	5.60aA	7.00aA	4.98aA	4.08aA
L4422	3.40aA	5.58aA	4.15abA	5.87aA	7.30aA
L3683	2.15aA	2.50aA	1.35bA	3.52aA	3.95aA
L1947	2.65aA	4.47aA	2.40abA	3.70aA	2.98aA

a, b, c: Each value is the mean of three replicates of each entry (column).
A, B, C: Each value is the mean of three replicates in each flooding time (row).
Means with the same letters are not significantly different using least significant difference (LSD) test under completely randomized design.

Table 13. The effect of Flower number on ascorbate peroxidase activity of tomato.

Entry	Ascorbate peroxidase activity (mmol/g FW)				
	Flooding time				
	0 hr	12 hr	24 hr	48 hr	120 hr
TNVEG 6	57.9aA	73.1aA	57.7abA	44.7aA	40.5aA
L4422	56.4aA	48.4aA	64.7abA	79.2aA	49.6aA
L3683	46.7aA	51.6aA	36.2bA	48.7aA	109.2aA
L1947	39.9aB	49.7aAB	105.8aAB	234.3aA	72.8aAB

a, b, c: Each value is the mean of three replicates of each entry (column).
A, B, C: Each value is the mean of three replicates in each flooding time (row).
Means with the same letters are not significantly different using least significant difference (LSD) test under completely randomized design.

Table 14. The effect of Flower number on total ascorbate content of tomato.

Entry	Total ascorbate content (mmol/g FW)				
	Flooding time				
	0 hr	12 hr	24 hr	48 hr	120 hr
TNVEG 6	1266.6aA	1749.0a A	1062.7aA	2302.3aA	1115.9bA
L4422	3008.0aA	1587.0aA	1720.0aA	1760.0aA	1402.0abA
L3683	1666.7aA	1872.3aA	1769.4aA	1645.6aA	1835.7aA
L1947	1363.0aA	1825.0aA	3707.0aA	2705.0aA	901.0bA

A, B, C: Each value is the mean of three replicates in each flooding time (row).
Means with the same letters are not significantly different using least significant difference (LSD) test under completely randomized design.

參考文獻

1. 米莫爾、吳登琳、阮育奇. 1994. 番茄嫁接對淹水之影響. 科學農業 42(3, 4):57-64.
2. 陳正次. 1998. 番茄育種. 蔬菜育種技術研習會專刊 231-239. 台灣省農試所特刊第 73 號.
3. Ahmed S., Nawata E., Hosokawa M., Domae Y., Sakuratani T. 2002. Alterations in photosynthesis and some antioxidant enzymatic activities of mungbean subjected to waterlogging. Plant Sci. 163:117-123.
4. Allen RD. 1995. Dissection of oxidative stress tolerance using transgenic plants. Plant Physiol. 107:1049-1054.
5. Anderson JV, Chevone BI, and Hess JL. 1992. Seasonal variation in the antioxidant system of eastern white pine needles. Plant Physiol. 98:501-508.
6. Asada K. 1992. Ascorbate peroxidase-a hydrogen peroxide-scavenging enzyme in plants. Physiol. Plant. 85:235-241.
7. Bruggemann W., Beyel V., Brodka M., Poth H., Weil M., Stockhaus J. 1999. Antioxidants and antioxidative enzymes in wild-type and transgenic Lycopersicon genotypes of different chilling tolerance. Plant Sci. 140:145-154.
8. Cakmak I, and Marschner H. 1992. Magnesium deficiency and high light intensity enhance activities of superoxide dismutase, ascorbate peroxidase, and glutathione reductase in bean leaves. Plant Physiol. 98:1222-1227.
9. Chaudiere J., Ferrari-Ilious R. 1999. Intracellular antioxidants: from chemical to biochemical mechanisms. Food and Che. Toxi. 37:949-962.
10. Cho U.H., Park J.O. 2000. Mercury-induced oxidative stress in tomato seedlings. Plant Sci. 156:1-9.
11. Cakmak I. And Marschner. H. 1992. Magnesium deficiency and high light intensity enhance activities of superoxide dismutase, ascorbate peroxidase, and glutathione reductase in bean leaves. Plant Physiol. 98:1222-1227.
12. Drazkiewicz M., Skorzynska-Polit E., Krupa Z. 2003. Response of the ascorbate-glutathione cycle to excess copper in *Arabidopsis thaliana* (L.). Plant Sci. 164:195-202. Grichko V.P., Glick B.R. 2001. Ethylene and flooding stress in plants. Plant Physiol. Biochem. 39:1-9.
13. Gullner G., Dodge A.D. 2000. Effect of singlet oxygen generating substances on the ascorbic acid and glutathione content in pea leaves. Plant Sci. 154:127-133.
14. Gupta AS, Webb RP, Holaday AS, and Allen RD. 1993. Overexpression of superoxide dismutase protects plants from oxidative stress. Plant Physiol. 103:503-506.
15. Herbinger K., Tausz M., Wonisch A. a, Soja G., Sorger A, Grill D. 2002. Complex interactive effects of drought and ozone stress on the antioxidant defence systems of two wheat cultivars. Plant Physiol. Biochem. 40:691-696.

16. Hodges D.M., Andrews C.J., Johnson D.A., Hamilton R.I. 1997. Antioxidant enzyme and compound responses to chilling stress and their combining abilities in differentially sensitive maize hybrids. Published in Crop Sci. 37:857-863.
17. Kao C. H., Weei P. H. 1994. Effect of flooding on the activities of some enzymes of activated oxygen metabolism, the levels of antioxidants, and lipid peroxidation in senescing tobacco leaves. Plant Growth. Regul. 14:37-44.
18. Kato C., Ohshima N., Kamada H., Satoh S. 2001. Enhancement oof the inhibitory activity for greening in xylem sap of ssquash root with waterlogging. Plant Physiol. Biochem. 339:513-519.
19. Rodriguez-Rosales M.P., Kerkeb L., Bueno P., Donaire J.P. 1999. Changes induced by NaCl in lipid content and ccomposition, lipoxygenase, plasma membrane H+-ATPase and antioxidant enzyme activities of tomato (*Lycopersicon esculentum* Mill) calli. Plant Sci. 143:143-150.
20. Sairam R.K., Deshmukh P.S., Saxena D.C. 1998. Role of antioxidant systems in wheat genotypes tolerance to water stress. Biologia Plantarum 41(3):387-394.
21. Sairam R.K. and Srivastava. G.C. 2002. Changes in antioxidant activity in sub-cellular fractions of tolerant and susceptible wheat genotypes in response to long term salt stress. Plant Sci. 162:897-900.
22. Schwanz P, Picon C. Vivin P, Dreyer E, Guehl JM, and Polle A. 1996. Responses of antioxidative systems to drought stress in pendunculate oak and maritime pine as modulated by elevated CO2. Plant Physiol. 110:393-402.
23. Sgherri CLM, Pinzio C, and Navari-Izzo F. 1993. Chemical changes and O_2 production in thylakoid membranes under water stress. Physiol. Plant. 87:211-216.
24. Tausz M, Peters J, Jimenez MS, Morales D, and Grill D 1998: Element contents and stress-physiological characterization of Pinus canariensis needles in Mediterranean type field stands in Tenerife. Chemosphere 36(4-5):1019-1023.
25. Webb JA and Fletcher RA. 1996. Paclobutrazol protects wheat seedlings from injury due to waterlogging. Plant Growth Regul. 18:201-206.
26. Yu Q and Rengel Z. 1999. Drought and salinity differentially influence activities of superoxide dismutases in narrow-leafed lupins. Plant Sci. 142:1-11.
27. Zhang J and Kirkham MB. 1996. Enzymatic responses of the ascorbate-glutathione cycle to drought in sorghum and sunflower plants. Plant Sci. 113:139-147.

Abstract

Tomato ASVEG 6, L4422 (*L. pimpinellifolium* Mill.), L3683 (*L. hirsutum* Humb & Bongl) and L1947 (*L. peruvianum* Mill) were flooded for 0, 8, 24, 48, 120 hrs at 2 months after sewing. The symptoms included epinasty, yellowing of lower leaves, advetious roots formation and wilting in order. According to the appearance, L3683 was most flooding-tolerant, L1947 the second, ASVEG 6 the least. There were main effects of flooding time on fresh weight of plant, root and main root, dry weight of main root, leaf relative water content, and stomatal conductivity. Main effects of entry on fresh and dry weight of plant, fresh weight of tops and root, fresh and dry weight of main root, and chlorophyll content also existed. Interaction of flooding time and entry only existed on stomatal conductivity. Among 4 entries, ASVEG 6 possessed highest chlorophyll content. L1947 had the lowest fresh and dry weight of plant and root. During 120 hr of flooding, L1947 maintained stable leaf relative water content. Ascorbate peroxidase activity of L1947 at 48 hr of flooding was significantly higher than 0 hr. From 12 through 120 hr, stomatal conductivity of L1947 significantly decreased when comparing to 0 hr. Among 4 entries, L1947 had the lowest stomatal conductivity after flooding 24 hr. Decreased stomatal conductivity after 12 hr flooding and increased ascorbate peroxidase activity after 48 hr flooding should be two of the mechanisms of L1947 being more flooding-tolerant than ASVEG 6. L4422 at 24 hr and ASVEG 6 at 48 hr of flooding, stomatal conductivity increased, but lowered afterward. L4422 showed significantly more flowers than ASVEG 6 and L1947. The stomatal conductivity of L3683 had no change during 48 hr of flooding, but that of 120 hr was significantly higher than 48 hr. L3683 also had the higher total ascorbate content than L1947. Increased total ascorbate content and decreased stomatal conductivity after 120 hr of flooding should be two of the mechanisms of L3683 being more flooding-tolerant than ASVEG 6.