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The Pattern of Seed Development and Maturation in Cauliflower (*Brassica oleracea* L. var. *botrytis*)

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With 7 Figures

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Summary

GURUSAMY C. & THIAGARAJAN C. P. 1998. The pattern of seed development and maturation in cauliflower (*Brassica oleracea* L. var. *botrytis*). – Phyton (Horn, Austria) 38 (2): 259–268, with 7 figures. – English with German summary.

The physical, physiological and biochemical changes in developing seeds of cauliflower (*Brassica oleracea* L. var. *botrytis*) cultivar Kibo Giant were followed from 7 days after anthesis up to maturity, grown under field conditions. Silique growth and weight, seed weight, germination capacity and speed, seedling length and dry weight, dehydrogenase activity, protein and oil accumulation followed almost a sigmoidal pattern. Seeds started precocious germination from 28 days after anthesis onwards. Cell membrane integrity increased with the advancement of seed maturity. Dehydrogenase activity correlated positively with seed quality and seedling vigour, and negatively with seed moisture content. A significant amount of oil accumulation started later than protein, but continued even after protein accumulation ceased. While protein accumulation slowed down earlier, oil accumulation continued up to harvest. The best time to harvest the seed crop was within a week after physiological maturity (49 days after anthesis), which identified visually by change in colour of siliques and seeds from green to pinkish yellow and brown, respectively.

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Zusammenfassung

GURUSAMY C. & THIAGARAJAN C. P. 1998. Das Muster der Samenentwicklung und Reifung bei Karfiol (*Brassica oleracea* L. var. *botrytis*). – Phyton (Horn, Austria) 38 (2): 259–268, 7 Figuren. – Englisch mit deutscher Zusammenfassung.

Die physikalischen, physiologischen und biochemischen Veränderungen in sich entwickelnden Samen von Karfiol (*Brassica oleracea* L. var. *botrytis*) cv. Kibo Giant wurden beginnend mit 7 Tagen nach der Blüte bis zur Reife unter Feldbedingungen untersucht. Das Wachstum und das Gewicht der Schoten, Samengewicht, Keimfähigkeit und Geschwindigkeit, die Länge der Sämlinge und das Trockengewicht, die Dehydrogenaseaktivität, die Protein- und Ölakkumulation folgten einem beinahe sigmoiden Verlauf. Die früheste Keimung der Samen setzte mit dem 28. Tag der Blüte ein. Die volle Ausbildung der Zellmembran nahm mit dem Fortschreiten der Samenreife zu. Die Dehydrogenaseaktivität korrelierte positiv mit der Samenqualität und deren Vitalität bzw. negativ mit ihrem Feuchtigkeitsgehalt. Eine signifikante Anreicherung von Öl begann später als beim Eiweiß, aber hielt noch an, nachdem die Proteinakkumulation bereits endete. Während die Proteinakkumulation früher nachließ, setzte sich die Ölakkumulation bis zur Ernte fort. Die beste Zeit um die Samen zu ernten, lag innerhalb einer Woche nach der physiologischen Reife (49 Tage nach der Blütenbildung), welche visuell durch die Verfärbung der Schoten und Samen von grün zu rosa-gelb bzw. braun festgestellt werden konnte.

Introduction

Cauliflower belongs to the *Brassica* genus and is a popular cruciferous vegetable crop, which is cultivated in almost all the countries of the world from temperate to tropical including India (LAL 1993). As cauliflower is a temperate or cold climate adapted plant, its seeds take a long time for development from flowering to maturity. India produces the seed of early and mid season varieties in plains, but the seed of late season varieties in hills (SINGH 1992). In TamilNadu, it is cultivated mainly in the hills of Udhagamandalam and Kodaikanal for both curd and seed purposes. The changes in developing seeds has been reported in some brassicas such as mustard (SEXENA & KUMAR 1981) and rapeseed (DASGUPTA & MANDAL 1993). Though the production and utilization of cauliflower is increasing in India due to its rich sources of vitamins and minerals (CHATTEREJEE 1986), survey of literature indicates that research related to seed development is lacking compare to works on curd. Hence, the physical, physiological and biochemical changes in developing and maturing seeds of tropical cauliflower were studied.

Materials and Methods

Fifty to sixty plants of cauliflower (*Brassica oleracea* L. var. *botrytis*) cultivar Kibo Giant were grown in Wood House Farm, Horticultural Research Station, TNAU, Udhagamandalam with all the recommended agronomic practices. The curds were left in situ to flower and produce seeds (SINGH 1992). Developing siliques were collected at 7, 14, 21, 28, 35, 42, 49 and 56 days after anthesis (DAA). After measuring length, width and fresh weight, the siliques were rapidly separated into seeds and hulls and the seed fresh weight recorded. Both siliques and seeds were subsampled for dry weight and moisture content estimation (ISTA 1993 a, b) and further analysis.

Following parameters were analyzed in developing seeds according to the method of authors given in parenthesis: Speed of germination (MAGUIRE 1962), germination, seedling length and dry weight (ISTA 1993 a, b), electrical conductivity (EC) of seed leachate (PRESLEY 1958), free amino acids (CHING & CHING 1964), free sugars (SOMOGYI 1952), total dehydrogenase activity (KITTOCK & LAW 1968), protein (ALIKHAN & YOUNGS 1973) and oil content (RAO & al. 1960).

The results of measurements represent the mean values of 50 samples. The results of biochemical analyses represent the mean values of 6 replications, each contained the following size of seed samples as indicated in parenthesis: EC (250 mg), free amino acids (250 mg), free sugars (250 mg), dehydrogenase activity (25 seeds), protein (100 mg) and oil content (5g). The vertical bars in figures represent the standard deviation of the mean.

Results

Physical and physiological changes

The length and width of the siliques both rapidly increased until 49 DAA, after which it stabilized (Fig. 1). The most rapid early silique growth, over 70 %, achieved between 7 and 14 DAA. This indicates the rapid cell division and elongation. Fresh and dry weight of the siliques increased rapidly until 42 DAA, continued at a lower rate until 49 DAA and decreased during the dehydration stage (Fig. 2). The fresh and dry weight of seeds also increased rapidly with the advancement of maturity

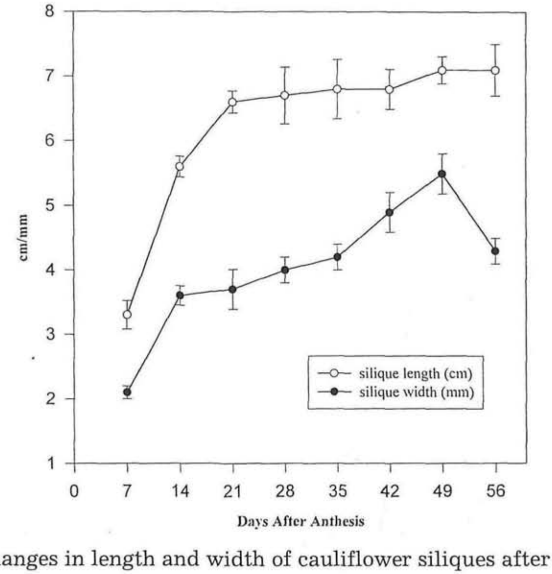

Fig. 1. Changes in length and width of cauliflower siliques after anthesis.

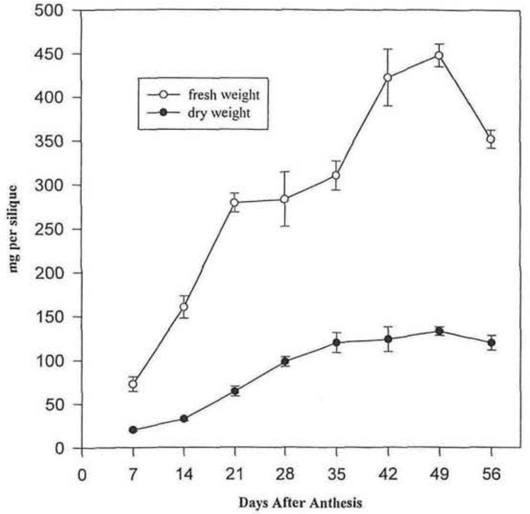

Fig. 2. Changes in fresh weight and dry weight of cauliflower siliques during development.

and reached a maximum on 49 DAA (Fig. 3). The rate of accumulation of seed fresh and dry weight was comparatively higher between 14–21 DAA and 21–28 DAA, respectively. The pattern of growth and development of siliques and seeds both were similar and followed a sigmoidal pattern.

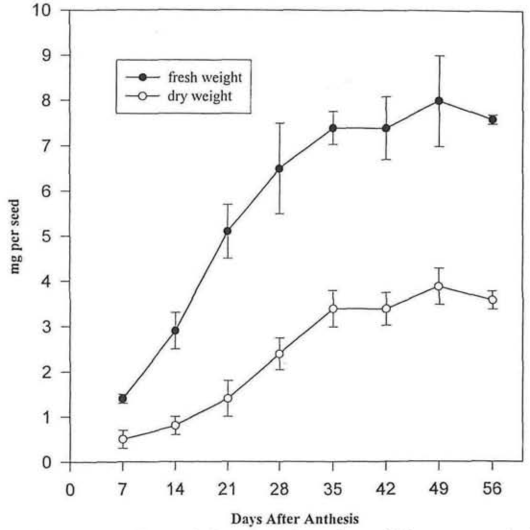

Fig. 3. Changes in fresh weight and dry weight of cauliflower seeds during development.

Although a gradual reduction in the moisture content occurred over an extended period, both in siliques and seeds, rapid losses of about 12 % in siliques and about 28 % in seeds were recorded (Fig. 4). A colour change in siliques and seeds was observed from green to pinkish yellow and brown, respectively on 49 DAA.

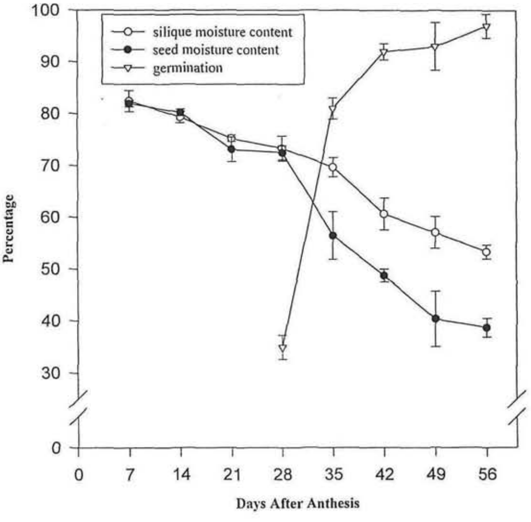

Fig. 4. Changes in moisture content and germinability of cauliflower seeds during development.

Cauliflower seeds started precocious germination from 28 DAA onwards with 35 % and it increased as maturity advanced (Fig. 4). Like seed germination, its speed also increased slowly until 49 DAA, then decreased during dehydration. Seedling length and dry weight increased progressively and reached a maximum at maturity stage (Fig. 5).

Biochemical changes

Electrical conductance of seed leakage is an indirect measure of membrane integrity (KHATTRA & al. 1993). Electrolyte leakage from seeds declined with the advancement of development (Fig. 6). Free amino acid and free sugar contents in seed leakage increased rapidly from the beginning until 21 DAA, continued to decline slowly until 28 DAA and then decreased fastly towards maturity (Fig. 7). Seeds collected first two weeks after anthesis were so small and not usable for the estimation of dehydrogenase activity and oil content. As maturity advanced, dehydrogenase activity increased slowly and reached a maximum on 56 DAA (Fig. 6). Protein accumulation continued linearly upto 28 DAA, after which declined slowly until maturity. Oil accumulated steadily upto harvest (Fig. 7).

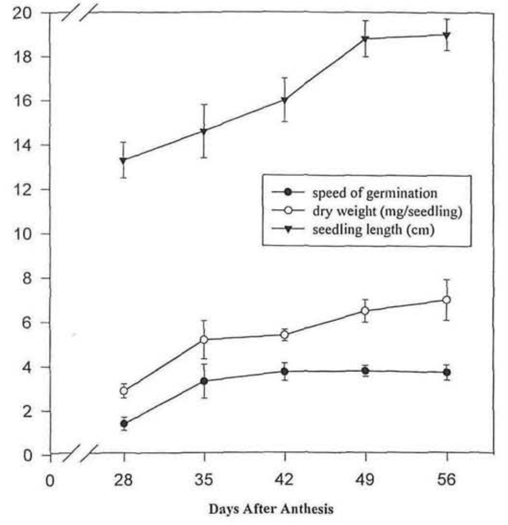

Fig. 5. Changes in speed of germination, seedlings dry weight and length in cauliflower during development.

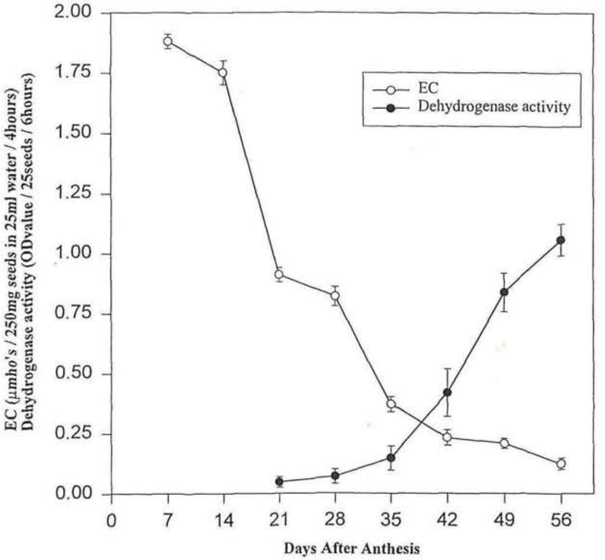

Fig. 6. Changes in electrical conductivity and dehydrogenase activity in developing cauliflowers seeds.

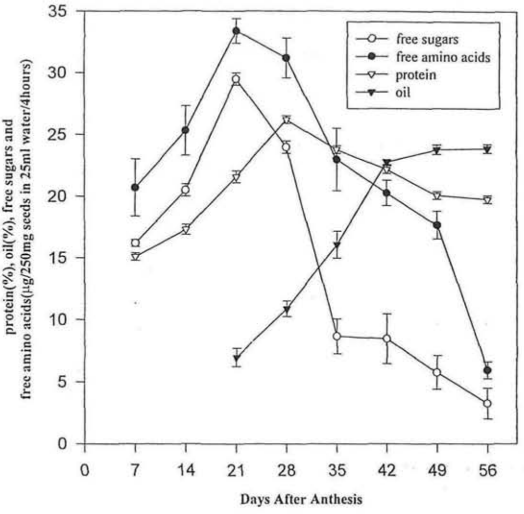

Fig. 7. Biochemical changes during seed development and maturation in cauliflower.

Discussion

The increase in length and width of siliques towards maturity would have reflected the growth of seeds, accumulation of weight and storage materials, relative to moisture content which showed a sharp fall. The simple sigmoidal curves which demonstrated almost a perfect synchronization in accumulation of fresh and dry weight in both siliques and seeds. This interrelation between fruit and seed development were similar to those reported for *Brassica juncea* (AHUJA & al. 1981). As reasons for the reduction of seed weight, silique weight and dimensions after physiological maturity, oxidation and volatilization (HARRINGTON 1972), desiccation (RAO & RAO 1975) and loss of nutrients (RAUF 1978, SREERAMULU & al. 1992) are reported in literature.

Physiological maturity denotes the stage of development when the seed reaches its maximum dry weight and marks the end of the seed filling period (SHAW & LOOMIS 1950). Here, physiological maturity coincided with the time when the moisture content of seeds on the plant had naturally fallen to 40 %. The loss of water during maturation is an inherent phase of development (MCIIRATH & al. 1963). The decrease in moisture content of siliques and seeds, in the present study, as maturity advanced is probably due to the utilization of water in various metabolic activities and removal of water by desiccation caused by surrounding environment (SREERAMULU & al. 1992).

Seed maturation is not an obligatory process for the acquisition of germinability, that the seed or at least the embryo therein, is capable of germinating during development (BEWLEY & BLACK 1994). In this study, seeds started germination precociously, but both germination capacity and its speed increased with increase in maturity. This might because early during development the embryos initially lack sufficient nutrients to support their continued development to a germinable stage, and also lack the nutrients and stored reserves to support germination and post germination growth (BEWLEY & BLACK 1994). Seedling length and dry weight increased with maturity. Similar results were previously reported in legumes (ELLIS & al. 1987).

Increased EC of leachates from seeds reflects poor integrity of cell membranes (KHATTRA & al. 1993) and availability of most of the reserve materials in free form, rather than bound form, which is actively utilized, during initials stages of rapid growth, by metabolic processes probably to meet the energy requirements for the various anabolic processes. Reduction in electrolyte leakage from seeds in the present study clearly indicated the improvement in cell membrane integrity and increase in the deposition of storage reserves in bound form over a period of development. This is also confirmed by measuring reduced amounts of free amino acids and free sugars in same leachate. Increase in dehydrogenase activity is an indication of high vigour of the low moisture seeds (KHATTRA & al. 1993). In this study, dehydrogenase activity showed a positive correlation with seed quality and subsequent seedling vigour and a negative correlation with seed moisture content. BURRIES & al. 1969 reported a similar correlation between tetrazolium staining with seed quality and seedling vigour in soybean.

The decline of the protein content in seeds during maturation was possibly due to the utilization towards the growth of fruit (KESTA 1991). Here, the protein accumulated in early half and declined in later half of development. This indicated that storage of transport nutrients in seed, from other parts of the plant when it was plenty as a precautionary measure and later on reconverted into simpler forms for continued development and maturation when such nutrients were deficient in other parts of plant. During initial stages of development, oil accumulated slowly, and presumably because the absence or less synthesis of the appropriate enzymes (BEWLEY & BLACK 1994). The continued and discontinued accumulation of oil and protein, respectively are in agreement with the results reported in *Brassica juncea* (SEXENA & KUMAR 1981) and *Brassica campestris* (DASGUPTA & MANDAL 1993). Thus the development of the seeds of cauliflower may be conveniently divided into three stages namely histodifferentiation or cell division and early expansion stage (upto 14 DAA), reserve accumulation stage (14 to 49 DAA) and dehydration stage (49 to 56 DAA). These stages are more or less similar to developing seeds of rapeseed (NORTON & HARRIS 1975) and mustard (DASGUPTA & MANDAL 1993).

HARRINGTON 1972 has suggested that physiological maturity is the developmental stage at which seeds achieve maximum viability and vigour since nutrients are no longer entering the seed from the plant, and that thereafter seeds begin to age. Physiological maturity is the most suitable stage at which seeds should be harvested (ELLIS & al. 1987). In the present investigation, based on various changes in developing and maturing seeds of cauliflower, 49 and 56 DAA were identified as physiological and harvestable maturity stages, respectively. Harvesting of cauliflower seed crop within a week after physiological maturity will enable to get seeds of best quality.

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