UNIVERSITI PUTRA MALAYSIA

FLOWER ABSCISSION OF CHILLI (*CAPSICUM ANNUUM* L. VAR. KULAI) UNDER HUMID TROPICAL CONDITIONS AND THE USE OF PLANT GROWTH REGULATORS TO IMPROVE FRUIT SET AND YIELD

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By

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Dissertation Submitted in Fullfilment of the Requirements for the Degree of Doctor of Philosophy in the Faculty of Agriculture, Universiti Putra Malaysia.

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This work is dedicated to 'El-Nizamiah' - a school of thought established in remembrance of Shehu Usman Danfodio and his Jama'a.

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BY

USMAN INUWA SHEHU

JUNE 1997

Chairman: Awang Soh Mamat, Ph. D.

Faculty: Agriculture

A series of experiments were carried out under glasshouse and field conditions, at the Universiti Pertanian Malaysia (UPM), Serdang (latitude $30^0$2'N and longitude $101^0$42'E), during the period January 1994 to December 1996. The main objective of the research is to study the nature of abscission of chilli flowers and to use plant growth regulators (PGRs) to improve fruit set and yield of chilli under heat stressed tropical conditions. Most of the flowers fall 3 days after anthesis. This suggest that flower abscission under heat stress is related to the ontogenic changes taking place in the flowers at this stage (pollination and fertilization). Pollen viability and pollen tube growth were not impaired by the stress. Also seed production and viability were similar under both glasshouse and open conditions.

Electron microscopic observations revealed an abscission zone between the peduncle and the twig. The first morphological evidence of abscission by way of cell separation became visible at anthesis. Energy dispersive X - ray scan of this zone showed higher accumulation of Ca^{2+} relative to the surrounding areas. The visibility of cell separation at anthesis indicated that the process of abscission begun prior to pollination and fertilisation.

Endogenous hormone analysis in abscising chilli flowers showed that peak production of ethylene and its precursor 1- aminocyclopropane-1-carboxylic acid (ACC) was at anthesis. Similarly, highest levels of indole acetic acid (IAA) were detected at this stage. The level of abscissic acid (ABA) increased with advancement of abscission.

On the use of PGRs to improve fruit set and yield of chilli, naphthalene acetic acid (NAA), paclobutrazol (PP333), gibberellic acid (GA_{4+7}), and triacontanol (TRIA) were applied to pot grown chilli plants. The GA_{4+7} treatment proved superior over other PGRs in flower count, fruit count, fruit size and total fruit yield. The yield increase following NAA application has not been consistent. The application of TRIA proved effective only in the open. PP333 application increased fruit set and gave the least recorded abscission. In addition this treatment gave yields that are comparable to other PGRs. GA_{4+7} and PP333 were selected for the next stage of the study.

In the second stage, GA_{4+7} maintained superiority in plant height, fruit yield, fruit size and ascorbic acid content of fruits. Its application hastened fruit maturity and favoured heavier early harvests. The yield of fruits increased with change in application time of GA_{4+7} from early flowering (EF) to peak flowering (PF) and then double application (EF+PF). The application of PP333 resulted in delayed maturity and heavier late season harvest. The depressing effect of PP333 on plant height was more pronounced in the glasshouse than in the field. PP333 applied at PF tended to be superior in yield parameters, followed by double application (EF+PF) and then EF treatment. Application of GA_{4+7} increased the total capsaicinoid content of chilli fruit.

Abstrak Disertasi yang diserahkan kepada Senat Universiti Putra Malaysia sebagai memenuhi sebahagian daripada keperluan untuk ijazah Doktor Falsafah

KECENDERONGAN PELURUHAN BUNGA CILI (*CAPSICUM ANNUUM* L. VAR. KULAI) DALAM KEADAAN TROPIKA YANG LEMBAB DAN PENGGUNAAN PENGAWALATUR PERTUMBUHAN POKOK UNTUK MENINGKATKAN PEMBENTUKAN BUAH DAN HASIL.

OLEH

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JUNE 1977

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Satu siri ujikaji telah dijalankan di dalam rumah kaca dan di ladang di Universiti Putra Malaysia (UPM), Serdang (garis lintang 30^{0}2'U and garis bujur 101^{0}42'T), Selangor, Malaysia mulai Januari 1994 hingga Disember 1996. Objektif utama penyelidikan ini ialah untuk mengkaji tabiat peluruhan bunga cili dan penggunaan pengawalatur pertumbuhan pokok untuk meningkatkan pembentukan buah dan hasil cili dalam keadaan tegasan haba tropika. Sebahagian besar daripada bunga-bunga cili luruh dalam masa 3 hari selepas antesis. Ini menunjukkan bahawa peluruhan bunga dalam keadaan tegasan haba berkait dengan perubahan ontogenik yang berlaku dalam bunga pada peringkat ini (contoh: pendebungaan dan persenyawaan). Kebolehhidupan debunga dan

pertumbuhan tiub debunga tidak berubah disebabkan tegasan haba. Pengeluaran dan kebolehhidupan biji juga didapati sama diantara di dalam rumah kaca dan di ladang.

Pemerhatian dengan menggunakan imbasan mikroskop electron (scanning electron microscopy) menunjukkan kewujudan zon peluruhan di pertemuan antara tangkai bunga dan ranting. Bukti morfologi yang pertama yang menunjukkan bahawa peluruhan berlaku melalui pemisahan sel-sel jelas kelihatan semasa antesis. Imbasan penyebaran tenaga sinaran-X (Energy dispersive x-ray) pada zon ini menunjukkan kehadiran Ca^{2+} yang banyak berbanding dengan kawasan keliling. Pemisahan sel-sel yang dilihat semasa antesis menunjukkan bahawa proses peluruhan bermula sebelum pendebungaan dan persenyawaan.

Analisa hormon endogen keatas bunga-bunga cili yang luruh menunjukkan pengeluaran etilena dan prekursornya [1-aminocyclopropane-1-carboxylic acid (ACC)] yang memuncak semasa antesis. Paras asid indola-asetik (IAA) yang tinggi juga dikesan pada peringkat ini. Paras asid absisik (ABA) bertambah dengan penambahan peluruhan.

Mengenai penggunaan pengawalatur pertumbuhan untuk meningkatkan pembentukan buah dan penghasilan cili, pokok cili di dalam polibag dirawat dengan asid asitik naftalena (NAA), paklobutrazol (PP333), asid gibralik

(GA_{4+7}) dan triakontanol (TRIA). GA_{4+7} didapati lebih baik daripada pengawalatur pertumbuhan yang lain, disegi peningkatan jumlah bunga, jumlah buah, saiz buah dan jumlah hasil. Pertambahan hasil selepas menggunakan NAA didapati tidak tetap. Penggunaan TRIA berkesan hanya di ladang. Penggunaan PP333 meningkatkan pembentukan buah dan memberi jumlah bunga luruh yang paling rendah. Rawatan ini juga memberi hasil yang setara dengan pengawalatur pertumbuhan yang lain. GA_{4+7} dan PP333 kemudiannya dipilih untuk ujikaji seterusnya.

Dalam peringkat kedua, GA_{4+7} didapati masih meningkatkan ketinggian pokok, penghasilan buah, saiz buah dan kandungan asid askorbik. Penggunaan GA_{4+7} mempercepatkan kematangan buah dan lebih banyak buah dipungut awal. Pengeluaran hasil buah cili berubah mengikut masa penggunaan GA_{4+7}. Semburan semasa pembungaan awal (PA) memberi hasil paling rendah. Hasil bertambah apabila semburan dibuat semasa pembungaan puncak (PP). Seterusnya, hasil paling tinggi dipungut daripada pokok yang menerima semburan berganda (PA+PP). Penggunaan PP333 menghasilkan buah yang mempunyai kandungan melewatkan kematangan dan lebih banyak buah dipungut lewat. Kesan pengurangan ketinggian pokok oleh PP333 lebih jelas di dalam rumah kaca berbanding dengan di ladang. PP333 yang disembur semasa pembungaan puncak (PP) lebih berkemungkinan memberi hasil yang lebih baik. Ini diikuti oleh penyemburan berganda (PA+PP), dan penyemburan semasa pembungaan awal (PA). Penggunaan GA_{4+7} meningkatkan jumlah kandungan kapsaisinoid di dalam buah cili.

CHAPTER I

INTRODUCTION

Role of Plant Growth Regulators in Growth and Development

Communications within the plant as in animals is mediated by the action of chemical substances called hormones. A hormone is defined as any organic compound synthesised in one organ in response to a stimulus, and transported to another organ where a response is produced. In recent years, the hormone concept has been questioned by different sources. The chemicals involved do not necessarily move from their site of synthesis. In view of this, and because many aspects of their action are on plant growth they have been called 'growth substances' synonymous to 'growth regulators' (Van Overbeek, 1954).

Plant growth substances regulate the physiological and morphological processes taking place in the plant. This control is achieved through a complex interaction between plant internal factors and the environment. Auxins, gibberellins and cytokinins have their most pronounce effects on growth, flowering, fruit and seed set. Whereas ethylene and abscissic acid are associated with ripening, senescence and abscission of plant organs. For a normal growing plant that is at equilibrium with its environment, sufficient endogenous levels of the individual hormones are usually available. A deviation from this equilibrium results in changes in the levels of the hormones which is usually accompanied with plant response to this change. For instance endogenous levels of ABA and ethylene increase under water stress and the plants respond to this stimulus by slowed growth, stomatal closure and increase in protein synthesis. This is probably a survival mechanism for the plant to overcome the stress. Similarly, modifications in growth would occur due to high levels of these growth retardants in the case of air pollution, pest damage, flooding, etc.

The growing plant passes through several stages of development that are associated with definite morphological and physiological changes. Similarly, a single organ of the plant may pass through several developmental sub-phases. In the stem for instance, older internodes are completing their development when younger ones are just beginning. This decreasing rate of elongation has been correlated with the increasing ability of the tissues to destroy IAA in Japanese morning glory (Yoneda and Stonier, 1966).

The transition from vegetative to flowering stage is a complex morphological event. The ability to flower is attained when the plant has reached a certain size or age. In some plants flowering occur independent of the environment (autonomous induction). Other plants require exposure to appropriate environmental conditions. Day length and temperature are the most important environmental factors controlling flowering.

As in the case of growth, there is a hormonal control of flowering. This response occurs in the growing points, not yet ascribed to any particular day length. A specific flowering hormone in the name of "floragen" was postulated in the 1930's by Michael Chailakhyan working in Russia. Many attempts have been made to extract and isolate this hormone but without much success (Zeevart and Boyer, 1987; Zeevart, 1984; and Lang et al., 1977). Thus, despite unequivocal data showing that a transmissible factor regulates flowering, the involved substances are yet to be characterised. Gibberellins play an important role in flowering. Exogenous gibberellin has been found to substitute for photoperiodic induction in some plants (Lang, 1957). In particular, GAs cause flowering when applied to long day plants that grow as rosettes in short days. In these plants the flowering response in accompanied by elongation of the flowering stem.

Senescence also called ageing of the plant, is the stage preceding death or in the case of organs, preceding abscission. Many physiological changes accompany the ageing process. Translocation of food materials away from the senescing organ has been put forward as a basis for senescence. However, studies indicated that hormones are responsible. According to this view a deficiency of one or more of the growth regulators leads to senescence (Osborne, 1963). Thus, auxin content declines with age of leaf and towards death is too low to measure accurately. This decline in auxin is accompanied by a decline of other substances, perhaps because of a direct effect of auxin on phloem transport. Therefore, older leaves senesce more rapidly in the presence of young auxin-rich leaves above them. Senescence can actually be delayed by treating leaves with growth regulators. Kinetin delays sequential ageing and auxin delays synchronous ageing. Growth retardants may also be used successfully (Kesler et al., 1967) even when cytokinins fail.

ABA greatly accelerates senescence of leaves. Ethylene has been found to play a role in the senescence of oat leaf segments, but ABA appears to be the initiating agent. Whereas ethylene exerts its effect at a later stage (Gepstein and Thimann, 1981). Leaf senescence has been studied extensively and the physiological, anatomical and biochemical changes that take place during this process have been described (Nooden and Leopold, 1988).

Role of Growth Regulators in Abscission

Ethylene appears to be the primary regulator of the abscission process, with auxin acting as a suppressor of the ethylene effect. A model of hormonal control of leaf abscission that explains the process in three distinct phases has