# 產脲節桿菌株TC4-1C分解羽毛特性及促進青花菜生長之研究[1]

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## 摘　要

產脲節桿菌株TC4-1C (*Arthrobacter ureafaciens* TC4-1C)具溶磷及耐鹽能力，可利用多種高氮資材如羽毛、菜籽粕、雞糞及牛糞作為繁殖所需碳氮源，其培養液之菌數皆可達$10^9$ CFU/ml。菌株TC4-1C培養於含1%台肥即溶肥料5號或6號環境中，經培養4天可完全分解羽毛，可應用於生產高磷鉀且富含胺基酸之液體肥料。菌株培養於3%羽毛、0.5%磷礦石粉及0.5%草木灰，其羽毛分解液經澆灌於基肥施用菜籽粕之青花菜根系，其單株花球鮮重235.1 g，較未澆灌處理組可增加66.6 g，達顯著差異；與施用化學肥料處理組則無顯著差異。此外，澆灌羽毛水解液肥有增加花球植體鉀含量之趨勢，並可顯著提高根圈土壤植物可利用性之鎂、錳及鐵含量，顯示菌株TC4-1C產製富含胺基酸之羽毛水解液肥，可提升青花菜對豆粕養分利用率及增加土壤養分有效性，藉以提高生產效能。

**關鍵詞：**羽毛分解菌、產脲節桿菌、青花菜

## 前　言

氮為作物生長所需，有機栽培常以氮質海鳥糞或豆粕做為氮肥補充，然其價格高昂。羽毛可做為替代氮源，提供作物所需氮素(11)，但因羽毛角蛋白質含量豐且其雙硫鍵多結構緊密，因此不易分解，市面上常以酸鹼水解羽毛作為液肥應用，然而酸鹼處理會破壞部分胺基酸結構，且製程具化學品腐蝕之危險性及產品無法應用於有機農業之缺點；另應用於飼料添加之研究指出，以高溫及高壓處理羽毛作為飼料添加，常因胺基酸結構，如methionine、lysine及tryptophan易受破壞，而導致其作為飼料添加之營養價值減損(26)。微生物轉換羽毛廢棄物將可避免胺基酸遭破壞，可提高肥料與飼料添加之價值(3,10,11,15)。

蛋白水解後之胺基酸除作為氮肥外，亦具有生物刺激素功能，可增加作物抵抗環境逆境、作為植物生長激素前驅物、增加植體氮同化、鉗合微量元素、促進種子發芽及增進作物產量(5,8,17)，亦可應用於減少施用農用化學品(22)，為未來重要之製肥原料之一。

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磷為作物生長所需之必要元素，然因磷肥施用至土壤後易形成磷酸鈣、磷酸鋁及磷酸鐵沉澱而降低磷之植物有效性[2,25]，若因磷之植物有效性低而大量施用磷肥，則會導致施肥成本增加且造成環境汙染[23]。溶磷菌可經由產酸、鉗合及氧化還原等作用而溶解難溶性磷[6,9]，提高土壤有效性磷含量。本試驗將探討具溶磷能力及羽毛分解能力之產脲節桿菌株TC4-1C蛋白質分解特性，並應用於促進青花菜生長之研究。

## 材料與方法

### 一、產脲節桿菌株TC4-1C分解蛋白質能力分析

本試驗配製50 ml之BH礦物鹽培養基[4]:每公升添加1 g磷酸二氫鉀、1 g磷酸氫二鉀、0.2 g硫酸鎂及0.02 g氯化鈣，其中於BH培養基添加1% (W/V)的羽毛為BHF培養基、添加1% (W/V)的菜籽粕為BHB培養基、添加1% (W/V)的雞糞為BHG培養基而添加1% (W/V)的牛糞為BHC培養基。

挑選產脲節桿菌株TC4-1C之單一菌落並培養於上述4種培養基，經30℃及120 rpm培養4天後，進行菌數及培養液成分分析，對照組為不接種菌株之培養基。以上處理皆以3重複進行。

### 二、培養液之菌落數及pH、EC、元素養分分析

本試驗之培養液以10倍連續稀釋法，取樣100 µl塗抹於nutrient broth (NB)固態培養基中，培養3天後計算菌落數。另其培養液以Whatman No. 1濾紙過濾後，其濾液以電極分析pH及EC，銨態氮及全氮以微量擴散法測定[14]，鉀以火焰光度計測定(Sherwood flam photometer 410)，磷以鉬藍法測定[20]，而鈣及鎂則用原子吸收光譜儀(Hitachi Polarized Zeeman Atomic absorption spectrophotometer Z-5000)分析。以上處理皆以3重複進行試驗。統計分析以Least Significance difference (LSD)法進行比較，表中相同字母表示彼此間無顯著差異(p=0.05)。

### 三、菌株溶磷能力分析

菌株溶磷活性分析為挑選產脲節桿菌株TC4-1C之單一菌落至50 ml磷酸三鈣培養基中，經培養4天後，以鉬藍法分析可溶性磷含量。培養基配製及溶磷活性檢測參照肥料檢驗方法(方法編號AFS3183-1)。以上處理皆以3重複進行。

### 四、菌株耐鹽能力分析

本研究配製0%、3%、4%及5%氯化鈉之5 ml NB培養基，經接種產脲節桿菌株TC4-1C之單一菌落於此培養基，於30℃及120 rpm培養培養24 hr後測定培養液pH及EC值，並以連續稀釋塗抹於NB固態培養基，培養3天後計算菌落數。以上處理皆以3重複進行。

### 五、菌株於含即溶肥料培養基之羽毛分解能力

產脲節桿菌株TC4-1C之單一菌落培養於含有3種即溶肥料之50 ml液態培養基，分別為F1培養基，添加1%羽毛、1%台肥即溶1號及0.5%草木灰；F5培養基，添加1%羽毛、1%台肥即溶5號及0.5%草木灰及F6培養基，添加1%羽毛、1%台肥即溶6號及0.5%草木灰，經30℃及120

rpm震盪培養4天後，觀察羽毛分解狀況，有分解者進行培養液菌數及肥分分析(如前所述)。以上處理皆以3重複進行。

## 六、胺基酸分析

培養液之胺基酸分析方法，參照前人研究方法[18]並修改步驟為取培養液於4℃、9,500 g離心20 min，取上清液1 ml加0.5 ml之醋酸緩衝液(2 M，pH 5.2)及0.5 ml之3%二氫茚三酮試劑於各試管中充分混合，於100℃煮沸15 min後，於冷水浴中冷卻後，加入10 ml的50%酒精，充分混合。靜置30 min，測定$OD_{570}$，另以固定濃度glycine配製標準品，藉以推估培養液之胺基酸含量。

## 七、青花菜肥料試驗

產脲節桿菌株TC4-1C之單一菌落培養於2種培養基，分別為(1) MB培養基：含1%糖蜜及0.5%菜籽粕及(2) FH培養基：含3%羽毛、0.5%磷礦石粉及0.5%草木灰，經30℃及120 rpm震盪培養4天後之培養菌液應用於澆灌青花菜(brassica oleracea var. italica)根系。

本試驗田於彰化縣福興鄉進行，試驗區分成4處理，分別為(1)基肥施用菜籽粕(Rap)、(2)基肥施用菜籽粕加施含菌之培養菌液MB (Rap-MB)、(3)基肥施用菜籽粕加施含菌之培養菌液FH (Rap-FH)及(4)施用化學肥料(CF)。化學肥料處理組依作物施肥手冊中青花菜施肥建議，以單質肥料硫酸銨、過磷酸鈣及氯化鉀施用。試驗小區畦寬135 cm、畦長15 m，試驗採RCBD，4處理4重複。單畦雙行種植，株距50 cm。

Rap、Rap-MB及Rap-FH處理組之基肥施用菜籽粕(7-3-1.5)，其用量以每公頃2,000 kg換算成每小區用量。化學肥料處理組(CF)其施肥用量為每公頃氮素-磷酐-氧化鉀210-100-180。本試驗4處理皆於106年9月27日施基肥，10月5日定植青花菜(青花42，購買自博華蔬菜育苗場)。澆灌培養液處理組(Rap-MB及Rap-FH)於10月5日及10月20日澆灌200倍稀釋菌液，每株澆灌200 ml。化學肥料處理組(CF)於10月16日、11月1日及11月15日進行追肥。4處理皆於12月12日採收調查。採收期調查全株重、市場可販售單株重(含花球梗)、花球重。植體分析花球養分，試驗後採集根圈土壤以分析土壤肥力。

植體以濃硫酸及雙氧水消化分解[16]，氮用微量擴散法測定[14]，磷用比色法定量[20]，鉀用火焰光度計測定，鈣及鎂用原子吸收光譜儀分析。微量元素銅、錳、鋅及鐵則以1 N鹽酸反應[27]並以原子吸收光譜儀分析。土壤分析為樣品先經風乾處理，經2 mm篩網過篩後分別測定土壤化學性質。土壤pH及電導度以水：土比1:1，分別以電極法測定。土壤有機質含量採用總有機碳分析儀(Elementar vario MAX C)測定。以1 M醋酸銨(pH 7.0)，土：溶液比1:10抽出，濾液用感應耦合電漿光譜分析儀(Inductively Coupled Plasma-Atomic Emission Spectrometry; ICP-AES, HORIBA JOBIN- YVON ULTIMA 2)測土壤交換性鉀、鈣及鎂含量。以Bray No. 1方法抽取[20]，並用感應耦合電漿光譜分析儀測土壤有效性磷。土壤微量元素以0.1 N鹽酸萃取[1]，並以感應耦合電漿光譜分析儀測定。

# 結果與討論

## 菌株TC4-1C分解蛋白質能力分析

菌株TC4-1C培養於基本礦物鹽並以羽毛做為碳氮源之培養基、經培養4天可觀察到羽毛完全分解，並明顯提高培養液之pH、EC及全氮量，除羽毛外，菌株亦可利用菜籽粕、生雞糞及生牛糞作為碳氮源，此四處理之菌數皆可達$10^9$ CFU/ml (表一)，顯示菌株可利用多種高氮有機資材。

表一、產脲節桿菌株 TC4-1C 之分解蛋白質能力分析
Table 1. Hydrolysis analysis of multiple protein-rich materials by *Arthrobacter ureafaciens* TC4-1C

| Treatment[1] | pH | EC (mS/cm) | $NH_4^+$ (mg/L) | Tot-N (%) | P (mg/L) | K (mg/L) | Ca (mg/L) | Mg (mg/L) | Bacterial number CFU×$10^9$/ml |
|---|---|---|---|---|---|---|---|---|---|
| BHF-TC4-1C | 8.4±0.2 (SD) | 4.0±1.0 | 534.5±6.4 | 0.50±0.00 | 418.3±72.4 | 750.9±0.1 | 1.6±0.14 | 1.6±0.6 | 3.1±1.1 |
| BHF-BK | 6.8±0.0 | 1.7±0.6 | 11.4±0.9 | 0.01±0.00 | 413.5±7.8 | 717.6±41.7 | 1.9±0.4 | 17.4±0.1 | - |
| BHB-TC4-1C | 7.8±0.1 | 3.9±0.1 | 190.4±11.5 | 0.20±0.00 | 322.9±9.8 | 593.0±3.0 | 7.0±0.0 | 16.5±0.5 | 3.4±0.4 |
| BHB-BK | 6.3±0.1 | 2.6±0.1 | 43.7±7.2 | 0.06±0.00 | 320.0±20.1 | 772.7±18.8 | 17.7±5.8 | 36.7±2.3 | - |
| BHG-TC4-1C | 7.1±0.1 | 3.5±0.0 | 46.0±2.0 | 0.30±0.00 | 309.5±14.5 | 904.5±5.5 | 8.5±0.5 | 33.0±2.0 | 1.9±0.1 |
| BHG-BK | 7.1±0.3 | 3.4±0.0 | 35.5±2.5 | 0.05±0.00 | 382.5±55.5 | 944.0±57.0 | 8.9±3.9 | 42.0±3.0 | - |
| BHC-TC4-1C | 7.0±0.1 | 2.9±0.1 | 23.5±1.5 | 0.03±0.00 | 300.0±8.0 | 785.0±11.0 | 9.0±0.0 | 26.0±1.0 | 1.2±0.3 |
| BHC-BK | 6.6±0.2 | 3.0±0.0 | 7.5±3.5 | 0.01±0.00 | 353.5±50.5 | 836.0±51.0 | 6.3±2.7 | 25.5±0.5 | - |

[1]Basal mineral medium with different organic materials such as feather (BHF), rapeseed meal (BHB), chicken dropping (BHG) and cow dung (BHC), -TC4-1C means inoculation of *Arthrobacter ureafaciens* TC4-1C, -BK means no inoculation.
[2]The pH, EC, nutrients and bacterial numbers were analyzed after incubating the isolate TC4-1C at the fourth day.

羽毛與粕類常作為蛋白質水解物之原料，其水解產物具生物刺激素之功能，可促進多種作物生長及生產(7)，本試驗菌株可應用於酵素水解法，生產蛋白質水解物。牛糞萃出物可作為Pseudomonads培養基，其中，未額外添加碳源會導致菌株生長較培養於king's medium為差，然而牛糞萃出液添加甘油、丁二酸鈉或檸檬酸鈉作為碳源，則菌株生育良好(24)。本研究菌株TC4-1C則可以牛糞作為碳氮源，菌數可達$10^9$ CFU/ml與培養於NB培養基相比(表二)，菌數未有明顯降低。雞糞為氮磷含量高之養分，可運用於微藻類液態培養基，促進藻類生長(12)，未來似可應用於菌株培養基，降低菌劑生產成本。

## 菌株溶磷及耐鹽能力

本試驗挑選菌株TC4-1C之單一菌落至50 ml磷酸三鈣培養基中，經培養4天後，可溶出65.5±2.0 mg/L之水溶性磷，菌株具溶磷能力。另，本試驗之菌株TC4-1C培養於不同氯化鈉濃度之NB培養基中，經培養24 hr後，不同處理間其培養液之pH及菌落數隨鹽濃度增加而降低，EC值則顯著增加，菌株培養於含4%氯化鈉之培養基，其菌數仍有$3.1\times10^9$ CFU/ml，然而氯化鈉濃度增加至5%則會稍微降低菌落數(表二)，菌株TC4-1C於4%氯化鈉環境中仍具生長能力，具有與化學肥料混合使用之潛力。

表二、菌 TC4-1C 培養於不同氯化鈉濃度之 NB 培養基經培養 24hr 之培養液 pH、EC 及菌數分析
Table 2. The pH, EC and bacterial numbers of NB culture medium after inoculation of isolate TC4-1C and incubation for 24 hours

| Conc. of NaCl % | pH | EC (mS/cm) | CFU×$10^9$/ml |
|---|---|---|---|
| 0 | 7.9±0.2 (SD) | 3.3±0.1 | 6.30±0.30 |
| 3 | 7.2±0.2 | 55.8±0.9 | 4.30±2.20 |
| 4 | 7.2±0.2 | 67.4±0.5 | 3.10±1.90 |
| 5 | 6.7±0.1 | 73.9±4.2 | 0.17±0.08 |

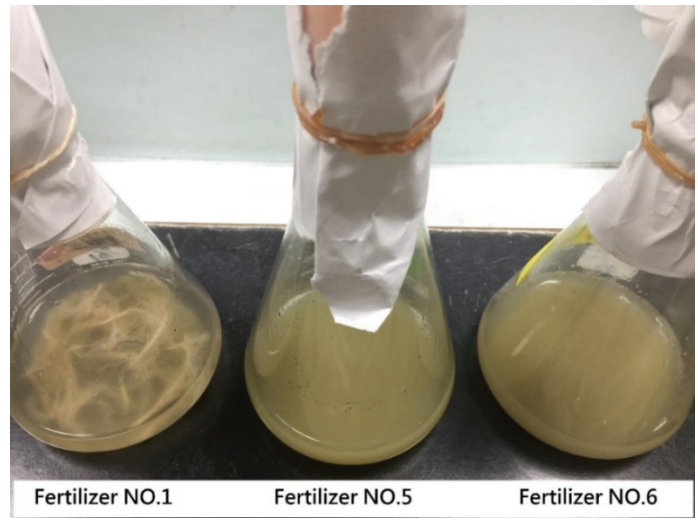
## 菌株於含即溶肥料培養基中分解羽毛

菌株TC4-1C分別培養於1%台肥即溶5號或6號環境中，仍具分解羽毛能力，其羽毛水解液之特性如表三所示。接種菌株TC4-1C之羽毛水解液，其pH值較未接菌高，EC亦較未接菌高3 dS/m，全氮約可提高0.4~0.5%，培養於1%即溶5號或6號培養基中，其鈣及鎂含量顯著低於未接菌處理組，顯示菌株生長繁殖，吸收利用可溶性養分，導致鈣鎂含量顯著降低，分解液之TC4-1C菌數皆高於$10^8$ CFU/ml，顯示菌株TC4-1C於相對較高濃度之磷鉀肥環境中，仍具分解羽毛能力。然而，前人研究提及羽毛分解菌於高可溶性氮(如銨離子與硝酸根離子)含量之培養基中，會抑制菌株分解羽毛能力[19]，與本研究發現菌株培養於含1%台肥即溶1號之羽毛培養基中，羽毛分解能力下降有一致性(圖一)。菌株TC4-1C可於高磷鉀肥之環境中分解羽毛，可應用於調配高磷鉀含量且富含胺基酸之液體肥料。

表三、菌株 TC4-1C 培養於含不同即溶肥料之羽毛分解液肥分分析
Table 3. Nutrients content of feather hydrolysate of isolate TC4-1C incubated in different instant chemical fertilizers-contained media

| Treatment[1] | pH | EC | $NH_4^+$ | Tot-N | P | K | Ca | Mg | Total amino acids | Bacterial number |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (dS/m) | (mg/L) | (%) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | CFU×$10^9$/ml |
| F5-TC4-1C | 8.3 ±0.3 (SD) | 17.7 ±0.5 | 1412.3 ±185.8 | 1.5 ±0.01 | 739.8 ±56.6 | 2631.9 ±172.9 | 0.1 ±0.0 | 0.1 ±0.0 | 1541.1 ±24.0 | 1.4 ±0.4 |
| F5-BK | 7.1 ±0.1 | 15.2 ±0.3 | 1100.0 ±19.0 | 1.1 ±0.0 | 614.1 ±66.1 | 2477.1 ±65.1 | 0.6 ±0.3 | 10.4 ±3.6 | 689.0 ±12.0 | - |
| F6-TC4-1C | 8.4 ±0.3 | 13.4 ±0.3 | 958.5 ±54.8 | 1.0 ±0.02 | 428.7 ±64.5 | 2506.5 ±61.9 | 0.2 ±0.0 | 0.1 ±0.0 | 824.0 ±25.3 | 0.9 ±0.3 |
| F6-BK | 6.6 ±0.3 | 10.7 ±0.3 | 453.5 ±25.5 | 0.5 ±0.03 | 550.6 ±85.6 | 2482.8 ±184.8 | 10.0 ±7.0 | 46.0 ±3.1 | 280.9 ±13.1 | - |

[1]Different instant chemical fertilizers such as 1% instant fertilizer NO. 5 (F5) or NO. 6 (F6) in culture medium with 1% feather and 0.5% plant ash, -TC4-1C means inoculation of *Arthrobacter ureafaciens* TC4-1C, -BK means no inoculation.




圖一、菌株 TC4-1C 培養於 1%台肥即溶 1 號、5 號及 6 號，經培養 4 天其羽毛分解情形
Fig. 1. Demonstration of feather hydrolysis via incubating isolate TC4-1C irrespectively in 1% instant soluble fertilizer NO. 1, NO. 5 and NO. 6, 0.5% plant ash for 4 days

**青花菜試驗**

本試驗前土壤特性為pH 7.9、EC (1:1) 0.88 dS/m、有機質2.2%、Bray-1-P 4 mg/kg、交換性K 72 mg/kg、交換性Ca 1,816 mg/kg、交換性Mg 270 mg/kg、Cu 10 mg/kg、Mn 288 mg/kg、Zn 9 mg/kg及Fe 1,121 mg/kg。培養液MB及FH之肥分分析如表四及表五所示，菌株TC4-1C培養於MB培養基中，菌數可達$10^9$ CFU/ml，然其肥分含量低；菌株TC4-1C培養於FH培養基，經培養4天羽毛可完全分解，培養液之全氮、胺基酸含量及水溶性養分亦顯著高於對照組，菌數可達$10^8$ CFU/ml以上。未接菌之糖蜜與豆粕培養基(MB-BK)，其胺基酸含量較未接菌之羽毛培養基高(FH-BK)，顯示豆粕蛋白質較羽毛角蛋白質易分解，此外，高溫高壓滅菌過程即可能釋放出胺基酸。

青花菜採收調查資料如表六所示，青花菜株高及結花球率於各處理間無顯著差異。然而，青花菜全株重、市場可販售型態鮮重及花球重，以施用化學肥料處理組(CF)及施用菜籽粕搭配澆灌FH培養液處理組(Rap-FH)較高，菜籽粕處理組(Rap)最低，彼此間達顯著差異。施用菜籽粕肥料並澆灌MB培養液，可些微提高青花菜鮮重，MB培養液養分濃度低對促進青花菜生長效果未如澆灌養分濃度較高之FH培養液佳，顯示菌株功能搭配胺基酸養液其施用效果更佳。施用FH培養液，可顯著提升青花菜鮮重，其效果與施用化學肥料處理組相似，推測原因除菌株TC4-1C之分解蛋白質及溶磷能力，有助於菜籽粕分解及促進根系生長外，羽毛水解物富含胺基酸，亦可能提升青花菜之生長。前人研究提及，施用胺基酸肥料有助於作物生長且可與微量元素鉗合，提高作物對微量元素吸收[13,21]，於中鹼性土壤環境中，微量元素有效性即可能影響作物生產。

表四、菌株 TC4-1 培養於 MB 培養基之菌數及肥分分析

Table 4. Bacterial number and nutrient content of MB medium after incubating isolate TC4-1C for fourth day

| Treatment[1] | pH | EC | $NH_4^+$ | Tot-N | P | K | Ca | Mg | Total amino acids | Bacterial number |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (dS/m) | (mg/L) | (%) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | CFU×$10^9$/ml |
| MB-TC4-1C | 5.0 ±0.4 (SD) | 1.8 ±0.0 | 10.5 ±0.5 | 0.02 ±0.00 | 4.6 ±0.6 | 344 ±10 | 76 ±1 | 41 ±0 | 333.3 ±43.3 | 3.4±0.2 |
| MB-BK | 3.7 ±1.1 | 3.9 ±1.2 | 30.0 ±2.0 | 0.06 ±0.00 | 16.5 ±0.5 | 486.5 ±11.5 | 137.0 ±3.0 | 53.5 ±0.5 | 337.3 ±47.3 | - |

[1]MB means cultured medium with 1% molasses and 0.5% rapeseed meal, -TC4-1C means inoculation of *Arthrobacter ureafaciens* TC4-1C, -BK means no inoculation.

表五、菌株 TC4-1C 培養於 FH 培養基之菌數與肥分分析

Table 5. The bacterial number and nutrient content of FH medium after incubating isolate TC4-1C for fourth day

| Treatment[1] | pH | EC | $NH_4^+$ | Tot-N | P | K | Ca | Mg | Total amino acids | Bacterial number |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (dS/m) | (mg/L) | (%) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | (mg/L) | CFU×$10^8$/ml |
| FH-TC4-1C | 8.8 ±0.0 (SD) | 7.1 ±0.6 | 806.0 ±64.2 | 0.94 ±0.07 | 18.6 ±2.4 | 1263.2 ±85.9 | 6.3 ±0.3 | 5.5 ±1.6 | 1654.2 ±12.5 | 5.3±0.9 |
| FH-BK | 8.7 ±0.0 | 3.6 ±0.2 | 17.7 ±13.4 | 0.06 ±0.02 | 25.4 ±3.9 | 1197.6 ±69.9 | 2.6 ±0.6 | 6.5 ±0.6 | 153.8 ±5.5 | - |

[1]FH means cultured medium with 3% feather, 0.5% rock phosphate and 0.5% plant ash, -TC4-1C means inoculation of *Arthrobacter ureafaciens* TC4-1C, -BK means no inoculation.

表六、青花菜於不同肥料處理之採收生育調查

Table 6. Investigation of broccoli growth in different fertilization treatments after harvest

| Treatment | Formation rate of flower head | Plant height | Whole plant weight | Weight of flower head with stem | Weight of flower head |
|---|---|---|---|---|---|
| | (%) | (cm) | (g) | (g) | (g) |
| Rap-FH | 94.4[a] | 30.3[a] | 1,254.2[ab] | 492.2[a] | 235.1[a] |
| Rap-MB | 95.0[a] | 31.8[a] | 1,140.8[bc] | 440.5[ab] | 202.4[ab] |
| Rap | 94.2[a] | 29.1[a] | 1,105.8[c] | 388.2[b] | 168.5[b] |
| CF | 97.6[a] | 31.3[a] | 1,279.2[a] | 481.3[a] | 220.7[a] |

Significant in comparison with control at P = 0.05 (LSD test).

本試驗之花球植體養分分析如表七所示，其中澆灌FH培養液處理組(Rap-FH)，其植體鉀含量與施用化學肥料處理組(CF)無顯著差異，未澆灌處理組(Rap)與澆灌MB培養液(Rap-MB)，

其鉀含量顯著低於化學肥料處理組，澆灌培養液處理組(Rap-MB及Rap-FH)鎂含量有較低趨勢，其他養分於花球植體中彼此間無顯著差異。

表七、不同肥料處理之青花菜花球植體養分分析
Table 7. Nutrient content of broccoli flower ball in different fertilizer treatment

| Treatment | N | P | K | Ca | Mg | Cu | Mn | Zn | Fe |
|---|---|---|---|---|---|---|---|---|---|
| | % | | | | | ppm | | | |
| Rap-FH | 2.7[a] | 0.52[a] | 3.5[ab] | 0.65[a] | 0.28[ab] | 5.0[a] | 22.0[a] | 33.7[a] | 50.7[a] |
| Rap-MB | 2.6[a] | 0.48[a] | 3.1[c] | 0.60[a] | 0.26[b] | 4.3[a] | 20.8[a] | 31.0[a] | 47.5[a] |
| Rap | 2.9[a] | 0.48[a] | 3.3[bc] | 0.67[a] | 0.29[a] | 5.0[a] | 21.3[a] | 32.8[a] | 44.3[a] |
| CF | 2.9[a] | 0.54[a] | 3.9[a] | 0.66[a] | 0.29[a] | 4.5[a] | 19.5[a] | 31.0[a] | 51.3[a] |

Significant in comparison with control at P = 0.05 (LSD test).

本試驗後各處理之青花菜根圈土壤肥力分析如表八所示，其中pH以CF處理組及Rap-FH處理組較低，磷與鉀含量以CF處理組最高，鎂及錳含量以Rap-FH處理組最高，且高於化學肥料處理組，銅含量以Rap-FH最低，鐵含量以Rap-FH處理組較Rap及Rap-MB處理組高，澆灌較高胺基酸含量之羽毛水解液肥(FH)，可顯著提高根圈土壤植物可利用性鎂、錳及鐵含量，顯示施用較高濃度之胺基酸肥料可提高根圈土壤中某些植物有效性微量元素之含量。

表八、試驗後根圈土壤肥力分析
Table 8. Rhizospheric soil nutrient content in different treatments after harvest

| Treatment | pH | EC (1:1) | OM | N | P | K | Ca | Mg | Cu | Mn | Zn | Fe |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1:1) | (dS/m) | (%) | | | | mg/kg | | | | | |
| Rap-FH | 7.8[b] | 3.5[a] | 2.8[a] | 0.16[a] | 15.3[b] | 67.8[b] | 5,029.8[a] | 477.5[a] | 6.0[b] | 208.0[a] | 7.3[a] | 110.5[b] |
| Rap-MB | 8.0[a] | 3.1[a] | 2.8[a] | 0.16[a] | 11.5[b] | 76.8[b] | 4,303.3[a] | 344.3[b] | 7.5[a] | 169.3[bc] | 8.0[a] | 92.0[c] |
| Rap | 8.0[a] | 3.6[a] | 2.9[a] | 0.17[a] | 17.3[b] | 85.3[b] | 4,364.0[a] | 393.3[ab] | 7.8[a] | 176.3[b] | 8.8[a] | 94.0[c] |
| CF | 7.7[b] | 3.7[a] | 2.5[a] | 0.15[a] | 67.8[a] | 167.0[a] | 4,708.0[a] | 329.3[b] | 7.5[a] | 145.0[c] | 11.0[a] | 131.8[a] |

Significant in comparison with control at P = 0.05 (LSD test).

## 結　論

本試驗結果顯示，具耐鹽及溶磷能力之產脲節桿菌株TC4-1C可分解多種蛋白質類有機物質，其中可以羽毛作為菌株TC4-1C繁殖所需之碳氮源，於基本礦物鹽、相對高磷鉀之即溶化學肥料或磷礦石粉與草木灰之培養環境中完全分解羽毛，生產富含胺基酸之培養菌液且菌數可達$10^8$ CFU/ml以上。此外，基肥施用菜籽粕搭配澆灌菌株TC4-1C之羽毛水解液，可提升青花菜花球鮮重且與施用化學肥料處理組無顯著差異，具推廣應用於友善農耕作物肥培管理之潛力。

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# Research on Feather-hydrolyzing Characteristics of *Arthrobacter ureafaciens* TC4-1C and Application in Promoting Broccoli Growth [1]

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## ABSTRACT

*Arthrobacter ureafaciens* TC4-1C, with phosphate-solubilizing and slat-tolerant ability, can use multiple high nitrogen contained materials as carbon and nitrogen sources for reproduction. In liquid culture using feather, rapeseed meal, chicken dropping or cow dung as nutrient source, bacterial numbers higher than $10^9$ CFU/ml can be achieved. Strain TC4-1C can degrade feather in the medium contained one percentage of the instant soluble fertilizer Taifer NO. 5 (10-20-20) or NO. 6 (5-18-18) after 4 days of incubation can produce liquid fertilizer containing amino acids and high concentration of phosphorous and potassium. After four days of incubation of strain TC4-1C in liquid medium contained 3% feather, 0.5% rock phosphate and 0.5% plant ash (W/V), the produced feather hydrolysates were applied to broccoli supplemented with rapeseed meal used as base fertilizer in the experimental field. Experimental results showed application of the feather hydrolysates can increase 66.6 g of fresh weight of single flower ball compared with treatment without feather hydrolysate drench and showed significant differences between treatments. However, the fresh weight of single flower ball followed by feather hydrolysate drench was not significantly different with that applying chemical fertilizer. Application of feather hydrolysates showed potassium-increasing tendency in flower ball and increase plant available Mg, Mn and Fe content in the rhizosphere soil. Feather hydrolysates containing amino acids produced by strain TC4-1C can increase nutrient availability of rapeseed meal and soil to increase broccoli productivity.

**Key words:** feather-hydrolyzing bacterium, *Arthrobacter ureafaciens*, broccoli

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