UNIVERSITI PUTRA MALAYSIA

NITROGEN UTILISATION OF LOWLAND CAULIFLOWER GROWN ON COCONUT COIR DUST

ASIAH AHMAD

FP 2003 21

NITROGEN UTILISATION OF LOWLAND CAULIFLOWER GROWN ON COCONUT COIR DUST

By

ASIAH AHMAD

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

January 2004

DEDICATION

This thesis is dedicated to my late parents, *Mr. Ahmad and Mrs. Sa'adah*, my husband, *Dr. Abdul Ghaffar Ramli* and my children;

Nursyahida

Mohd Amran

Nurhuda

Nur Izzati

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the Degree of Doctor of Philosophy

NITROGEN UTILISATION OF LOWLAND CAULIFLOWER GROWN ON COCONUT COIR DUST

By

ASIAH AHMAD

November 2003

Chairman: **Associate Professor Mohd Razi Ismail, Ph.D**

Faculty: **Agriculture**

Strong wind, high rainfall, the spread of diseases during rainy season and pests problems in open field agriculture have led to the current trend in growing vegetables under protected environment. The occurrence of soil borne disease, and limited suitable land for agriculture are some of the reasons to look for alternative media such as coconut coir dust. The basic properties of coconut coir dust as a soilless growing medium and the utilisation of nitrogen (N) fertiliser for the lowland cauliflower grown in them have not been thoroughly investigated and are therefore not well understood. This study has been conducted by the need to provide a basis for determining optimal levels/concentration and forms of nitrogen supply, and by the need to minimize environmental consequences of lowland cauliflower production. It focuses on the effects of N supply in terms of different levels of N and ionic N forms in the nutrient solution, on the growth,

development and N utilisation of cauliflower grown in coconut coir dust under greenhouse condition in the lowlands. Based on the plant growth parameters studied coconut coir dust was found to be more suitable than oil palm empty fruit bunch as a growing medium. From the growth and development study using coconut coir dust, it can be deduced that the N requirement by the plant is less at later growth stage regardless of low or high level of N in the nutrient solution. However, low level of N of 50 mg l^{-1} was found to be inadequate for plant growth and curd yield. The N concentration levels of 200 mg l^{-1} in the nutrient solution optimised both the vegetative and curd production. A somewhat lower level of N (170 mg l^{-1}) produced curd weight not significantly different from N level of 200 mg l^{-1}. The plant growth and curd yield was reduced by about 29.0% at 400 mg N l^{-1}. The N level of 400 mg l^{-1} in the nutrient solution may be in excess to that actually required by the plant, resulting in a high unused N nutrient accumulated as NO_3^- at high concentration in the leaves (1.41% dry weight) and in the stems (1.90% dry weight). The concentrations of most free amino acids found in the leaves and curds were high at 100 mg l^{-1} N and 200 mg l^{-1} as compared to the other levels of N in the nutrient solution. At both levels of N, the NO_3-N concentration in the curd (0.14% - 0.22% dry weight) was within an acceptable limit with reference to broccoli. The N forms experiment indicated that ammonium (NH_4^+) as the sole N form used at 50 mg l^{-1} N inhibited the plant growth, which may be related to the absence of NO_3^- in the leaves tissues and NH_4^+ accumulation. In comparison to NO_3^- nutrition, NH_4^+-grown plants showed higher levels of arginine (45.60 umol g^{-1} dry weight) and serine (12.15 umol g^{-1} dry weight) accumulation in the leaves tissues, which may indicate that the plant was subjected to stress. Data from the mixture of NO_3^- and NH_4^+ as NH_4NO_3 treatment provided no evidence of better plant growth and yield over the NO_3^- treatment alone. Differences in growth responses to ionic N forms may partly be due to different sites of N assimilation. The results from experiments using NH_4^+ or NO_3^- labelled with ^{15}N showed that NO_3^- was assimilated mainly in the leaves, but on the other hand, NH_4^+ was almost completely assimilated in the roots of the cauliflower plant. Results from experiments using $^{15}NH_4NO_3$ or $NH_4{}^{15}NO_3$ indicated the plant preferred NO_3^- to NH_4^+ for N absorption.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENGGUNAAN NITROGEN OLEH TANAMAN KUBIS BUNGA YANG DITANAM MENGGUNAKAN HABUK SABUT KELAPA

Oleh

ASIAH AHMAD

November 2003

Pengerusi: **Profesor Madya Mohd Razi Ismail, Ph.D**

Fakulti: **Pertanian**

Masalah angin yang kuat, kekerapan hujan, penyakit yang tersibar semasa musim hujan dan serangga perosak dalam penanaman sayur-sayuran secara terbuka di tanah rendah telah mengubah arah aliran penanaman sayur-sayuran kepada penanaman di bawah struktur pelindung. Kejadian penyakit bawaan tanah dan kekurangan tanah yang sesuai untuk pertanian adalah diantara sebab utama diperlukan media tanaman seperti habuk sabut kelapa sebagai pilihan kepada tanah. Sifat asas habuk sabut kelapa yang digunakan sebagai media tanaman untuk tanaman kubis bunga serta penggunaan baja nitrogen (N) untuk tanaman tersebut belum dikaji dengan mendalam menyebabkan pemahaman mengenai perkara tersebut amat kurang. Kajian ini dijalankan berdasarkan keperluan untuk memberikan maklumat asas mengenai aras/kepekatan dan sumber bekalan nitrogen serta mengurangkan kesan ke atas alam sekitar akibat

penanaman kubis bunga. Kajian tertumpu kepada kesan pembekalan N pada kepekatan dan sumber ion N yang berlainan di dalam larutan nutrien terhadap pertumbuhan, perkembangan dan penggunaan N oleh tanaman kubis bunga di dalam rumah hijau. Hasil kajian berdasarkan parameter pertumbuhan tanaman menunjukkan bahawa habuk sabut kelapa lebih sesuai daripada tandan kosong kelapa sawit sebagai media tanaman. Kajian ke atas pertumbuhan dan perkembangan tanaman kubis bunga yang ditanam di dalam habuk sabut kelapa menunjukkan bahawa keperluan baja N oleh tanaman kubis berkurangan di peringkat akhir pertumbuhan tanpa menghiraukan kepekatan N yang tinggi atau rendah di dalam larutan nutrien. Bagaimanapun bekalan N yang rendah pada kepekatan 50 mg l^{-1} didapati tidak mencukupi untuk tanaman membesar dan menghasilkan bunga kubis yang baik. Pertumbuhan vegetatif dan penghasilan bunga kubis yang optimum diperolehi pada aras kepekatan 200 mg N l^{-1}. Tanaman pada aras kepekatan nitrogen yang agak rendah (170 mg l^{-1}) daripada 200 mg l^{-1} menghasilkan berat bunga kubis yang tidak berbeza secara signifikan. Pertumbuhan dan hasil bunga kubis berkurang sebanyak 29% pada kepekatan 400 mg N l^{-1} . Aras N pada kepekatan 400 mg l^{-1} di dalam larutan nutrien didapati melebihi keperluan sebenar tanaman menyebabkan banyak nutrien N tidak digunakan dan berkumpul dalam bentuk NO_3^- pada kepekatan yang tinggi di dalam daun (1.41% berat kering) dan di dalam batang (1.90% berat kering). Kepekatan asid amino bebas di dalam daun dan bunga kubis adalah lebih tinggi pada aras kepekatan 100 mg N l^{-1} dan 200 mg N l^{-1} jika dibandingkan dengan aras kepekatan N yang lain di dalam larutan nutrien. Kepekatan NO_3-N (0.14%-

0.22% berat kering) di dalam bunga kubis pada kedua-dua kepekatan ini adalah pada had kepekatan yang diterima merujuk kepada tanaman brokoli. Kajian terhadap jenis sumber N menunjukkan bahawa pada kepekatan 50 mg N l^{-1}, ammonium (NH_4^+) merencat pertumbuhan tanaman. Ini mungkin berkaitan dengan ketiadaan NO_3^- di dalam tisu daun dan pengumpulan NH_4^+. Tanaman kubis bunga yang ditanam menggunakan NH_4^+ juga mengandungi aras pengumpulan arginin (45.60 umol g^{-1} berat kering)dan serin (12.15 umol g^{-1} berat kering) yang tinggi di dalam tisu daun jika dibandingkan dengan tanaman yang menggunakan sumber NO_3^- (1.17 dan 3.88 umol g^{-1} berat kering). Ini menunjukkan tanaman tersebut terdedah kepada ketegangan. Data yang diperolehi daripada penggunaan campuran baja di antara NO_3^- dan NH_4^+ dalam bentuk NH_4NO_3 tidak menunjukkan pertumbuhan dan hasil bunga kubis yang lebih tinggi daripada tanaman yang ditanam menggunakan NO_3^-. Perbezaan gerakbalas yang ditunjukkan oleh tanaman terhadap jenis baja N yang digunakan mungkin disebabkan oleh tempat asimilasi N yang berlainan. Hasil kajian menggunakan NH_4^+ atau NO_3^- yang dilabel dengan ^{15}N menunjukkan bahawa asimilasi NO_3^- berlaku terutamanya di dalam daun manakala asimilasi NH_4^+ berlaku di dalam akar tanaman kubis bunga. Berdasarkan kajian menggunakan $^{15}NH_4NO_3$ atau $NH_4{}^{15}NO_3$ didapati tanaman bunga kubis lebih cenderung terhadap NO_3^- daripada NH_4^+.

ACKNOWLEDGEMENTS

In the course of pursuing this research, I am indebted to the following people for their contributions:

Associate Prof. Dr. Mohd Razi Ismail, who has read chapters of the thesis and has made most helpful comments and suggestions. Thanks are also due for his interest and supervision of this research and his efforts in obtaining some financial support for the running of the experiments.

Associate Prof. Dr. Mohd Khanif Yusop, for his useful comments and discussions concerning the content and accuracy of the N experiments.

Prof. Dr. Marziah Mahmood, for the intriguing discussions on matters related to amino acids.

Dr. Shaharuddin Mohd, for his suggestions on the amino acids work.

Dr. Richard Parson of the School of Biological Sciences, University of Dundee, for his collaboration, guidance, assistance and useful discussions on the ^{15}N labelled amino acids analysis in the plant samples using the GC-MS. Thanks are also due to his family, Dr. Andrea Baker for their generous hospitality and concern during my stay in Dundee.

Dr. Yahya of Veterinary Department, Petaling Jaya for allowing me to work in his laboratory for amino acids and minerals analysis.

Mr. Ismail Muid (Veterinary Department), an experienced technician for his cooperation and kind help in the samples preparations, HPLC and AAS analysis.

Dr. Mohd Awang and Mr. Amirul of the Malaysian Institute for Nuclear Technology Research for their help, guidance and assistance on the freeze drying of the plant samples using the freeze drier.

Dr. Nahrul Khair Alang Mat Rashid (Deputy Director of Research and Development , MINT) and Dr. Norimah Yusof (Director of Agrotechnology and Bioscience) by keeping me free for some time from working and administrative responsibilities to complete this thesis.

Mrs. Latifah Nordin, the assistants of the N and ^{15}N laboratory staffs, of MINT for their help on ^{15}N analysis.

My employer, Malaysian Institute For Nuclear technology Research, Ministry of Science, Technology and Environment and Public Services Department for granting me study leave and scholarship for the execution this research.

Last but not least, my heartiest thanks and deepest gratitude to my husband, Dr. Abdul Ghaffar Ramli, for his continued support and encouragement throughout my study and corrected the English to improve the thesis by valuable suggestions and stimulating critics.

Finally to all my children especially my youngest daughter (Nur Izzati) for their patience and understanding throughout this time consuming process as most of the time has been used to complete this thesis than spending the time together with them.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Cauliflower (*Brassica oleracea var. botrytis*), a high-value temperate vegetable, is one of the popular Cruciferous vegetables grown mainly in the highlands in Malaysia. In 2000, provisional figures indicate 10,944 tonnes of cauliflower were imported from Australia and China valued at RM38 million (Mal. Agric. Directory Index, 2001/2002). Although the highlands are more climatically suitable, however, due to the terrain and limited available land, there is a need to cultivate them in the lowlands (Illias and Ramli, 1994) to meet increasing local demands and reduce import value.

With the development of heat tolerant varieties, it can now be cultivated in an open field in the lowlands under tropical environment (Rahman et al., 1987). However it was reported that several major problems exist in the cultivation of cauliflower using conventional open field in the lowlands such as high rainfall, strong winds, diseases and pests.

Lowland cauliflower is very susceptible to pest attack when planted in the open fields. It was reported that leafy and headed Cruciferous vegetables (such as cabbage and cauliflower) are very susceptible to *Plutella* and *Hellula* (Leong et al., 1994) attack when planted in the open fields (Leong et al., 1994). They suggested that by cultivating the vegetables under protected environment such as netted rain shelter could prevent the entry of adults of both insects. Spraying against such insects is therefore unnecessary. It is also necessary to shade the developing curd from direct sunlight to obtain a compact curd of good quality (Fadelah et al., 1993). Therefore, it was recommended that lowland cauliflower should be cultivated under protected environment (Ilias and Ramli (1994).

Besides the problem with pest, development and spread of diseases such as black rot and wet rot caused by *Xanthomonas campestris* and *Erwinia carotovora* are rapid during rainy season. These are serious limitations to the production of lowland cauliflower in the open field (Fadelah et al. 1993). It was also reported that soil-borne bacterial disease is common in Cruciferous vegetables especially if cultivated continuously on the same piece of land (Leong et al., 1994). Since soil-borne diseases are difficult to control, the Cruciferous vegetable is rotated with non-Cruciferous vegetable. A grower would plant the infected area for producing non-Cruciferous vegetables such as amaranthus, kangkung and lettuce to reduce the occurrence of the disease (Leong et al., 1994). It is therefore not possible to plant Cruciferous vegetables that include lowland cauliflower continuously in the soil in an open field condition. Therefore high rainfall, pests, diseases, and increased use of pesticides in lowland cauliflower cultivation are some of the reasons to look for alternative media.

Soilless medium such as coconut coir dust has been proven successful in production of both woody (Laiche, 1995) and subtropical ornamental plant (Meerow, 1994 and 1995). Furthermore, it does not have pathogenic microorganism and their presence near the roots can suppress the development and proliferation of some soil borne diseases (Cresswell, 2002). Therefore, coconut coir dust needs to be evaluated for potential utilisation in container (such as vertical or flat bag) production of lowland cauliflower. Another reason for using coconut coir dust is due to difficulty in getting good topsoil in this country (Yahya et al., 1997). However, coconut coir dust is inadequacy in nutrition particularly nitrogen (N) contents, and much lower capacity than soil mixes to store and supply nutrients around the root system. For this reason, enough nutrients must be supplied to the root zone for successful plant growth and yield when growing cauliflower using coconut coir dust.

Nutrient solution based on the application of nitrate as N source is a common practice for supplying nutrient to crops grown in soilless media (Cooper, 1979). Inadequate and excess application of N fertiliser to the crops is among the most critical aspects of producing containerised crops. When N is out of balance severe deficiencies or toxicity may occur. A study showed that N deficiency result in a reduction in appearance, size of product, internal quality and generally reduced yield. When the N in the solution is applied in excess to the growth media than what is required by the plants, there will be vigorous vegetative growth and a large amount of unused N fertiliser. This may also result in significant N losses through leaching, which may cause environmental contamination. Prasad (1996) found that leaching of water-soluble N was marginally higher in coconut coir than in peat. A proper N nutrition management is one possible solution to this problem. In addition, cauliflower grown with high nitrate fertiliser can contain high curd tissue concentrations of nitrate (Kaniszweki and Rumpel, 1998). The nitrate content of vegetables has been given much attention recently, because of its consequences for human and animal health. In this case, the use of forms of N other than nitrate should be considered to reduce the nitrate accumulation in the curd.

The concentration of nitrogen compounds such as amino acid, which is important for all aspects of plant metabolism, is also affected by N fertilisation. The nutritional value of N compound or of crude protein in man is dependent on their content of essential amino acids, which have to be present in the food in certain amounts (FAO/WHO 1973). Generally, there is a decline in the concentration of most amino acids concentration except glutamic in cauliflower with high N supply (Eppendorfer, 1996). Thus, the N nutrient solution should be tailored to the demands of the plants, which can be economically and environmentally sound practice in maximizing containerised lowland cauliflower production. This can be achieved by optimising the N nutritional management, which requires an understanding of how a variety of factors interact to affect N uptake, plant growth and curd quality of the lowland cauliflower grown in coconut coir dust. These include factors such as levels of N supply and N forms.