Physiological Studies on Growth, Flowering and Fruit-setting of Sweet Pepper

By

MOHAMED ADEL HOSNY EL GHANDOUR
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INTRODUCTION

Peppers are considered among the most important vegetables grown in the United Arab Republic. In the 1966-67 season peppers were harvested to some 15,000 feddans with a production of 95,000 tons. Pepper plants are cultivated in U.A.R. as summer, nili, and winter harvests. Most of the area, however, is planted for summer harvest as a result of its superior performance and high potential for providing higher yields. One of the winter production problems that usually occurs in U.A.R. is the slow recovery from conditions which cause serious stunting. Such stunting results in winter plants which produce a low yield of commercially desirable fruits.

However, winter harvests are locally consumed with higher prices, besides its importance for exportation. An increase and improvement of winter production of sweet pepper (Capsicum annuum L.) therefore, greatly affects both the supply of the local market and for the export. A some of 584 tons (82,414 L.E.) of green sweet peppers of the winter harvest was exported to foreign markets in the 1968-69 season.

It has been repeatedly shown that environmental and internal factors are responsible for differences in growth behavior and yields of various plant species (Cochran, 1936; Dorland and Went, 1947 ; Wells, 1967). Flowering, fruit-setting and shedding all are physiological processes of vital importance, contributing in yield control. The value of exogenous growth regulators in modifying different phases of growth and in regulating different physiological phenomena has been extensively studied; few reports are available, however, concerning their mode of action and their effect on the relative levels and effectiveness of the endogenous growth substances. Application of different growth regulators to modify certain physiological processes and to improve pepper yield has been practiced by some earlier investigators (Audus, 1959; Leopold, 1964; Singh and Nettles, 1964).

This investigation was undertaken to study the physiology of growth in both winter and summer plants and to determine the effect of planting date on flowering, fruiting, shedding and yield pertaining to pepper. This has involved studies on the effect of four different growth regulators on such physiological processes. Furthermore, gradual changes in levels of endogenous growth substances as affected by several spray applications of these chemicals were also studied for winter and summer planted peppers.

REVIEW OF LITERATURE

I History

It is now nearly hundred years since Julius Sachs in 1880 (Addicott, 1957) advanced the idea of specific organ-forming substances in plants. This was proposed on the basis of certain observations, that root forming and flower-forming substances are manufactured in different parts and by moving in very low concentration through the plant, cause the development of these organs.

It is quite clear now that endogenous and exogenous regulators in plants play an important role in modifying many physiological processes (Mitchell and Marth, 1950 ; Addicott, 1957 ; Chailakhyan, 1968). Flowering, fruit-setting, flower and fruit abscission, fruit growth, maturation and dormancy are of the physiological processes controlled by the gradual changes in the naturally-occuring growth active materials during different growth stages. Furthermore, these stages are greatly influenced by environmental conditions and can be modified by application of a wide variety of exogenous growth regulators such as auxins, gibberellins, Kinens, morphactins and phenols (Hemphill, 1949; Mitchell and Marth, 1950; Addicott, 1957; Crane, 1964; Vegis, 1964; Carns, 1966; Chailakhyan, 1968; Wittwer, 1968.) Growth regulating substances have assumed an important role in the culture of plants during the past 30 years. Some of these regulators are now being used on a large scale to increase the yield of many horticultural crops.

II Some factors affecting growth

1. Effect of temperature and day length :

An extensive study on the effect of temperature on growth and fruit setting in pepper plants was demonstrated by Cochran (1936).

Using different ranges of temperatures, together with other factors Cochran's general conclusion was, that temperature had greater effect on flowering and fruiting than any other factors studied. At the highest temperatures no fruits were setted and most flower buds were dropped off before opening. When plants were shifted to lower temperatures, however, fruit-set immediately increased. Dorland and Went (I947) reported that the stem elongation of chili pepper plants grown to maturity under different controlled external conditions was greatly affected by night temperatures. Flowering, fruiting and fruit weight were also temperature dependant, since it was favoured by low night temperatures. Eagles and Wareing (I963) further, reported on the retarded growth of the shoot apices and buds of Betula pubescens plants maintained under short day conditions. Under long days, however, plants attained normal vegetative growth. The results of recent research (Vegis, I964), using many plant species, have varified the opinion of some earlier workers (Hemberg, I949; Hendershott and Bailey, I955) who supposed that the dormant condition in plants is induced by external factors among which temperature being of chief importance.

According to the many response types theory Salisbury (I963) indicated that pepper plants (Capsicum annuum L.) are day neutral or quantitative short day plants promoted by temperature alternation. Deli and Tiessen (I966) again reported that sweet pepper seedlings exposed to low night temperature produced more flowers than those exposed to higher temperatures. The response to temperature was most intense, however, when plants reachedthe 3rd true leaf stage of development.

Hamadeh (I967) indicated that low fruit set, caused by post-anthesis abscission of flowers and young fruits in the pepper varieties

Vinedale Pennwonder and Keystone Resistant, was linked with unfavourable warm temperatures during June, July, and early August. Temperature requirements for optimum fruiting comprised a sequence of warm (70° - 80° F.) temperatures prevailing during the pre-anthesis stages followed by cool (50° - 60° F.) to medium (60° - 70° F.) temperatures during the post anthesis stages. Cool temperature alone did not permit flowering, while medium temperature was moderately favourable for fruiting and warm temperature impaired the reproductive process. Similarly, Filius (1967) indicated that changes in temperature affected vegetative growth more than many other factors studied. The response of two pepper varieties, Delaware Belle and Pennwonder, subjected to 4 different night temperatures (50° , 60° , 70° and 80° F.), while the day temperature was maintained at 78°, was investigated by Wells (1967). It was found that greater number of flowers per plant occured at night temperatures of 60° and 70°, whereas the greatest number of fruits and highest percentage fruit set existed at 50° and 60°. Both flowering and fruiting were found to be cyclic in habit. At 60° night temperature there was one cycle of flowering and one cycle of fruiting. At 50° , 70° and 80° there was also one flowering cycle, while two fruiting cycles were evident with the flowering peak occuring midway between the two fruiting peaks.

2. Effect of some growth substances :

The idea that the growth and development of plants might be governed by different natural and synthetic growth substances is not one which burst suddenly upon the mind of any single person; rather did it evolve over a period of time as a result of the accumulation of evidence from several sources. Yet the overt acceptance of this view may be traced back to two of the biological giants of the nineteenth century, Charles Darwin and Julius Sachs. Among those growth substances; however, some are of special interest for this study.

a. Effect of gibberellins.

It was recognized as early as I926 by Kurosawa that gibberellins (GA) play an important role in modifying different growth phases of higher plants (Heslop-Harrison, I963). One of the most characteristic effects of this group of substances is the abnormal growth in length of stems and leaves. However, GA has been repeatedly shown by many workers to have a manifold effects on a wide variety of different physiological processes.

Wittwer and Bukovac (I958) reported that treating cotton plants with GA broke the so-called cut-out dormancy, hence preventing cotton plants from going into a cessation of vegetative and fruiting bud development apparently caused by the load of developing fruits preventing further fruiting and vegetative growth until some of the fruiting load matures or is removed. Lockhard (I96I) pointed out that visible radiation, through an unknown sequence of reactions, act to reduce the amount of available gibberellin inducing a decreased plasticity of cell walls and growth accordingly, was reduced. The retardation of the stem elongation of pinto bean at high light intensities was mainly due to a deficiency of GA .

On the other hand, the beneficial effect of GA on the growth of spinach plants was believed by Radly (I963) to be due to the stimulation of cell division by the increased amount of native GA when plants were transferred to continuous light for one day.

b. Effect of cycocel.

Application of chemicals to plants is of great use not only agriculturally, as modifiers of nutrition or as regulators of growth, but in the experimental sence of offering a wide range of possibilities for exploring physiological phenomena inside the plant. Cycocel (CCC) is one of those chemicals which many plant physiologists show an increasing interest in studing its effect and mode of action in higher plants.

Cathey (1964) showed that pith parenchyma cells, in Pharbitis seedling treated with ccc , had a larger diameter than those in untreated plants. Furthermore, at low levels of CCC in solution culture or soil treatments, wheat plants showed increased vegetative growth and dry matter accumulation. Humphries (1964), however, showed that with some concentrations of CCC, leaf area may be unaffected or even increased. Conflicts in the data obtained by different workers suggest that CCC is not necessarily a growth retardant, but rather it can be thought of as a growth regulator which may have positive effect on growth. This hypothesis is in good agreement with the findings of Chailakhyan and Kocankov (1967) who showed that the growth of long day plants including Rudbeckia Bicolor and Brassica Crenata was retarded by low concentrations and that of dayneutral plants including Vicia faba, by high concentrations; the growth of short day species, including Perilla and Chrysanthemum, was stimulated by low concentrations and retarded by high concentrations. On the other hand, Dennis (1968) concluded that neither CCC nor phosphon was effective in retarding or hastening flowering of both apple and pear seedlings.

C. Effect of Auxins

The substances collected by went in 1928 from the tips of oat coleoptiles were detected through their ability to promote extension growth in the subapical cells of the coleoptile. By general usage, the term auxin has come to refer to all substances, natural and artificially synthesized, having this property.

In higher plants, survival depends upon the spatial and temporal co-ordination of growth and development between the several structural elements of which it is composed. This co-ordination is a flexable one, showing remarkable self-regulatory powers, which was shown by Heslop-Harrison (1963) and others that it is greatly influenced by the type and amount of auxins present.

A general relationship of auxin to growth has been shown in different tissues in a variety of ways. It was shown by Hatcher (1959), as reported by Vegis (1964), that auxin content in apple twigs rises in the spring as growth gets under way, and it subsequently declines through the growing season following the decline in the growth rate until autumn. Furthermore, Leopold (1964)indicated that auxins often occurs most abundantly in the most actively growing tissues. He reported that in Lens roots, for instant, auxin was most abundant in the area of the most active growth (2 mm from tip).

The stimulation in fruits presents another illustration of the role of auxin which may be associated with growth. Nitsch (1950) showed that the threshold of rapid growth phases of fruits was accompanied by preceding surge in auxin production. However, the manifold effects of auxins on flowering, fruit setting, shedding and yield has been recognized by many investigators and are reviewed below.

III Some factors affecting flowering, fruit setting, shedding & yield:

With some plants, especially some herbaccous annuals, the time of flowering seems to be largely independent of the environment so long as conditions of light, temperature, and moisture are such as to allow for food manufacture and growth. The sequence of seed germination, vegetative growth, flowering, fruiting, senescence, and death follows is regular order. However, with many plants, even annuals, rapid vegetative development seems somewhat restricted to certain rather definite seasons, and flowering and fruiting may be still more strictly seasonal. Like any other physiological process, flowering is ultimate, and determined by the genotype of the plant. In many other plants, however, flower initiation is dependant on the interaction of the genotype and very specific environmental conditions. Such conditions are a period of low temperature, day length or photoperiod. The control of flowering by low temperature is known as vernalization. In 1918, Gassner found that winter forms require cold and that they differ in this requirement from spring forms; he discovered the phenomenon of thermoinduction in plants (Leopold, 1964).

During the half century that has passed since that time, the physiology of flowering was enriched with new basic data and with essential theoretical conclusions. The discovery that perception of photoinduction occurs in the leaves while the response-differentiation of flower primordia of course takes place in the buds was the first basis for the flower-hormone concept in photoperiodism. This concept was enunciated by Chailakhyan in 1936 (Lang, 1965) who proposed to call the hormone "florigen". Repeated efforts were made at extracting the active substance from photoinduced plants or other material. Only, few years ago it was announced by Lincoln, et al.(1961) that they had consistently succeeded, to obtain from flowering Xanthium pensylvanicum plants a crude extract which when applied to non induced individuals, caused part of them to initiate flowers. Somewhat later, Lincoln et al.(1962) also succeeded in obtaining flower formation in Xanthium by application of similar extracts from sunflower, an (essentially) day-neutral plant. Considerable amount of work, however, has been done on effects of plant growth hormones and related synthetic substances on flower formation. The growth substances mostly used have been auxin and more lately gibberellin, while work with kinetin has been much more limited(Lang ,I965).

Fruit-setting is the process of which the flower fertilizes. The process of fertilization and hence seed production is correlated with the production of plant hormones in the fruit, which encourage its enlargement (Leopold, I964). Very little is known at the present time, however, about the physiological mechanism of fruit set which is the basic step in the life cycle of higher plants.

Flower abscission frequently limits fruit set in many plants, whereas fruit shedding limits the yield. In many woody plants,Fehr (I925) found that the abscission of the mature fruits was caused by the development of a separation layer through the activity of secondary cell division (Lee and Carolus, I949). Studying the effect of growth substances on the abscission layer in Coleus leaves, Myers (I940) reported that abscission could be accelerated by a number of external factors such as high or low light intensity, water supply, temperature, and low concentrations of anesthetices toxic concentrations of acids and salts, ethylene gas, and wounding or complete removal of the blades. It was concluded that, these external factors which influence abscission possibly could effect the synthesis of the growth substances being associated with this process. It has been shown by Carns (I966) that Jacob (I962),Rubinstein and Leopold (I964), Addicott (I965), have each assigned to auxin a specific and differing regulatory role in the abscission process.

Flowering, fruit setting, flowers and fruits shedding all are physiological processes by which the yield of fruit crops is greatly determined and which, in turn, are greatly affected by environmental condition as well as by chemical regulators.

1. Effect of temperature and day length

Flowering of many biennial and perennial plants, is regulated by low temperature treatments,while it is less common for flowering to be caused by high temperatures (Leopold, I964). The promotive effects of low temperature on flowering were termed "vernalization" and were described by several authors as early as in the middle of the I9th century (Lang, I965).

In an extensive study, investigating the effects of some environmental factors on flowering and fruiting of pepper plants, Cochran (I936) pointed out that temperature had the greatest effect on these physiological processes. The time of bud formation, anthesis, and fruit maturity were all found to be temperature dependants. Dorland and Went (I947) reported that flowering of pepper was most abandant at 20.5 - I5.5°C. night temperature for young plants, whereas in older plants the optimum night temperature shifted to 8.5°C. Later, pepper (Capsicum annuum L.) was described by Salisbury (I963) to be day-neutral plant which is promoted by temperature alternations. It was shown by Wells (I967) that the greatest number of flowers per pepper plant occurred at night temperatures of 60° and 70°F. Furthermore,both flowering and fruiting were found to be cyclic in habit.

Cochran (I936) reported that the effect of temperature on fruit setting was very pronounced. By altering the temperature, from 50° to 100° F, under which pepper plants were grown, the set of fruit varied from 0 to practically 100 percent. At highest temperatures no fruits were set, but when plants were shifted to lower temperatures fruit set immediately increased. Furthermore, Hamadah (I967) showed that low fruit-set caused by post-anthesis abscission of flowers and young fruits in the pepper varieties Vinedale, Pennwonder and Keystone

Resistant, was linked with unfavourable warm temperatures during June, July and early August. Meanwhile, the greatest number of fruits and highest percentage fruit set was found to exist at 50° and 60°F (Wells, I967). Generally, Hamadeh (I967) indicated that at highest temperatures fruit set was checked and flower buds failed to produce either fruits or fertile flowers. Such results were in line with those previously mentioned by (Cochran, I936).

The effect of temperature on the yield of higher plants has been repeatedly illustrated by many investigators. Brasher and Westover (I932) and Porter (I935) found that, under Connecticut conditions, hardened tomato plants consistently yielded lower early production than did the unhardened or tender plants. Higher yields of capsicums were obtained, by Spender (I96I), from plants sown in early february than those sown in autumn or winter.

2. Effect of some growth substances :

a. Effect of gibberellins.

Gibberellins are the only chemicals which have so far been found to induce and promote flower formation in numerous plants, and moreover plants belonging to well defined physiological groups, namely long-day, long-short-day and short-long-day and cold-requiring plants (Phinney and West, I960; Rappaport, I960; Heslop-Harrison, I963; Lang, I965; Chailakhyan, I968).

Not only gibberellins are produced as a product of fungus Gibberella fujikuroi, but they are also found in so many plant species. These substances are probably ubiquitous in higher plants and may play direct or indirect roles in almost every physiological process (Phinney and West, I960). By latest count, 22 chemically different gibberellins are known which have been isolated and their chemical structures elucidated (Wittwer, I968).