AUTHOR DECLARATION

بسم الله الرحمن الرحيم

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged.

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ABSTRAK

Pokok cili mudah diserang oleh kulat *Colletotrichum* mengakibatkan kerugian besar hasil pertanian ini. Penelitian ini menilai kemampuan bakteri asid laktik (LAB) sebagai kawalan bio terhadap kulat ini. Tiga ratus dua puluh empat LAB telah dipencilkan dari sumber yang berbeda di Malaysia dan diniali untuk aktiviti antikulat *C. capsici* dan *C. gloeosporioides*. Dua isolat LAB-C5 dan LAB-G7 menunjukkan aktiviti yang baik terhadap kedua kulat dan di kenalpasti dengan menggunakan API 50CHL dan 16S rDNA sebagai *L. plantarum* dan *L. pentosus* LAB-G, masing-masing. Bijibenih yang dirawat dengan sel LAB-C5 menunjukkan perbezaan ketara (P<0.05) pada peratus percambahan dan pertumbuhan plumule dan radikal yang baik berbanding dengan rawatan supernatan LAB-G7. Pengaruh rawatan sel LAB-C5 dan *C. capsici* ke atas pokok Chillibangi telah diniali. Semua pokok Chillibangi menunjukkan peningkatan berat kering bahagian atas pokok dan akar. Analisis biokimia menunjukkan peningkatan jumlah fenol yang ketara (P<0.05) dalam buah chili (2.71 mg/g) dibandingkan dengan kontrol (1.83 mg/g). Peningkatan aktiviti enzim peroksidase (PO=175.54 unit/aktiviti enzim) dan polyphenoloxidase (PPO=172.47 unit/aktiviti enzim) pada daun yang di inokulasi dengan sel LAB-C5 adalah lebih tinggi dan ketara (P<0.05) dari kontrol (PO=89.86 dan (PPO=97.27) Unit / enzim, masing-masing). Peningkatan kadar lignin (LC) dari akar adalah 0.799 mg/g berbanding dengan kontrol (0.329 mg/g). Sel LAB - C5 dan supernatan LAB - G7 adalah sesuai digunakan sebagai bio - control *in vitro* terhadap infeksi kulat pada buah chilli merah dan hijau yang didapati dari pasar, dan buah Cilibangi yang telah disimpan selama 45 h pada 28°C. Penelitian ini menunjukkan bahwa inokulasi LAB mampu menghasilkan daya ketahanan terhadap infeksi terhadap *C. capsici* dan *C. gloeosporioides* pada bijibenih, buah dan pokok chilli. Perubahan biokimia pada pokok chilli adalah faktor yang mempengaruhi ketahanan varieti chilli seperti yang ditunjukkan oleh rawatan dengan sel LAB-C5. Menggunakan *L. plantarum* LAB-C5 sebagai bio-control terhadap *C. capsici* pada tanaman chilli dapat mengurangkan penggunaan fungisida kimia di masa hadapan.
Chilli plants are easily attacked by fungi *Colletotrichum* resulting in great loss of this agricultural produce. This study evaluated the ability of lactic acid bacteria (LAB) as possible bio-control against fungi. Three hundred twenty four LABs were isolated from different sources in Malaysia and were evaluated for antifungal activity against *C. capsici* and *C. gloeosporioides*. The two isolates with good activity against both fungi were identified using API 50CHL and 16S rDNA as *Lactobacillus plantarum* LAB-C5 and *Lactobacillus pentosus* LAB-G7. Seeds treated with cell LAB-C5 showed significantly (P< 0.05) good germination percentage and growth of plumules and radicals compared to supernatant LAB-G7. The effect of chilli plants with LAB-C5 cells and *C. capsici* was evaluated. All chilli varieties showed increase in shoot and root dry weight with improved plant vigor. The biochemical analysis showed an increase in the total phenol compounds in fruits (with mean 2.71mg/g than control 1.83 mg/g). Increase in activity of enzymes peroxidase (PO) and polyphenoloxidase (PPO) in leaves was noted in plants treated with LAB-C5 cell. The PO was 175.54 and PPO was 172.47 unit /enzyme of plant tissue, higher than control with PO of 89.86 and PPO of 97.27 unit/enzyme. An increase in lignin content (LC) of roots was 0.799 mg/g compared with control (0.329 mg/g). The cells LAB-C5 and supernatants LAB-G7 were effective as bio-control *in vitro* against fungal infection on red and green chilli obtained from markets and Cilibangi fruits during storage for 45 days at 28°C. Inoculation of LAB was able to generate resistance to fungal infection against both fungi in seeds, fruits and plants. Changes in biochemical compounds in chilli plants are factors that may contribute to the development of resistance in chilli varieties as shown by plants treated with LAB-C5 cell. The potential of using *L. plantarum* LAB-C5 as bio-control against *C. capsici* in chilli plants is possible and may reduce the use of chemical fungicides in the future.
الملخص
ثمار و نباتات الفلفل تكون سهلة الاصابة بواسطة فطر المسبب لمرض الانثراكنوز وهذا يؤدي إلى الخسارة العظيمة في الانتاج الزراعي. لذلك تحتاج لطرق متطورة للسيطرة على المرض ومنع نمو الفطر. هذه الدراسة تقييم قدرة بكتيريا الحمض اللبنى كمكافحة حيوية ضد الفطرين حيث في هذه الدراسة 24 عزلة من مصادر مختلفة في ماليزيا كانت مجموعة كمشروع معادي ضد فطر الإنثراكنوز. نبات من عزلات بكتيريا الحمض اللبنى شهدت ذات نشاط معادي جيد ضد فطري الإنثراكنوز تم تعريفها بطريقة دليل التحليل الطيفي Lactobacillus ونسل الAPI 50CHL وعندما كانت العزلة L. pentosus G7 والعزلة plantarum C5 الفلفل عواملت مع خلايا بكتيريا (C5) كانت نتائج المعالمة بهذه البكتيريا ذات فروق معنوي عالية (P>0.05) في زيادة اقتصاد المجموع الخضري والجذري في كل أنواع الفلفل المختبرة مقارنة ببذور الفلفل C. glosoporioides وC. capsici مع عزلة معزولة بكتيريا الحمض البنين (C5) مع الفطر C. capsici. تأثير التربة المنخفضة بكتيريا الحمض البنين (G7) مع فطر C. capsici مع عزلة G7 خلايا البكتيريا C5 وانزيمات البكتيريا G7 ان امكانية استعمال هذه البكتيريا المختارة كمقاومة حيوية ضد فطر الانثراكنوز في نباتات الفلفل محتملة وقد يخفض من استعمال مبيدات الفطر الكيميائية في المستقبل كما حسبت وطورت نمو ومقاومة النباتات لمرض الانتراكنوز.
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LIST OF ABBREVIATIONS

API  Analysis Profile Index
CaCO$_3$  Calcium carbonate
H  Hour
H$_2$O$_2$  Hydrogen peroxide
LAB  Lactic acid bacteria
µg  Microgram
Mm  Millimeter
MRS  de Man Rogosa Sharpe
PDA  Potato Dextrose agar
NA  Nutrient agar
Nm  Nanometer
OD  Optical density
PCR  polymerase chain reaction
Sp /spp.  Species
NaCl  Sodium chloride
CB  Chilibangi Seeds
CP  Chilli Padi Semerah Seeds
KU  Chilli Kulai Seeds
MC11  Mardi chilli Seeds
LAB-G7  Cells of *Lactobacillus pentouces*
LAB-G7S  Supernatant of *Lactobacillus pentouces*
LAB-C5  Cells of *Lactobacillus plantarum*
LAB-C5S  Supernatant of *Lactobacillus plantarum*
C.c  *Colletotrichum capsic*
C.g  *Colletotrichum gloesporioides*
DW  Distilled water
CL  Chlorinated water
Cm  Centimeters
mg  Miligram
g  Gram
U  Unit
CB1  
Cilibangi 1

CB2  
Cilibangi 2

CB3  
Cilibangi 3

TPC  
Total Phenols Compounds

PO  
Peroxidase

PPO  
polyphenol oxydase

LC  
Lignin content

Leu. Citreum  
Leuconostoc citreum

Lact. Lactis  
Lactococcus lactis

T. harzianum  
Trichoderma harzianum

B. subtilis  
Bacillus subtilis

G. roseum  
Gliocladium roseum

S. noursei  
Streptomyces noursei

P. guilliermondii  
Pichia guilliermondii

P. commune  
Penicillium commune

P. roqueforti  
Penicillium roqueforti

A. fumigates  
Aspergillus fumigates

C. albicans  
Candida albicans

B. cinerea  
Botrytis cinerea

A. solani  
Alternaria solani

P. drechsleri  
Phytophthora drechsleri

F. oxysporum  
Fusarium oxysporum

M. laxa  
Monilinia laxa

E. fibuliger  
Endomyces fibuliger

X. campestris  
Xanthomonas campestris

E. carotovora  
Erwinia carotovora

M. phaseolina  
Macrophomina phaseolina

E. faecium  
Enterococcus faecium

A. alternate  
Alternaria alternate

E. repens  
Eurotium repens

E. rubrum  
Eurotium rubrum

F. sporotrichioides  
Fusarium sporotrichioides

V. dahlia  
Verticillium dahlia
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REFERENCES


Yoon, J. B. 2003. Identification of genetic resources, interspecific hybridization and inheritance analysis for breeding pepper (*Capsicum annuum*) resistant to anthracnose, Seoul National University.


