

PHYSIOLOGICAL ANALYSIS OF FIBRE DEVELOPMENT IN COTTON

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CERTIFICATE

This is to certify that the thesis entitled "PHYSIOLOGICAL ANALYSIS OF FIBRE DEVELOPMENT IN COTTON" submitted in part fulfilment of the requirements for the award of the degree of DOCTOR OF PHILOSOPHY (Agriculture) IN CROP PHYSIOLOGY to the Tamil Nadu Agricultural University, Coimbatore, is a record of **bona fide** research work carried out by Mr N KUMARAPERUMAL under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.

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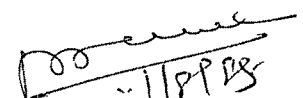

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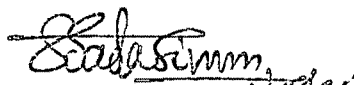
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Abstract

ABSTRACT

PHYSIOLOGICAL ANALYSIS OF FIBRE DEVELOPMENT IN COTTON

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Fibre ontogeny is a unique event in cotton boll physiology. Studies were aimed at to resolve the physiological, chemical, hormonal and nutritional changes in fibre and associated boll components of the developing boll of two elite cotton cultivars, viz., MCU 5 and Suvin belonging to Gossypium hirsutum L. and Gossypium barbadense L. respectively. A mutant of MCU 5 provided physiological evidences on characters leading to lintlessness.

Photosynthetic rate of leaf subtending the boll and specific source labelling with ^{14}C and the consequent apportionment of assimilates into various boll components indicated an ideal source-sink relationship in MCU 5. Suvin had higher photosynthetic rate per unit leaf area and the source area was comparatively restricted. Besides, part of the assimilates accumulated in the source leaf itself. MCU 5 mutant possessed exceptionally high source strength, however most of the assimilates stagnated in the source leaf.

Early flowering behaviour in MCU 5 adequately confirmed it as the projection of earliness of boll characters. Among the genotypes, MCU 5 mutant alone possessed exalted flower production. Relating heat units to flowering, it was inferred that higher the flowering intensity, higher were the accumulated heat units. Suvin manifested profuse floral structures which did not contribute substantially to the boll.

Boll characters were marked by earliness and dry matter partitioning to the boll components was higher in MCU 5 than Suvin. Seed development was also intensive in this cultivar in terms of high DM partitioning towards seed coat and kernel development. MCU 5 mutant invested more of its DM on bur and seed and adequately increased number of seed per boll as a compensatory mechanism. Besides, a high seed coat/kernel ratio in the mutant pointed out uneven seed development leading to physiological impediments relating to fibre initiation.

Fibre weight and wall thickness were significantly higher in MCU 5, while fibre desiccation was rapid as compared to Suvin. More number of seeds in the boll sustained higher fibre density in this cultivar. Suvin however possessed low fibre density per seed per boll and had greater fibre elongation. Fibre length was positively related to moisture content whereas fibre weight had a positive association with the weights of boll and its components as well as seed number in most of the stages in both the cultivars.

RGR of fibre persistently increased at early boll age in both cultivars indicating rapid fibre growth when RGR of other boll constituents declined. MCU 5 mutant too perceived this pattern, apparently specifying rapid expansion of bur and seed in the absence of fibre.

Cellulose deposition in the lint of MCU 5 was higher than that of Suvin. Presence of more of amino acid content particularly glutamate and aspartate was indicative of their probable involvement in cellulose deposition. Further, high cellulose as well as oil content in MCU 5 pointed out the availability of enough sugar for their synthesis. Low cellulose and oil content in MCU 5 mutant was perhaps due to derailment in their synthetic mechanisms as evidenced from higher sugar accumulation.

In general, nitrogen accumulated progressively in the kernel. The presence of phosphorus in the genotypes could be inferred that it provides energy for fibre elongation in Suvin and perhaps for cellulose deposition in MCU 5. More of potassium content in the lint of MCU 5 was related to greater fibre weight. Secondary and trace elements tended to accumulate in the mutant due to the absence of fibre. Redistribution of minerals was recorded during boll development.

Number of fibre initials and their elongation were more in MCU 5 when observed one day post-anthesis producing greater evidence for the enhanced fibre weight per boll as well as

earliness for fibre characters. The reverse was true in Suvin and yet this cultivar significantly maintained greater elongation of fibre from 14 days after anthesis, ultimately leading to more fibre length at harvest. These events were found to be related to the activity of phytohormones. Judicious levels of auxins in MCU 5 led to substantial cellulose deposition in lint thereby increasing fibre weight per boll. High endogenous gibberellins in Suvin provided impetus for greater fibre elongation. The existence of high level of ABA and low activity of auxins and gibberellins led to the absence of fibre initiation in MCU 5 mutant. In addition to high ABA content, presence of higher oxidase enzyme activity perhaps has depleted the auxin content in the mutant.

Fibre quality parameters evaluated at harvest indicated that Suvin possessed superior fibre quality as compared to MCU 5. Greater span length in this cultivar reflected on higher gibberellin activity.

Suvin possessed the benefit of high moisture status in the boll and fibre as well as longer boll duration which led to optimum physiological conditions for fibre elongation. In MCU 5, the physiological processes relating to fibre development were accelerated under a shorter boll period.

Introduction

CHAPTER I

INTRODUCTION

Among the fibre crops, cotton is a highly productive cash crop and has central importance to mankind in view of its economic utility. It is endowed with natural and versatile seed fibres, the most sought after material for textile industry.

In India, cotton is a fibre crop of great importance cultivated in about 8 million hectares. The lint production is 7.8 million bales, which forms 9 per cent of the total world production. Though India ranks first in cotton area (25.3 per cent of the total world cotton area), the lint yield is only 167 kg per hectare (Anon., 1984).

The cotton industry assumes importance next to agriculture in providing ample employment opportunity for both urban and rural population. It has been reported that this industry employs 18.7 million people. Besides, another three million farm labourers receive full employment in the cultivation of this crop (Ramamoorthy, 1984).

Tamil Nadu in southern cotton zone has a cotton area of 3.5 lakh hectares with a production capacity of 4.2 lakh bales of lint. It is impressive to note that

out of 805 mills in India, 303 mills (37.6 per cent) are situated in Tamil Nadu (Anon., 1983). This clearly implies that cotton industry in this State is highly viable, but the lint production is comparatively lower to meet the ever increasing demand of the mills.

Over a period of 15 years, cotton production of the country has increased from 52.6 lakh bales to 82 lakh bales and lint yield from 114 to 167 kg per hectare. In the north, advent of new high yielding varieties like Bikaneri Nerma, H 777 and F.414 had reduced the acreage under desi cottons. The central cotton zone comprising of the States of Madhya Pradesh, Gujarat and Maharashtra provides 49 lakh hectares under cotton. The southern cotton zone is mostly rainfed, where the dominant variety is Laxmi. In Tamil Nadu, the predominant cotton variety is MCU 5. MCU 9, a cross between MCU 8 and MCU 5 released in 1978 has yet to show its impact in replacing MCU 5 (Basu, 1984).

These research gains have desirable effects on imports also. India imported 1081 thousand bales of cotton during the period 1974-79. From 1980 onwards, this recurring drain on foreign exchange for annual import had been stopped and India has now become an established exporter. It is estimated that in 1983-84 cotton export will touch 225 thousand

bales. However either in comparison to Egypt or to the average world production of quality fibre, India's share is very poor. It is a meagre 150 thousand bales as compared to 1603 thousand bales produced in Egypt or 10179 thousand bales of the world production (Anon., 1984). This implies the need for more attention on producing quality cotton.

Cotton belongs to the genus Gossypium of Malvaceae family which includes 20 cultivated and wild species (Hutchinson, 1947). Gossypium herbaceum L., G. arboreum L., G. hirsutum L. and G. barbadense L. are the four species commonly cultivated in different agroclimatic regions of our country. Added to these, there are several other cultivated species and numerous wild types. All of them provide flexible range of morphological and genetic variabilities with regard to fibre production.

Gossypium hirsutum which is predominant species under cultivation occupies about 50 per cent of the area followed by G. arboreum (29 per cent) and G. herbaceum (21 per cent). The area under G. barbadense is negligible and covers a few thousand hectares only (Santhanam, 1976). However at present the above picture has changed considerably and distribution of the species mentioned above is 43, 26, 9 and 17 per cent respectively. The coverage of 17 per cent under G. barbadense includes hybrids (Marayanan, 1982).

Cotton production in India was designed to meet the requirements of the textile industry during British era. With the introduction of Agricultural Departments in various Provinces and States in 1904, pure American cotton varieties were introduced and cross-breeding between desi and American cottons were attempted. With the passage of time, improvements in fibre quality and yield were aimed at in a phased manner.

The enactment of Indian Cotton Cess Act in 1923, the establishment of Indian Central Cotton Committee in 1921 and the setting up of the Cotton Technological Research Laboratory in 1924 gave the necessary impetus for research activities for cotton improvement. As a result of these measures, considerable change in the pattern of production was observed and this was reflected in the release of high yielding superior quality cotton cultivars and hybrids viz., MCU 5, Hybrid 4, Sujatha, Suvin, Varalaxmi, etc. only a few to mention. At present, about 100 cultivars are in vogue.

During 1970s more emphasis was laid on the production of long and extra long staple cotton. Currently, the country needs medium and super medium staple cotton to a large extent. This shift in production pattern in favour of a particular category of staple length was found to vary depending upon the immediate requirements of the mills. Hence the research

activities for increasing the productivity in addition to improving the quality of fibre through production-cum-protection oriented programmes to cater to the specific needs of the textile industry will have to continue.

Among the various priorities in research, physiology of fibre requires more attention in view of its regulatory role on yield and quality parameters. The fibre per se is a single cell structure arising from the epidermis of seed cotton (Hawkins and Serviss, 1930). The process of fibre formation involves prominent biochemical events involving growth regulating substances also. Among these events, the intricate bio-conversion of glucose to cellulose deposition (Anderson and Kerr, 1938). needs special mention. In vivo and in vitro studies had established specific IAA and GA mediated effects on the fibre growth (Beasley, 1973).

The quantity and quality of fibre are the most important criteria in technological investigations. These parameters are extensively investigated with particular emphasis on the textile technology. However, marginal and fragmentary information are alone available in the physiological attributes of fibre development which could not be fully utilized for the production of acceptable and desirable

strains. Hence, aspects of fibre physiology - its genesis and development - are to be elucidated by systematic investigations to understand the complex and diverse facets underlying.

In this regard, the employment of mutant types could contribute functional evidences for presence or absence of a chosen character. The genetic variations in cultivated species and mutant types therefore offer precious avenues for experimental purpose on fibre physiology. Besides, useful information on the ontogeny of seed and boll development concomitant with fibre growth will be of immense value. The accumulated information will also be useful to the cotton seed byproduct industries too.

Keeping these factors in mind, experiments were designed to obtain information on the following aspects:

1. Flowering behaviour of the genotypes in relation to environment.
2. Processes contributing to fibre development and their relationship with other boll components.
3. Biochemical and nutritional status of fibre and seed during the course of boll development.

4. The pattern of photosynthate distribution from subtending leaf to the boll through ^{14}C labelling and

5. Physical parameters connected with fibre quality characteristics.

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Physiological complexities involved in fibre genesis and subsequent development are unique phenomenon in fibre crops. Earlier work on fibre had comprehensive relevance to the textile technology with considerable biophysical approach. In more recent years, a shift in emphasis is towards the 'fibre developmental physiology' to bring out distinct characters contributing to quantity and quality of fibre. It is therefore expected that these characters will be useful to the breeder to screen varieties for fibre yield and quality improvement. On above lines of thinking, the literature pertaining to the proposed study are presented.

2.1. Flowering

It has been observed that flowers produced during first three fortnights of flowering period determined the yield potential (Ahlawat, 1979). The flowering efficiency also varied from 43 to 60 per cent (Goswami and Dayal, 1980). A comparison of cotton species clearly revealed that the rate of flowering was more slower for Gossypium barbadense than G. hirsutum (Kittook et al., 1981).

It was shown that MCU 5 did not flower under long days or long days with high temperature (Bhatt, 1977). In Suvin, a reduction of three hours sunshine delayed flowering resulting in reduction of seed and fibre yield (Bhatt and Nathan, 1977).

2.2. Boll development

Of the various developmental events in the physiology of cotton, boll development assumes greater importance. Following anthesis, boll growth has a clear set pattern relating to the phases of enlargement and maturation. It has been indicated that boll development varied only in its time scale (Evenson, 1960).

Beginning with fertilization, boll enlarged gradually and was set for maturation. Boll attained its full size in first half of its maturation period and began to crack 45 days after anthesis (Balls, 1915). It was reported that growing boll attained maximum size about 21 days after bloom (Martin et al., 1923; Leffler, 1976). The first two weeks in the life of boll were an 'intensive period' of development both in size and weight. In this period alone, more than 80 per cent of boll size and weight was formed (Kamel, 1951).

When the enlargement phase was completed, the boll began to mature. Three pronounced phases of boll maturation

were shown (Helmer and Samir Abdel-Al, 1965). Early bolls matured in 42.57 days whereas late ones in 44.55 days (Martin et al., 1923). However, a variation of 34 to 46 days for boll maturation was reported (Memon and Malik, 1970).

During boll development, the dry weight gain was slow following anthesis and then became linear (Eaton and Rigler, 1945). Contrary to this, boll moisture gradually declined and at boll cracking the level of moisture was about 12 per cent (Helmer and Samir Abdel-Al, 1965).

Boll dehiscence occurred about 48 to 50 days after flowering (Simpson, 1935; Brown, 1955), while a considerable variation in number of days for boll dehiscence has been shown as 30 to 50 days after anthesis (Saxena, 1962; Helmer and Samir Abdel-Al, 1965; Memon and Malik, 1970; Pundir, 1972).

Information on the 'ontogenetic relationship between boll and fibre' was not sufficiently available. It had been reported earlier that fibre wall thickening was completed when the bolls attained maturity (Hawkins and Serviss, 1930). In terms of chemical composition, it was shown that concentration of total sugars decreased with the attainment of maximum fibre length (Krieg et al., 1972). Dry weight accumulation of bur and fibre was studied in detail by

Leffler (1976). His findings showed that bur dry weight was maximum when fibre weight was 40 per cent. It was later emphasized that cotton fibre development synchronized with boll growth (Meinert and Delmer, 1977). Similarly, plotting fibre length and dry weight against boll age, four distinct stages of development viz., initiation, elongation, secondary thickening and maturation were recognized (Rama Rao et al., 1980).

2.3. Seed development

The developing seeds contribute necessary assimilate to the growing fibre.

An account of embryogenesis as a prelude to seed ontogeny is briefly considered. It was amply shown that endosperm was fully developed in 20 days old cotton ovules, whereas embryo enlargement began 25 to 30 days after anthesis (Leahy, 1948). The ovule reached its final size 18 to 20 days after fertilization (Tharp, 1965). Seed coat also simultaneously developed with significant histological changes along with seed ripening. The ovule has two integuments, both contributing to formation of seed coat (Pollock and Jensen, 1964) and mature seed coat consisted of seven distinct zones (Ramchandani et al., 1966).

Seed development was a continuous process beginning with anthesis and seed reached its maximum growth between

18 and 20 days after pollination (Balls, 1915) and seed surface area was more rapid from 10 to 18 days (Armstrong and Bennett, 1933). The seed attained full physiological maturity at boll dehiscence (Thiagarajan and Ramaswamy, 1979).

Seed moisture decreased with its maturation (Caskey and Gallup, 1931). Developmental studies indicated that seed moisture was highest during early stages of development and declined to a lower level at maturity (Ali and Ullah, 1963; Memon and Malik, 1970). It is interesting to note that the maximum seed weight reached at 80 per cent seed moisture level and half of the seed moisture occurred between 40 and 45 days after anthesis (Delouche, 1973).

Seed dry weight began to increase one week after flowering (Ali and Ullah, 1963). It has been demonstrated that seed weight increased rapidly up to 45 to 52 days and the maximum weight was attained between 57 and 59 days (Pandey, 1972). An intensive accumulation of seed DM was noticed up to 15 days after anthesis (Shafi-zade, 1975). The study of DM distribution indicated that the capacity of seeds to accumulate dry matter continued for a period of six weeks (Leffler, 1976).

Very little information on 'seed-fibre relationship' is available. It had been shown that fibres ceased to elongate

in unfertilized ovules (Hawkins and Serviss, 1930). This clearly demonstrated the importance of fertilized ovule for fibre elongation. However, evidences are available which showed that fibre continued to elongate for few days without fertilization (Quintanilha et al., 1962). Investigations on cotton seed development revealed that fibre weight accumulation reflected seed weight accumulation and fibre dry weight per seed increased linearly between 10 and 42 days after flowering (Leffler, 1976).

2.4. Fibre development

Fibre development within the boll enclosure involved the following phases:

Initiation

Elongation

Secondary thickening and

Maturation

These phases were flexible and freely overlapped during the course of fibre ontogeny (Rama Rao et al., 1980).

2.4.1. Fibre initiation

Pollination is an important step in the process of fibre initiation (Harrison, 1931). With this event, fibres were initiated with significant histological changes on the

epidermal layers of cotton seed. Each cotton fibre originated as an outgrowth from a single epidermal cell of seed coat, soon after anthesis irrespective of fertilization (Hawkins and Serviss, 1930). During active fibre initiation, large number of dividing cells of epidermal layer was noticed (Farr, 1931). The formation of fibre had a slight swelling of the outer wall of epidermal cells at anthesis. The swelling elongated rapidly and on the day after flowering produced delicate tubular outgrowth, which formed young fibre cells (Anderson and Kerr, 1938). Electron microscopic studies revealed that fibre initiation began 8 hours before anthesis (Ramsey, 1973) and there were fibrillar components one day after anthesis (Ramsey and Berlin, 1976).

2.4.2. Fibre elongation

Fibre elongation following genesis is a crucial phase in the sequential process of fibre development. The elongation period varied from 12 to 30 days (Hawkins and Serviss, 1930; Anderson and Kerr, 1938). It was shown that the growth curve of the elongating fibre was sigmoid (Morris, 1962). Elongation ceased at 27 days after anthesis (Schubert et al., 1973, 1975; Benedict et al., 1973). There seem to be differences among Gossypium species and cultivars in their capacity for fibre elongation (Beasley, 1979; Basra and Malik, 1983a, 1983b).

2.4.3. Secondary wall thickening

As the rate of fibre elongation diminished, the rate of dry weight accumulation in the secondary wall increased. The thickening phase provided most of the properties essential for quality fibre. The most distinctive feature was cellulose deposition (Anderson and Kerr, 1938). In a time trend study, it had been shown that secondary wall thickening occurred between 25-30 and 50 days after anthesis (O'Kelley and Carr, 1953). Temporary reduction in fibre elongation with the onset of cellulose was also observed (Morris, 1962). However, considerable overlapping between elongation and secondary wall thickening was reported (Beasley, 1979; Naithani et al., 1982).

2.4.4. Fibre maturity

Maturity of cotton fibre indicated the nature of wall thickening in relation to its diameter. The presence of boll components also determined fibre maturity (Anon., 1980). Literature pertaining to this aspect is limited.

In addition to these phases of fibre development, the post-maturation phase following boll dehiscence has commercial importance. This phase was characterized by greater dehydration with significant drop in boll fresh weight (Leffler, 1976). The chemical analyses of seed and fibre were extensively made at this stage alone as this stage provides the harvestable product of greater economic value.

2.4.5. Fibre weight and length characteristics

Fibre development in terms of weight and length was temperature insensitive (Cipson and Joham, 1969). It has been reported that fibre growth occurred uniformly throughout the fibre length (Willison and Brown, 1977) and solely by tip growth (Meinert and Delmer, 1977).

Total length of fibre, a product of the rate of elongation per day and the total period of elongation, was genetically controlled (Naithani et al., 1982). Similarly, during the process of evolution, Gossypium hirsutum was accompanied by a slight reduction in fibre length and in Gossypium barbadense there was considerable increase in fibre length (Popova et al., 1979a).

2.5. Biochemical investigations and nutritional status

2.5.1. Sugars utilization

Metabolic status of the developing boll is required to be conducive for utilization of sugars for cellulose bio-conversion. Earlier studies revealed the relationship between sugar content and fibre length and cellulose deposition (Balls, 1919). In a comparative analysis of linted and lintless genotypes, sucrose, galactose and dextrose were found throughout fibre development (Santhanam and Sharda, 1962). Their classic experiments proved that there was greater accumulation of sucrose

in the lintless genotype. Accumulation of glucose, fructose and sucrose in the developing boll was also reported (Conner et al., 1972). Inter-conversion of these sugars was important in cellulose synthesis. Likewise, maximum fibre length was related to utilization of total sugars (Krieg et al., 1972).

The cellulose moiety consisted of β -1,4 linked D-glucosyl residues (Barber and Hassid, 1965) and GDP-glucose served as a precursor for primary wall cellulose (Delmer et al., 1974).

It has been suggested that the turnover rate of sucrose to supply glucose and fructose was the limiting step in fibre development (Singh and Singh, 1979). In labelled experiments, it was shown that sucrose was the best precursor for fibre (Pillonel et al., 1980). Based on these findings, it was concluded that inter-conversion and utilization of sugars towards cellulose synthesis is an important step in fibre formation (Singh et al., 1981).

2.5.2. Total phenolics content

Among the phenolics, monophenolics acted as IAA oxidase co-factors, whereas C-diphenolics were inhibitors (Cortner and Kent, 1953). The study of IAA oxidase distribution and inhibitors in cotton showed that an inhibitor system (phenolics) regulated IAA oxidase activity (Morgan, 1964). In this context

it is pertinent to indicate that phenolics were in abundance in plants only next to carbohydrate (Pridham, 1965). In relation to fibre, active involvement of phenol compounds in the growth process of fibre was known (Polesika, 1972). During fibre formation, a growth stimulating phenol compound was detected in ovules but was absent in genetically fuzzless types (Popova et al., 1979b). However, specific role of phenolic compounds in relation to fibre development was not well established.

2.5.3. Amino acid composition

There was marked variation in the amino acid composition of developing cotton seed (Elmore and Leffler, 1976). Irrespective of these changes in amino acid pattern, involvement of specific amino acids in cellulose biosynthesis had been indicated (Santhanam and Bhardwaj, 1962). The authors suggested glutamic activity as a key intermediate in cellulose deposition. However, no significant changes in cell wall amino acid composition was observed during fibre development (Meinert and Delmer, 1977). The presence of amino acids in developing boll provided evidence that the incorporation of glucose into cellulose was maintained at a higher level by soluble amino acids (King and Leffler, 1979).

2.5.4. Hormonal regulations

Phytohormones involvement in fibre development has been reported by Mitchell et al. (1967). Besides, in vitro studies of

unfertilized ovules with exogenous application of hormones also indicated hormonal regulation of fibre growth (Beasley, 1973; Birnbaum et al., 1974).

The preponderance of evidence showed the presence of auxins and gibberellins in the elongation and cellulose deposition of fibre (Beasley, 1971; Beasley and Ting, 1973). Later, it was shown that these phytohormones induced a marked stimulation of fibre production (Singh and Singh, 1975). Distinguishing the activities of auxins and gibberellins in relation to fibre growth, it was suggested with experimental evidence that IAA induced fibre growth while GA mainly promoted ovule growth (Dhindsa, 1973). It was further shown that genotypic differences in fibre length were related to the endogenous levels of gibberellins present in seeds (Bhardwaj and Lad, 1977).

Isolation of factors responsible for the abscission of young cotton fruit led to the identification of abscisic acid (Ohkuma et al., 1963). This identity later established various hypotheses on ABA activity. Dure's model for cotton embryo growth postulated that ABA was synthesized in ovule and transported to the embryo (Dure, 1975). This was supported by the presence of high amount of inhibitors particularly ABA during later developmental phase of fruits and seeds (Abdel-Rahman et al., 1975). However, ABA activity in relation to fibre development is little understood. Available findings indicate that ABA was

not needed for initiating fibre development in fertilised ovule (Singh and Singh, 1975). In vitro studies confirmed that ABA inhibited fibre growth (Dhindsa et al., 1976).

2.5.5. Enzyme systems

Considerable efforts were made to study enzyme systems connected with cellulose synthesis (Elbein et al., 1964; Pinsky and Ordin, 1969; Heiniger and Delmer, 1977). The occurrence of the enzyme was not clearly established.

The physiological significance of IAA oxidase has been shown by Galston and Dalberg (1954). In cotton ovule culture, the function of IAA oxidase in relation to auxin levels was suggested (Morgan, 1964). Changes in IAA oxidase and peroxidase activity showed that IAA catabolism was low during fibre elongation, while it was very high during secondary wall deposition (Jasdanwala et al., 1977). Peroxidase activity was located in the ovary wall (Wise and Morrison, 1971) and distinct variations between cytoplasmic and wall peroxidase activities during fibre formation were recorded (Rama Rao et al., 1982).

2.5.6. Cellulose synthesis

Cellulose synthesis and deposition in developing cotton fibre merit detailed consideration. Cotton hair cells are epidermal in origin with full of cellulose (Fryxell, 1963). It was suggested that synthesis of primary wall cellulose may be

a qualitatively different event from that occurring in secondary wall cellulose deposition during fibre development (Marx-Figini, 1966). Synthesis of cellulose from glucose precursor has been amply shown. The precursor was found to be GDP glucose for primary wall cellulose (Delmer et al., 1974) and involved UDP glucose in secondary wall cellulose deposition (Greathouse, 1953; Franz and Meier, 1969).

Cellulose deposition reached its maximum rate at 21 days after anthesis (Anderson and Kerr, 1938). This occurred uniformly along the length of fibre in daily rings (O'Kelley, 1953). High cellulose deposition at secondary wall formation was also reported by Marx-Figini (1966). It had been proved that the actual amount of cellulose in primary walls of elongating fibre was a constant value (Beasley, 1979). In terms of energy utilisation, the cellulose synthesis in cotton seed fibre required adequate supply of 'high energy phosphates' (Tarchevskii et al., 1980).

2.5.7. Nutrient levels

Nitrogen is supplied to the developing seeds in reduced form (Radin and Sell, 1975). Evidences strongly indicate that major form of nitrogen transported into the seed is asparagine and total nitrogen into the seed increased throughout development (Elmore and Leffler, 1976). Experiments with cotton ovule

culture adequately showed that ammonium ions were essential for ovule growth (Stewart and Hsu, 1977).

If sufficient phosphorus nutrition to the boll is available, it is used for seed development. Phosphorus was mostly accumulated in the form of phytin (Ergle and Guinn, 1959). Low phosphorus levels affected fibre development due to limitations in the availability of energy phosphorus (Tarcherski et al., 1980).

Potassium availability is closely associated with seed development and strongly influenced the quality parameters. It was shown that potassium addition increased mean fibre length and uniformity (Bennett et al., 1967). The importance of potassium to ovule and fibre growth has been indicated through in vitro studies (Beasley et al., 1974). Potassium acted as a counter ion for malate in the elongating fibre (Dhindsa et al., 1975). It was also suggested that favourable water status of boll was maintained by high potassium content (Leffler and Tubertini, 1976). Recently, it was reported that a high level of potassium was maintained during fibre elongation (Basra and Malik, 1982).

Information on the specific effects of other elements in fibre development was generally lacking. The effects of added elements on fibre quality were however reported. Calcium did not change fibre length or uniformity (Sabino, 1965).

Zinc had no effect on fibre, whereas manganese and iron decreased fibre length (Anter et al., 1976a, 1976 b).

2.5.8. Protein status

A close relationship between protein and seed weight had been reported (Grindley, 1950). It was noticed that protein gradually translocated from the fruit coat to the seed coat and then to the embryo, with high accumulation in the radicle (Pashchenko, 1957) and ultimately protein accumulated at an even rate in the cotton seed (El-Nockrashy et al., 1976). In relation to fibre development, a sharp decline in protein content with the onset of secondary wall deposition was evident (Delmer, 1977).

2.5.9. Oil content

Seed oil decreased with the depletion of carbohydrate reserve of the plants (Wadleigh, 1944) indicating the regulatory function of carbohydrate pool on seed oil content. Oil accumulation was independent as far as genetic constitution was concerned (Pope and Ware, 1945). Comparative studies on linted and lintless seeds revealed that oil content varied markedly between them (Christidis and Harrison, 1955). It was shown that oil deposition in cotton embryos occurred mostly between 25 and 42 days after fertilization (Tharp, 1965).

The weight of oil per seed began to increase one week after anthesis (Ali and Ullah, 1963) while relatively small

amount of oil formation was found during early stages of boll development (Memon and Malik, 1969). There is a positive correlation between seed weight and oil content; high seed weight was generally associated with high oil content (Pandey, 1972).

2.6. Photosynthetic efficiency

Cotton being indeterminate in habitat, bolls are set continuously and the developing bolls extensively demand assimilates. For this purpose, the sink should have sufficient development (Johnson and Addicott, 1967). Nutritional balance theory of shedding by Mason (1922) established a close relationship between carbohydrate production and the number of bolls remained.

Primary sources of photosynthate for developing fruit forms in cotton is the subtending leaf with small contribution from bracts (Ashley, 1972; Elmore, 1973; Brown, 1973). Five to ten per cent contribution of the bracts to the carbon balance of bolls was recorded (Benedict and Kohel, 1975; Constable and Rawson, 1980b). However, shading experiments showed that both bracts and boll wall contributed to the growth of fibres (Morris, 1965).

The maximal rate of photosynthate utilisation occurred when bolls were 8 to 10 days of age (Benedict et al., 1973) and

bolls however had competition for photosynthates (Leffler, 1976). Peak photosynthesis of about 110 mg CO₂ per hour was recorded 13-15 days after leaf unfolding (Constable and Rawson, 1980a). Significant correlation between carbon uptake and SIW in cotton has been recently reported (Kerby et al., 1980).

2.7. ¹⁴C investigations

¹⁴C labelled experiments revealed the contribution of assimilates from bracts and subtending leaves to the developing bolls. The contribution from the boll wall was negligible (Brown, 1968). The importance of subtending leaf as the assimilate source for boll development was demonstrated by Ashley (1972). Maximum incorporation of ¹⁴C assimilates in the developing boll walls and fibre was found to occur at 8 to 10 days and 23 to 40 days after anthesis respectively (Benedict et al., 1973). The percentage export of ¹⁴C was found to increase with leaf age (Constable and Rawson, 1982). Evidence indicated that 57 to 67 per cent of the total radioactivity in ovules was found in glucose (Benedict et al., 1976).

It emerges out convincingly from labelled experiments the importance of assimilate contribution of the subtending leaf with little contribution from boll wall and bracts towards sink development.

2.8. Seed and fibre yield and their relationship

The retention of bolls and seed cotton yield were dependent on vegetative and reproductive function of the plant (Katarki and Bhavikatti, 1971). Considering the reproductive function of the plant in relation to yield potential, it was shown that boll number had a positive association with seed index (Butany *et al.*, 1966; Bala Kotaiah and Butany, 1971). Although an increase in the number of seeds per boll is indicative of sink strength of the fruit, the relationship is not clearly known. However, a positive association of seed and lint yield was reported (Miller and Rawlings, 1967). Evidences adequately indicated a close relationship between lint yield and lint percentage (Al -Jibouri *et al.*, 1958; Meredith and Bridge, 1971), but a minor influence of lint percentage, boll and seed size on lint yield had also been reported (Ramey, 1972; Ramey and Worley, 1973).

Among all the yield characters, it was recognised that bolls were the major component contributing to lint yield (Stroman, 1930; Manning, 1956; Harrell and Culp, 1976). Obviously high lint percentage has been considered as an important selection criterion by the cotton breeders in their attempts to achieve higher yield.

2.9. Fibre quality characteristics

Considering the response to applied nutrients on the fibre quality, it was shown that phosphorus and nitrogen had

no significant effect on fibre properties (Nelson, 1949; Shalaby et al., 1977). However, increase of fibre length and fineness resulted from nitrogen (Crowther, 1934; Koli and Morrill, 1976). Potassium increased fibre length (Nelson, 1949; Bennett et al., 1965). Fibre quality response to varying levels of micro nutrients was reported earlier. Iron and copper decreased fibre maturity; manganese, molybdenum and boron tended to increase fibre strength. Boron however decreased fibre length (Anter et al., 1976a, 1976b, 1978). Among the biochemical parameters, oil per cent was positively correlated to fibre fineness (Turner et al., 1976).

In cotton improvement programmes, it is important to understand the relationship between yield and fibre characteristics. Boll and seed traits were related to fibre length, whereas seed-cotton weight and boll number showed negative or low association with fibre length (Hodson, 1920; Dunlavy, 1923; Bala Kotaiah and Butany, 1971). Similarly, genotypic correlation between fibre yield and quality traits were generally negative. Fibre length and strength were negatively correlated with yield (Miller et al., 1958; Al -Jibouri et al., 1958; Fotiadis and Miller, 1973; Scholl and Miller, 1976).

Materials and Methods

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The present investigations were directed towards understanding the physiology of fibre development in two elite cotton cultivars. A lintless mutant was maintained as a 'check'. The study was conducted at the Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore during 1982-84. The investigations were carried out in three separate experiments. Methodologies adopted in field, pot culture and laboratory investigations are briefly presented.

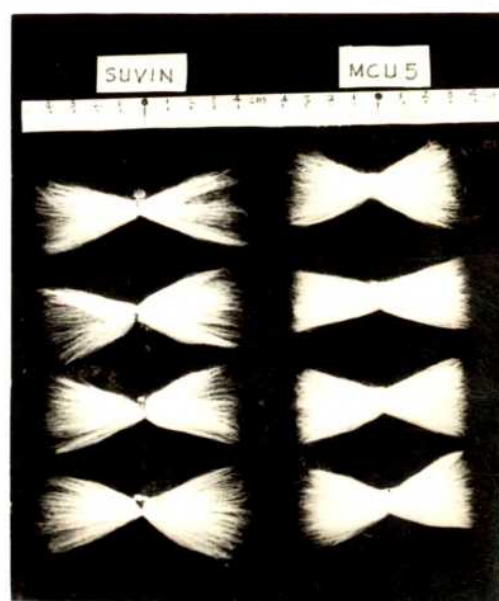
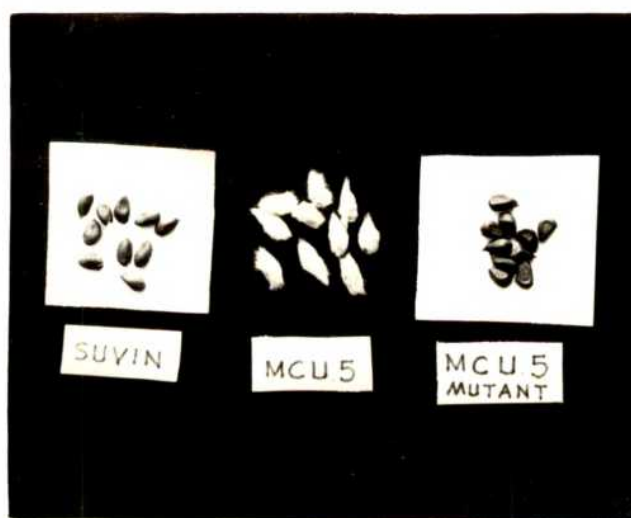
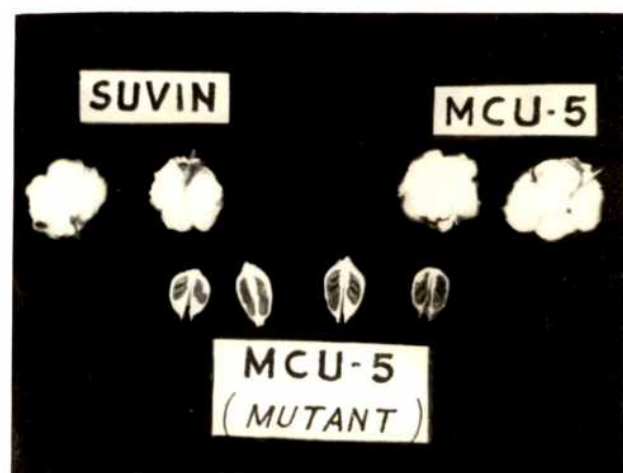
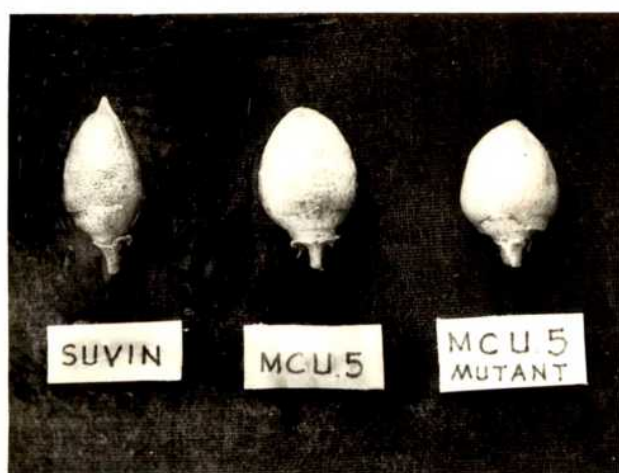
3.1. Materials3.1.1. Selection of experimental materials

The particulars on genotypic variations of Suvin, MCU 5 and MCU 5 mutant selected for the study are given in Table 1 and Plate 1.

Table 1. Particulars on genotypic variations of Suvin, MCU 5 and MCU 5 mutant

Genotype	Parentage	Duration	Fibre characters	Mean staple length (mm)
Suvin (<u>Gossypium</u> <u>barbadense</u> L)	Selection from a cross between Sujatha and Sea Island St. Vincent	180-200	Linted	35
MCU 5 (<u>G.hirsutum</u> L)	Developed from a cross involving Sea Island 542, MCU 1, MCU 2 and Gatooma	160-180	Fuzzy, linted	29
Mutant	Genetic mutant of MCU 5	160-180	Lintless	-

PLATE 1 : Showing plant and boll characteristics
of Suvin, MCU 5 and MCU 5 mutant



Other morphological characters are given in Table 2.

Table 2. Morphological characters of Suvin, MCU 5 and MCU 5 mutant at peak flowering stage*

Characters	Suvin	MCU 5	MCU 5 mutant
Plant height (cm)	52.1	65.6	72.0
Number of leaves/plant	71.5	103.9	130.7
Leaf area (sq.cm)/plant	3502.81	5217.53	6842.34

*Determined during summer season of 1983

The seeds were received from the Professor of Agricultural Botany (Cotton), School of Genetics, Tamil Nadu Agricultural University, Coimbatore.

3.1.2. Field studies

The cotton cultivars and mutant genotype were raised under field conditions. Field particulars are given below:

Location : Eastern Block, Central Farm,
Tamil Nadu Agricultural University

Experimental plot size : 24.38 sq.m. (6.50 x 3.75 m)

Spacing : Inter row spacing 75 cm
Intra row spacing 60 cm

Manuring	: Basal application of farm yard manure at the rate of 25 tonnes per hectare
Fertilizers	: 60:60:60 of NPK (kg per ha) as basal dose and 60 kg N per ha as top dressing
Design of experiment	: Randomised Block Design
Replications	: Eight

During the course of field studies, adequate crop protection, irrigation and other package of practices were followed.

3.1.2.1. Experiment I

The crop was sown in field on 18.2.1983 during summer to study the distinct physiological traits on flowering and development of boll and its components. Sampling details are given separately under the sub heading 3.1.4. From anthesis onwards, bur (fruit coat), seed and fibre in the developing boll were collected at an interval of 7 days and sampled for the determination of fresh and dry weights, moisture, seed number and fibre length. Relative growth rate of boll and its components were also determined. Totaly 840 samples were collected on 7 occasions till boll dehiscence.

3.1.2.2. Experiment II

Suvin, MCU 5 and MCU 5 mutant were sown on 15.8.1983. The hormonal, nutritional and chemical events associated with

fibre development in relation to lintless character in chosen stages viz., anthesis, fibre elongation, secondary thickening, maturation and post-maturation were determined. The physiological parameters on seed and fibre i.e., fresh weight, dry weight, moisture status, seed number, dry weight of seed coat and kernel, seed coat/kernel ratio and fibre length were also recorded at all these stages.

3.1.3. Experiment III - Pot culture studies

Besides the field experiments, a separate pot culture study employing the same cotton cultivars and mutant was conducted to investigate the pattern of distribution of labelled ^{14}C sucrose in boll components at fibre elongation phase.

For this purpose, full size mud pots (45 cm dia) were filled with a pot mixture of soil, farm yard manure and sand (5:1:1). Nitrogen, phosphorus and potassium as urea, super phosphate and muriate of potash were added in the ratio of 60:60:60 kg/ha on the basis of one million kilogram soil equivalent per hectare. Three seeds were sown in each pot on 15.8.1983. When the seedlings attained 20 days of age, only one healthy seedling was maintained in each pot for the study. The experiment was conducted at the Isotope laboratory.

3.1.4. Tagging of flowers, boll sampling and determination of sampling stages

During the course of experimentation (I and II) enough flowers at peak flowering phase were tagged daily with gem labels. The date of anthesis was noted on each tagged label and was considered as zero period of observation. At sampling, healthy and uniform bolls developed on the tagged flowers were collected from each plot replicationwise in all the genotypes. Five bolls collected at random from the replication lot formed the sampling unit for each replication for the determination of various physiological parameters. The sampling was done at seven days interval from anthesis onwards upto 42 days of boll age in experiment I.

In experiment II, the bolls were collected for chemical, hormonal and nutritional investigations in chosen fibre developmental stages only. This was done based on the periodical collection of bolls from tagged flowers in each cotton type and determining physiological and developmental characters of the fibre as well as seed from a field experiment conducted in a crop sown on 15th August 1982. Five developmental stages were selected for the study in the two cultivars, based on fibre growth from initiation to post-maturation period following dehiscence. The chosen boll age in MCU 5 was considered for sampling and analysis in MCU 5 mutant. The post-maturation stage was included

in the study due to the commercial importance of harvestable seed and fibre. Following stages were fixed for detailed chemical, hormonal and nutritional investigations.

Stages	Days after anthesis	
	Suvin	MCU 5
S ₁ Anthesis	0	0
S ₂ Fibre elongation	0 - 21	0 - 21
S ₃ Secondary thickening	21 - 35	21 - 35
S ₄ Maturation	35 - 49	35 - 42
S ₅ Post-maturation	< 49	< 42

3.2. Methods

3.2.1. Physiological analyses of boll development

3.2.1.1. Flowering behaviour

Ten plants were marked out for each cotton type replicationwise and the number of flowers formed on each day was recorded and continued upto cessation. Flower production per week was calculated for studying the flowering behaviour.

3.2.1.1.1. Accumulated degree-days and heliothermal units at flowering

The maximum and minimum temperature (°C) and sunshine (hr) during peak and total flowering periods were collected and the accumulated degree-days and heliothermal units for these periods were worked out:

Degree-days (Iwata, 1975)

$$\frac{(\text{Maximum temperature} + \text{Minimum temperature})}{2} - \text{Base temperature}$$

(Base temp. 15°C Ustimenko
Bakumovsky, 1983)

Heliothermal units (Sastri and Chakravarty, 1982)

Degree-days x Number of bright sunshine hours

3.2.1.2. Determination of change in boll components

Uniform bolls were selected from the sample lots in eight replications, five bolls in each replication at each stage of boll development. The bolls were immediately separated into different boll fractions - bur, seed and fibre, weighed and dried in an oven at 105°C. After complete drying they were re-weighed to determine the moisture and dry matter content.

3.2.1.3. Determination of relative growth rate (RGR)

Using the RGR formula (Williams, 1946), Relative Growth Rate of boll, bur, seed and fibre were calculated and expressed in $\text{g g}^{-1} \text{ day}^{-1}$.

$$RGR = \frac{(\log_e W_2 - \log_e W_1)}{(T_2 - T_1)}$$

where,

W_1 and W_2 = Dry weight of boll, bur seed and fibre at T_1 and T_2 respectively

T_1 and T_2 = Time in days

3.2.1.4. Measurement of fibre length

The length of fibre for each cultivar was determined at all the developmental stages, excepting anthesis following the method of Gipson and Ray (1969). A locule from the selected boll was dropped in boiling distilled water. For 20 days and older bolls, four drops of concentrated Hcl per 100 ml of water were added for easy separation of seeds. Ten seeds from each boll were collected for length measurement. Each seed was placed on the convex side of a watch glass and the fibres were streamed out with a jet of water. The length of the fibre was measured from the rounded side of the seed adjacent to the chalazal end.

3.2.1.5. Number of seeds per boll, dry weight of seed coat and kernel and seed coat/kernel ratio

The total number of seeds from five individual bolls per replication were recorded at chosen boll age and mean number per boll was presented.

The seed coat and kernel were carefully separated from 10 seeds picked at random from each replication at each specified stage, except anthesis. The dry weight of seed coat and kernel of 100 seeds were calculated. The seed coat/kernel ratio was arrived at by dividing the seed coat weight by kernel weight.

3.2.2. Histological investigations

Boll samples were collected at 24 hr post-anthesis in Survin MCU 5 and MCU 5 mutant. The bolls were fixed in formalin -acetic acid-alcohol (FAA) (5 ml of 40 per cent formaldehyde, 5 ml of glacial acetic acid and 90 ml of 50 per cent alcohol). After embedding in paraffin wax, 10 μ sections were taken with a rotary microtome. The sections were fixed on slide with Haupt's gelatin fixative and stained with iron-alum Hematoxylin following the procedure of Brooks *et al.* (1966). The number, length and width of fibre initials were measured at random under microscope. Photomicrographs were taken to depict the variations on fibre initials in Survin and MCU 5 as well as ovule of MCU 5 mutant.

3.2.3. Chemical, hormonal and nutritional investigations

In the developing boll, the seed coat, kernel and fibre were separated for each specified boll age, except anthesis. At anthesis, the ovule was used for chemical analyses. The analytical methods rarely used are alone given in detail.

For fresh analysis, one g sample was extracted with 80 per cent boiling ethanol (Jayapal and Mahadevan, 1963). From this extract, suitable aliquot was drawn for the following estimations. The mean value of two independent determinations were expressed as mg g^{-1} fresh weight/ $\mu\text{g g}^{-1}$ fresh weight.

3.2.3.1. Reducing sugar content

Reducing sugars were estimated by the method of Somogyi (1952) and expressed as glucose equivalents.

3.2.3.2. Total phenolics

Total phenolics were estimated by employing Folin-ciocalteu reagent (Bray and Thorpe, 1954).

3.2.3.3. Free amino acids

The ninhydrin method of Moore and Stein (1948) was adopted. The amount of free amino acids were expressed as leucine equivalents.

3.2.3.4. Paper chromatographic separation of amino acids

Whatman No. 1 filter paper spotted with 100 μl of the sample was rolled into a cylinder held together by a string. This was made to stand up on wide petri dishes placed on the bottom of chromatography chamber. By this way eight samples were simultaneously run in one chamber. The method proposed

by Block et al. (1958) was followed for the separation of amino acids and the method described by Demetriades (1956) was adopted for the quantitative estimation.

3.2.3.5. Extraction and identification of growth regulating substances

The bolls belonging to each developmental stage were split open with a sharp knife. The ovules (anthesis stage) and seed-cotton (rest of the stages) formed the sample for the cultivars, while the ovules/seeds were used for the extraction of growth regulating substances in MCU 5 mutant. The method proposed by Abdel-Rahman et al. (1975) was adopted.

Flow chart for the extraction and purification of growth substances

20 g sample

Extracted with cold methanol at 3°C;
and filtered

Filtrate reduced to a small
aqueous volume in vacuo at 40°C

Added absolute ethanol to precipitate
insoluble substances, filtered

Filtrate reduced to
a small volume

pH adjusted to 2.5 with 5 per cent HCl
partitioned four times with ethyl
acetate

Final ethyl acetate
fraction

Reduced to dryness and
re-dissolved in 1 ml methanol
for chromatographic separation

Chromatographic separation: Aliquots equivalent to 10 g fresh weight of the methanolic solutions were strip-loaded on No.3 Whatman chromatography grade paper. Chromatograms were developed by the descending method at 24°C. The solvent used was 10:1:1 (v:v) mixture of iso-propanol, ammonia and water and the chromatogram was stored in freezer. The paper was cut into equal bits each representing Rf zone 0.1 to 1.0 and used for bioassay after elution.

Bioassay methods

Wheat coleoptile straight growth test for auxin:

The method described by Mitchell and Livingston (1968) was followed employing wheat seeds (Triticum vulgare L.) var. Kalyan Sona.

The quantity of auxin calculated from the bioassay response was presented as IAA equivalent $\mu\text{g g}^{-1}$ fresh weight.

Rice second leaf sheath bioassay for gibberellins:

The method of Murakami (1959) was followed. The results were expressed as GA₃ equivalent $\mu\text{g g}^{-1}$ fresh weight.

Mustard seed germination bioassay for inhibitors:

The mustard seed germination bioassay test as described by Eidelnant et al. (1980) was adopted. The results were expressed as ABA equivalent $\mu\text{g g}^{-1}$ fresh weight.

3.2.3.6. IAA oxidase activity

The assay mixture consisted of 1 ml IAA solution containing 0.5 mM MnCl_2 , 0.25 ml of 0.1 mM 2,4 dichlorophenol and 3.5 ml of 0.05 M phosphate buffer, pH 7.5 and 1 ml of enzyme extract. It was incubated at 30°C for one hour in the dark. After incubation, two ml of the above reaction mixture was taken and 2 ml of Salkowski's reagent was added and incubated for 30 minutes. The optical density was recorded at 530 nm. The enzyme activity was expressed in terms of μg IAA oxidised per mg protein per hour (Malik and Singh, 1980).

3.2.3.7. Peroxidase activity

The method of Perur (1962) was followed. The results were presented as changes in optical density per 10 minutes.

3.2.3.8. Cellulose (Updegraff, 1969)

A quantity of 5 ml of acetic-nitric reagent (150 ml of 80 per cent glacial acetic acid was mixed with 15 ml of concentrated nitric acid) was added to a known quantity of sample in a test tube and mixed well. The tube was placed over a water bath at 100°C for 30 minutes. The contents were centrifuged at $2,100 \times g$ for 15 minutes and the supernatant was discarded. After washing the residue with distilled water, 10 ml of 67 per cent sulphuric acid was added, mixed well and

allowed to stand for one hour. One ml from this solution was diluted to 10 ml with distilled water. To 1 ml of the diluted sample taken in a test tube, 4 ml of distilled water and 10 ml of anthrone reagent were added and mixed well. Again the tubes were kept over a boiling water bath for 15 minutes, cooled and the optical density was read at 620 nm. The cellulose content was calculated from a standard curve prepared with pure cellulose.

3.2.3.9. Total nitrogen

Total nitrogen was estimated by the microkjeldahl method of Humphries (1956). The results are expressed in percentage.

3.2.3.10. Estimation of total phosphorus, potassium and calcium

These elements were determined from suitable aliquot drawn from the triple acid extract (500 mg sample digested with 2:9:1 mixture of concentrated sulphuric acid, nitric acid and perchloric acid).

Total phosphorus was estimated by the method described by Jackson (1962).

Potassium was determined in type 121 systronics Flame Photometer.

Calcium was estimated by Varsanate titration method (Sankaram, 1966).

The results of two independent determinations are expressed as percentage.

3.2.3.11. Estimation of zinc, iron and manganese

The above micronutrients were estimated in the triple acid extract of respective samples in Atomic Absorption Spectrophotometer Model AA 5 varian Techtron and values expressed in ppm.

3.2.3.12. Total protein

Total protein was estimated following the method of Lowry et al. (1951) and expressed in percentage.

3.2.3.13. Oil content

Soxhlet Extraction Method (A.O.A.C., 1960) was followed. The data are expressed in percentage.

3.2.4. Subtending leaf physiology

3.2.4.1. Specific leaf area (SLA)

By using the leaf area (determined in the photosensitive automatic portable area meter model LI 3000) and leaf dry weight, SLA at anthesis was calculated and expressed in $\text{cm}^2 \text{g}^{-1}$.

$$SLA = \frac{\text{Leaf area}}{\text{Leaf dry weight}}$$

3.2.4.2. Specific leaf weight (SLW)

Using leaf dry weight and leaf area, SLW at anthesis was calculated and expressed as mg cm^{-2} (Pearce et al., 1968).

$$SLW = \frac{\text{Leaf dry weight}}{\text{Leaf area}}$$

3.2.4.3. Photosynthetic rate

Photosynthetic rate of boll bearing sympodial subtending leaf at six stages in 7 days interval from anthesis onwards was measured in an Infra-Red Gas Analyser (IRGA) Model 225-2B-S⁹ Gas analyser, Hoddesdon, England employing differential technique.

The instrument was allowed to warm up. Initial adjustments made and set to read CO_2 concentration approximately at 300 ppm. The leaves were excised under water and placed inside a plexiglass chamber with a replaceable top which was connected to the instrument. The top of the chamber was tightly closed. The leaves were oriented towards an artificial light source to ensure incident light intensities greater than 8000 F.C. Change in the concentration of CO_2 inside the chamber was noted over a period of time (15 minutes) and the photosynthetic rate was calculated and expressed as $\text{mg CO}_2 \text{ dm}^{-2} \text{ h}^{-1}$ using the following formula:

$$FCO_2 = \frac{CaV}{tA}$$

where,

- Ca = Change in CO₂ concentration
over time interval of 't'
- V = Volume of the system
- t = Length of interval over which CO₂
concentration changes are recorded
- A = Area

3.2.5. ¹⁴C sucrose labelling and assay

In the pot culture experiment, 20 days old bolls during the peak flowering phase in both the cultivars and mutant were selected for the study. The sympodial leaf subtending the developing boll was treated with 0.01 ml aqueous solution of labelled ¹⁴C sucrose (0.10 microcurie at high specific activity). The isotope was applied as 5 mm diameter spot in the middle of the upper surface of the lamina.

The bolls were harvested 20 hours after the treatment. The subtending leaf, bur, seed coat, kernel and fibre were separately sampled. Ethyl alcohol and hydrochloric acid extractions of the sample were made as proposed by Bhatt (1976). One g sample was first extracted with 80 per cent ethyl alcohol and the residue was treated with 2N HCl in boiling water bath for 2.5 hours. The acid hydrolysate was neutralised with 2N NaOH.

The radioactive assay was determined in a liquid scintillation system model LSS 20 of ECIL.

3.2.6. Fibre quality characteristics

The fibre properties at harvest via., staple length, uniformity ratio, fineness, maturity coefficient and strength in the two cultivars were determined in the Cotton Technological Laboratory (ICAR) as per the standard procedure.

3.2.7. Statistics

The data collected during the course of experiments were subjected to detailed statistical scrutiny following the analytical procedures of Panse and Sukhatme (1961) to bring out genotype, stage and interaction effects. Correlation coefficient of characters was also worked out wherever necessary. The analysis was carried out in ECL Micro 2200 and BDP 100 ECIL micro computer systems.

Results

CHAPTER IV

RESULTS

The present investigation mainly aimed at to find out the developmental physiology of fibre and associated boll traits in two elite cotton cultivars. A lintless mutant was maintained as a 'check'. The data of field, pot culture and laboratory experiments are presented in this chapter after statistical analysis and also diagrammatically represented wherever necessary.

4.1. Time trend changes in flowering

The data relating to flowering are presented in Table 3 and Fig. 1. A perusal of the results indicated that Suvin, MCU 5 and MCU 5 mutant showed characteristic variation in flowering. The commencement of flowering occurred 8 weeks after planting in MCU 5, while in Suvin and MCU 5 mutant it was delayed by another one week.

The maximum flowering intensity occurred over a period of three weeks starting from 12 weeks after planting in MCU 5 was indicative of early flowering behaviour in this cultivar. This pattern of flower set commenced on the 14th week in the mutant with a plateau of high rate of flowering for a longer duration of four weeks. In Suvin, peak flowering occurred

Table 3a. Accumulated degree days and heliothermal units during peak and total flowering periods in Suvin, MCU 5 and MCU 5 mutant

Genotype	Accumulated degree days		Accumulated Heliothermal units	
	Peak flowering	Total flowering	Peak flowering	Total flowering
Suvin	191.4	1282.3	1056.6	9342.6
MCU 5	306.2	1116.3	2553.8	8967.0
MCU 5 mutant	395.1	1282.3	2815.3	9342.6

Table 3b. Fresh and dry weight (g)/flower in Suvin, MCU 5 and MCU 5 mutant

Genotype	Flower fresh weight (g)	Flower dry weight (g)
Suvin	2.620	0.520
MCU 5	1.600	0.320
MCU 5 mutant	1.000	0.240
SE(m)	0.1342	0.0255
CD(P=0.05)	0.4070	0.0774

Fig.1. Trends in flower production and single flower fresh and dry weight of Suvin, MCU5 and MCU5 mutant

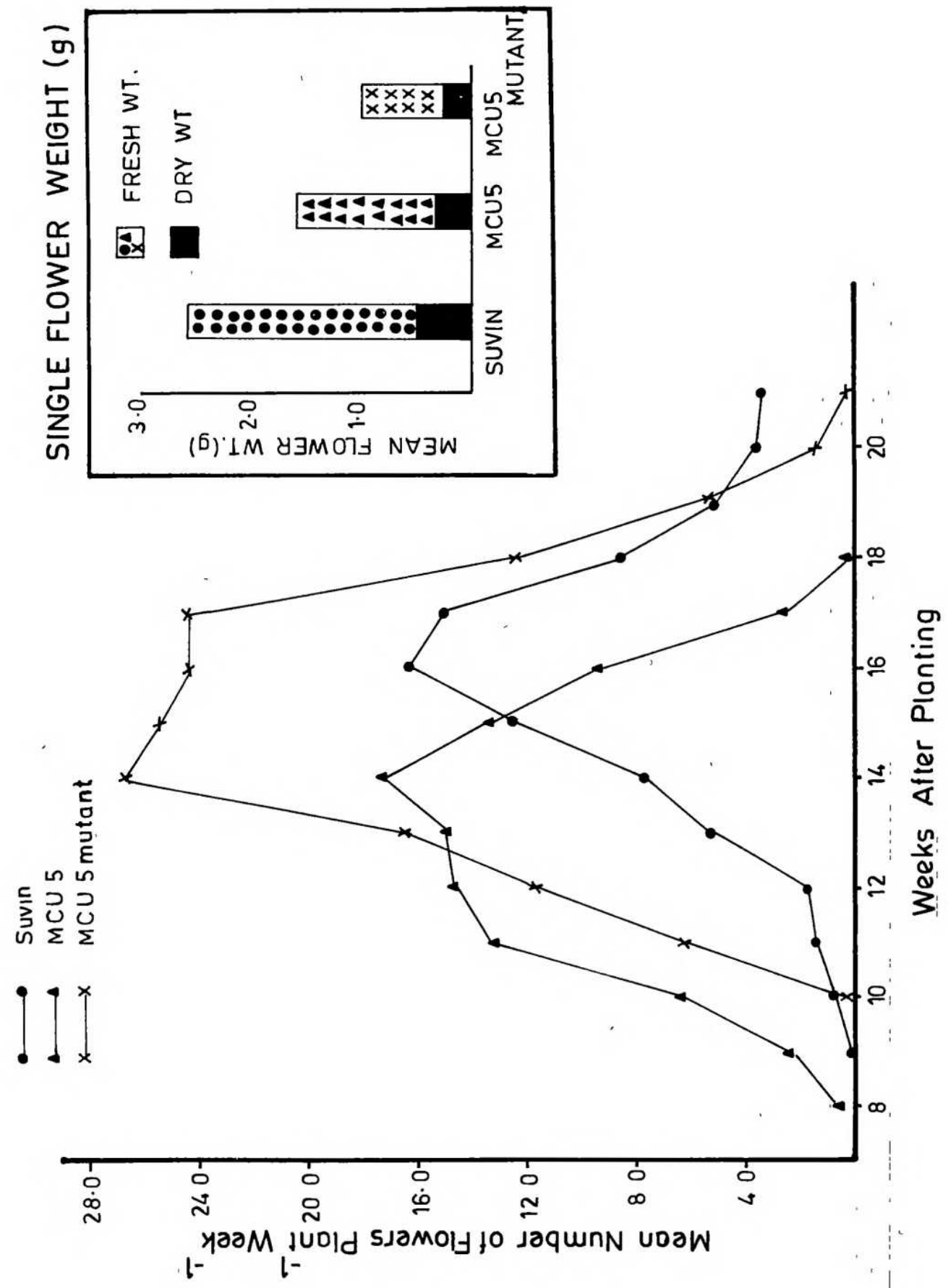


Table 3. Trends in flower production plant⁻¹ week⁻¹
in Suvin, MCU 5 and MCU 5 mutant

Week and date after planting		Suvin	MCU 5	MCU 5 mutant	Mean
8	21.4.83	-	0.63	-	0.21
9	28.4.83	0.15	2.28	0.03	0.82
10	5.5.83	0.65	6.23	0.88	2.59
11	12.5.85	1.53	13.08	6.23	6.95
12	19.5.83	1.83	14.75	11.68	9.42
13	26.5.83	5.43	14.80	16.45	12.23
14	2.6.83	7.83	17.18	26.63	17.21
15	9.6.83	12.60	13.38	25.38	17.12
16	16.6.83	16.40	9.28	24.40	16.69
17	23.6.83	15.10	2.50	24.45	14.02
18	30.6.83	8.48	0.13	12.45	7.02
19	7.7.83	5.20	-	5.35	3.52
20	14.7.83	3.70	-	1.48	1.73
21	21.7.83	3.48	-	0.35	1.23
Total		82.38	94.24	155.76	
Mean		6.34	8.57	11.60	

	Genotype (G)	Stage (S)	G x S	S x G
SE(m)	0.4338	0.5078	0.9271	0.8584
OD(P=0.05)	1.3270	1.4221	2.6423	2.3990

only for a shorter period of two weeks which commenced 16 weeks after planting. It is also interesting to note that in MCU 5, the entire flowering period ceased on the 18th week, whereas in Suvin and MCU 5 mutant, it continued upto 21st week. Further, the rate of flowering was more in Suvin even in the later stages showing indeterminate growth and flowering behaviour.

The peak flowering trends occurred under an accumulated degree days of 395.1 and 306.2 in MCU 5 mutant and MCU 5 respectively whereas it prevailed under a lower summation of degree days in Suvin (191.4). Similarly the accumulated heliothermal units during the peak flowering periods were found to be high in MCU 5 mutant (2815.3) followed by MCU 5 (2553.8). It was the least of 1056.6 units in Suvin (Table 3a).

The total number of flowers produced during the crop duration was 94.24 and 82.38 in a span of 11 and 13 weeks in MCU 5 and Suvin respectively while it was appreciably high in MCU 5 mutant (155.76) in a period of 13 weeks. The mean number of flowers per plant per week was 6.34, 8.57 and 11.60 in Suvin, MCU 5 and MCU 5 mutant respectively which differed significantly among them.

4.1.1. Flower fresh and dry weights

Flower fresh and dry weights also differed significantly among the genotypes. It was the highest in Suvin, followed by

Fig.2. Time trend changes in fresh weight of boll and its components of Suvin,MCU5 and MCU5 mutant

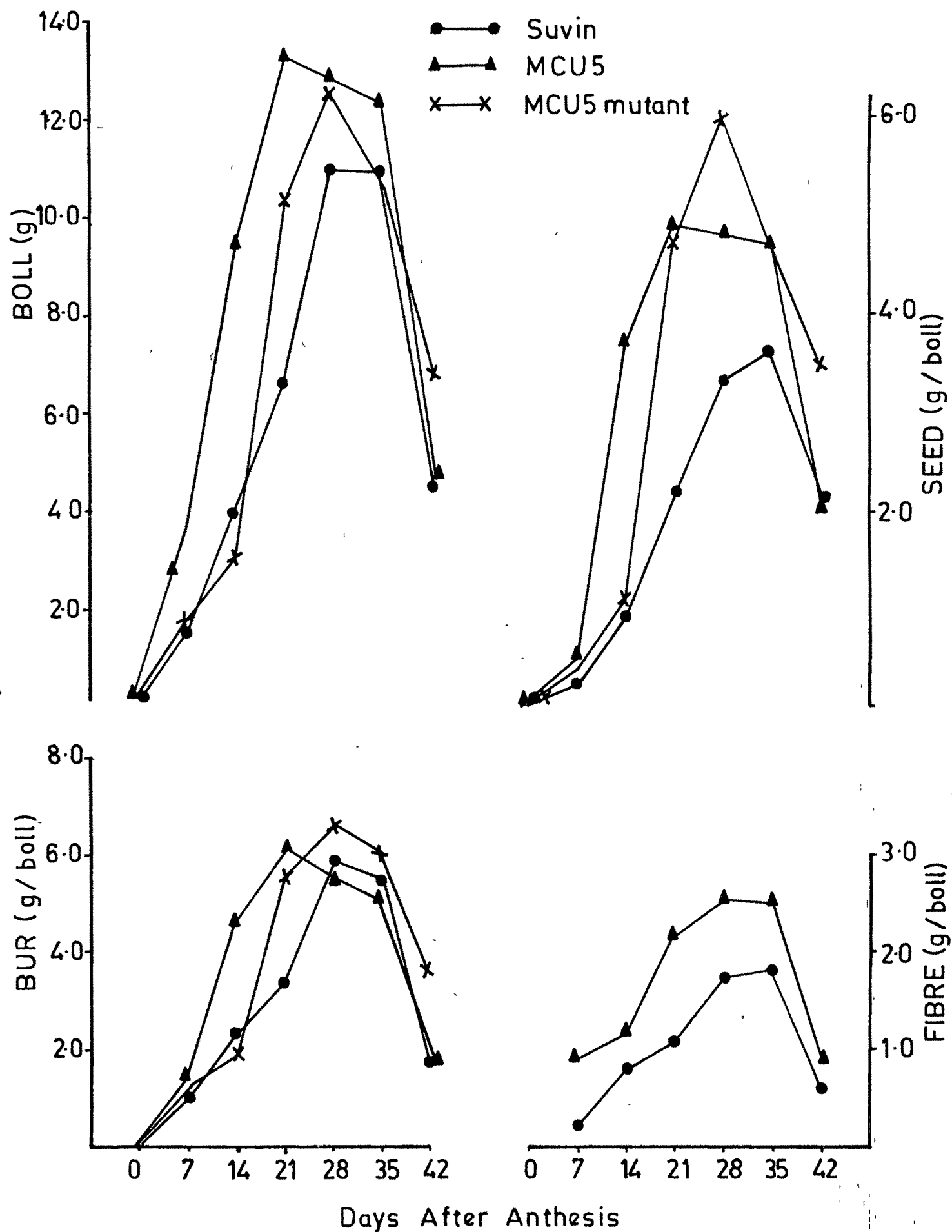


Table 4. Time trend changes in fresh weight of boll (g) and its components (g/boll) of Suvin. MCU 5 and MCU 5 mutant

Boll/ Component	Genotype	Days after anthesis							Mean
		0	7	14	21	28	35	42	
BOLL	Suvin	0.139	1.478	3.951	6.582	10.957	10.908	4.520	5.505
	MCU 5	0.136	2.793	9.421	13.181	12.853	12.314	4.606	7.901
	MCU 5 mutant	0.164	1.759	3.006	10.290	12.525	10.772	6.751	6.460
	Mean	0.146	2.010	5.459	10.018	12.112	11.315	5.292	
		Genotype (G)		Stage (S)		G x S		S x G	
	SE(m)	0.1423		0.1801		0.2852		0.2828	
	CD(P=0.05)	0.3034		0.3573		0.8338		0.4019	
BUR	Suvin	0.117	1.032	2.336	5.327	5.923	5.535	1.789	2.866
	MCU 5	0.110	1.430	4.507	6.110	5.508	5.080	1.720	3.495
	MCU 5 mutant	0.132	1.262	1.904	5.567	6.618	5.980	3.371	3.548
	Mean	0.120	1.241	2.916	5.001	6.016	5.532	2.293	
		Genotype (G)		Stage (S)		G x S		S x G	
	SE(m)	0.0748		0.0966		0.1544		0.1534	
	CD(P=0.05)	0.2269		0.2756		0.4467		0.4334	
SEED	Suvin	0.022	0.224	0.865	2.210	3.347	3.550	2.140	1.765
	MCU 5	0.026	0.448	3.733	4.909	4.815	4.748	1.969	2.950
	MCU 5 mutant	0.032	0.497	1.102	4.723	5.907	4.742	3.380	2.912
	Mean	0.027	0.390	1.900	3.947	4.690	4.347	2.496	
		Genotype (G)		Stage (S)		G x S		S x G	
	SE(m)	0.0722		0.0867		0.1475		0.1427	
	CD(P=0.05)	0.2190		0.2469		0.4269		0.4030	
FIBRE	Suvin	-	0.222	0.750	1.045	1.687	1.823	0.591	1.020
	MCU 5	-	0.915	1.181	2.162	2.530	2.486	0.917	1.699
	Mean	-	0.570	0.966	1.604	2.109	2.155	0.754	
		Genotype (G)		Stage (S)		G x S		S x G	
	SE(m)	0.0370		0.0552		0.0721		0.0731	
	CD(P=0.05)	0.1238		0.1584		0.2242		0.2098	

MCU 5. MCU 5 mutant recorded the lowest flower weights (Table 3b).

4.2. Time trend changes in fresh weight of boll and its components

Data on boll and its individual components development in terms of fresh weight are given in Table 4 and Fig. 2.

Boll fresh weight: The mean fresh weight of boll differed significantly among Suvin, MCU 5 and MCU 5 mutant. MCU 5 possessed the highest mean boll weight (7.901 g) followed by its mutant (6.460 g) whereas Suvin recorded the lowest weight (5.505 g).

Data on the stages mean indicated that the boll development was rapid upto 28 days after anthesis followed by significant decrease till harvest.

Considering the interaction effects between the genotypes at a stage, it is interesting to note that the boll weight did not differ significantly among them at peak anthesis. Thereafter, MCU 5 recorded a significantly superior fresh weight at all stages till 35th day, whereas at harvest it had more or less same weight as in Suvin. It is also interesting to note that at the time of harvest, MCU 5 mutant recorded a higher fresh weight of boll.

Data on the fresh weight of boll within each genotype indicated that in Suvin the weight reached a peak on the 20th day and this was maintained till 35th day followed by a rapid decline later. On the other hand in MCU 5, maximum weight was attained on the 21st day and this continued to be more or less the same till 35th day. It decreased immediately thereafter. In MCU 5 mutant, there was a significant increase in the boll fresh weight upto 28 days followed by a decrease.

The distribution of fresh weight amongst the boll components viz., bur, seed and fibre was also considered. The mean bur fresh weight in MCU 5 and its mutant was maintained more or less similar as against Suvin.

The bur weight increased significantly upto 28 days followed by a decrease and this was quite rapid just before harvest.

Within the stages, initially there was no significant difference among the genotypes upto 7 days. Subsequently MCU 5 recorded more fresh weight in the bur as compared to the other two genotypes. Later it was the mutant which had more fresh weight in the bur.

The bur development within a genotype showed an increase in the fresh weight upto 28th day in Suvin and MCU 5 mutant

followed by a decrease whereas in MCU 5 it was the maximum on the 21st day.

The mean seed fresh weight indicated that MCU 5 and its mutant had more or less the same fresh weights viz., 2.950 and 2.912 g respectively and these were significantly higher than that of Suvin (1.765 g).

The seed weight over the developmental stages increased significantly from anthesis till 28 days post anthesis (DPA) and declined later.

The interaction effects between genotypes and stages, also stages within a genotype were significant. Considering the genotype behaviour at a chosen stage of boll development, it was noticed that the seed weight during anthesis and 7 DPA did not vary. Afterwards, MCU 5 recorded the highest weight at all stages till 35 days of boll age as compared to Suvin. On 42nd day MCU 5 and Suvin had more or less same seed weight but this was significantly lower than that of MCU 5 mutant.

The seed weight changes between stages were well marked between 7 and 28 DPA in Suvin, while in MCU 5, it occurred for a shorter period (21 DPA). In MCU 5 mutant on the other hand, the weight increased significantly from anthesis to 23 days of boll age. After the maximum weight gain, it decreased steeply between 35 and 42 DPA, particularly in the cultivars.

Fig.3. Dry matter distribution in boll and its components of Suvin, MCU5 and MCU5 mutant

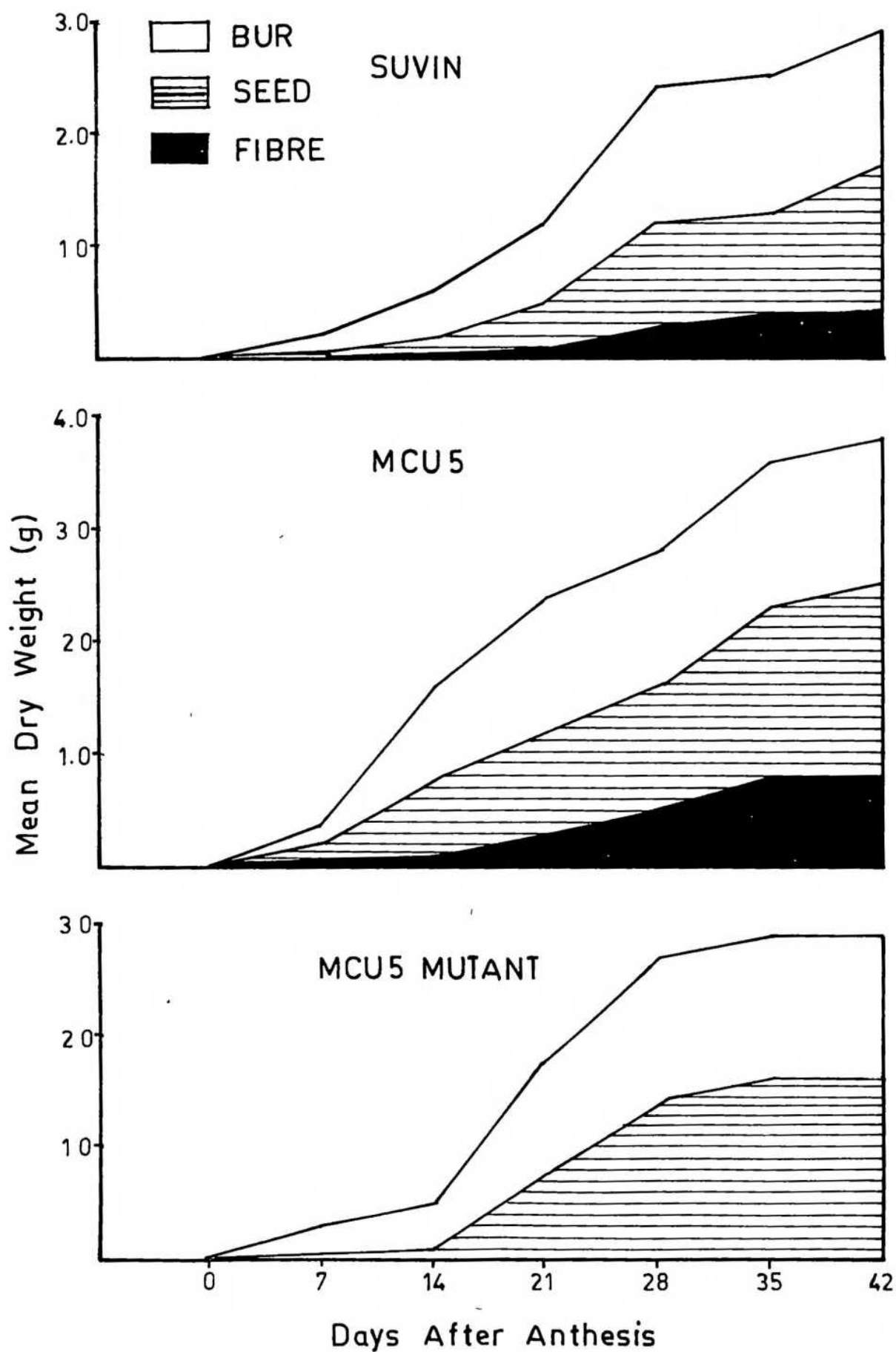


Table 5. Dry matter distribution in boll (g) and its components (g/boll) of Suvin, MCU 5 and MCU 5 mutant

Boll/ Component	Genotype	Days after anthesis							Mean
		0	7	14	21	28	35	42	
BOLL	Suvin	0.019	0.212	0.599	1.154	2.364	2.514	2.866	1.390
	MCU 5	0.019	0.407	1.639	2.416	2.799	3.568	3.768	2.088
	MCU 5 mutant	0.023	0.278	0.477	1.818	2.745	2.936	2.948	1.604
	Mean	0.020	0.299	0.905	1.796	2.636	3.006	3.194	
		Genotype (G)		Stage (S)		G x S		S x G	
	SE(m)	0.0267		0.0327		0.0579		0.0559	
	CD(P=0.05)	0.0812		0.0935		0.1692		0.1584	
BUR	Suvin	0.017	0.172	0.405	0.648	1.182	1.184	1.181	0.684
	MCU 5	0.016	0.250	0.871	1.226	1.217	1.224	1.231	0.862
	MCU 5 mutant	0.020	0.225	0.353	1.038	1.345	1.311	1.315	0.801
	Mean	0.018	0.216	0.543	0.971	1.248	1.240	1.242	
		Genotype (G)		Stage (S)		G x S		S x G	
	SE(m)	0.0124		0.0156		0.0307		0.0293	
	CD(P=0.05)	0.0376		0.0445		0.0884		0.0825	
SEED	Suvin	0.002	0.028	0.145	0.422	0.900	0.955	1.290	0.535
	MCU 5	0.003	0.075	0.655	0.903	1.046	1.530	1.721	0.848
	MCU 5 mutant	0.003	0.053	0.124	0.780	1.400	1.625	1.633	0.803
	Mean	0.003	0.052	0.308	0.702	1.115	1.370	1.548	
		Genotype (G)		Stage (S)		G x S		S x G	
	SE(m)	0.0205		0.0217		0.0361		0.0340	
	CD(P=0.05)	0.0621		0.0618		0.1049		0.0960	
FIBRE	Suvin	-	0.012	0.049	0.084	0.282	0.375	0.395	0.200
	MCU 5	-	0.082	0.113	0.287	0.536	0.814	0.816	0.441
	Mean	-	0.047	0.081	0.186	0.409	0.595	0.606	
		Genotype (G)		Stage (S)		G x S		S x G	
	SE(m)	0.0112		0.0122		0.0185		0.0168	
	CD(P=0.05)	0.0374		0.0352		0.0576		0.0481	

A perusal of data on fibre fresh weight indicated larger differences between Suvin and MCU 5. The mean weight was 1.699 g per boll in MCU 5 which was 66.57 per cent above that of Suvin.

The weight of fibre increased progressively till 28 days of boll age. Later it was maintained upto 35 days post anthesis followed by a significant decline on 42 DPA.

The interaction effects between cultivars within a stage indicated that in all the stages, the fibre weight was significantly higher in MCU 5 over Suvin.

The fibre fresh weight changes over the stages in the cultivars showed that the weight increased progressively till 28 days after anthesis in MCU 5 which later declined. The decline in weight was on par with the previous stage till 35 DPA. Later the decrease was found to be highly significant between 35 and 42 DPA only. In Suvin, the fibre weight increased continuously upto 28 days and it remained on par till 35 days. Later it declined at a faster rate in this cultivar too. It may be characterised from these findings that fibre desiccation occurred rapidly in MCU 5 as compared to Suvin.

4.3. Time trend changes in dry weight of boll and its components

Data on the dry matter production (DMP) of boll and its components are presented in Table 5 and Fig. 3.

The mean boll dry weight in the three genotypes differed significantly. It was maximum in MCU 5 (2.088 g) followed by its mutant (1.604 g) and then Suvin (1.390 g).

It is interesting to note that the dry matter accumulated in the boll continuously from anthesis till harvest.

The interaction effects of the genotypes at a particular stage of boll development showed that the boll dry weight did not vary among them during anthesis. On 7, 14 and 42 DPA too, the weight differed little between Suvin and MCU 5 mutant. MCU 5 on the other hand recorded the highest boll dry weight between 7 and 42 days of boll age. Compared to this cultivar, the mutant had significantly lower boll dry weight from 7 to 42 DPA, except on 28 days of boll age when they both had the same dry weight.

Considering the boll development within a genotype, it was observed that MCU 5 was more efficient in transferring the dry matter into the boll right from anthesis till harvest. Suvin and MCU 5 mutant on the other hand, also had a rapid boll DM accumulation till 23th and 35th day respectively. However, among them Suvin alone moved the dry matter into the boll towards harvest.

Next, the partitioning of boll dry weight into its components viz., bur, seed and fibre in the three genotypes was considered.

The mean bur dry weight in the three genotypes varied in the order MCU 5 > MCU 5 mutant > Suvin.

The mean bur dry weight over stages indicated that it increased only upto 28 days.

The bur dry weight of the genotypes at a chosen stage showed that it did not vary among the genotypes at anthesis. Later, MCU 5 retained more dry weight in the bur upto 21 days. Towards harvest the mutant had more dry weight than Suvin but it was on par with MCU 5.

The interaction effects between stages within a genotype provided time trend evidences that DM of bur increased progressively from anthesis to 28 days in Suvin and MCU 5 mutant while it continued for a shorter period in MCU 5 (upto 21 days).

Seed dry weight as in the case of bur registered the lowest mean weight in Suvin (0.535 g) when compared to the other two genotypes. It did not show any variation between MCU 5 and its mutant (0.848 and 0.803 g).

The mean data on seed dry weight for stages depicted a significant increase between 7 and 42 DPA.

The significant interaction effects between genotypes within a stage indicated that the seed DM varied little among the genotypes till 7 DPA. In later stage i.e., on 14 DPA, the weight gain was on par between Suvin and MCU 5 mutant. MCU 5 recorded distinctively higher seed weight between 14 and 42 DPA as against Suvin. MCU 5 mutant on the other hand recorded significantly higher seed DM from 28 DPA as compared to MCU 5, though the weight gain on 42 DPA was on par with MCU 5.

Considering the seed development in each of the genotypes over stages, it was noticed that seed DM had a distinct increase from 7 to 42 DPA in MCU 5 and Suvin while in the mutant it stopped on 35 DPA.

The pattern of fibre dry weight accumulation showed distinct variation between the cultivars. The mean dry weight was 0.241 g more in MCU 5 as compared to Suvin.

The mean dry weight of fibre increased significantly between 14 and 35 days post anthesis. Thereafter it remained more or less same till harvest.

The interaction effects between cultivars and the chosen stages showed that MCU 5 had the highest fibre dry weight at all stages of fibre development.

Considering the fibre dry weight accumulation between the stages within a cultivar, it was found that the weight

Fig 4 Time trend changes in moisture content of boll and its components of Suvin,MCU5 and MCU5 mutant

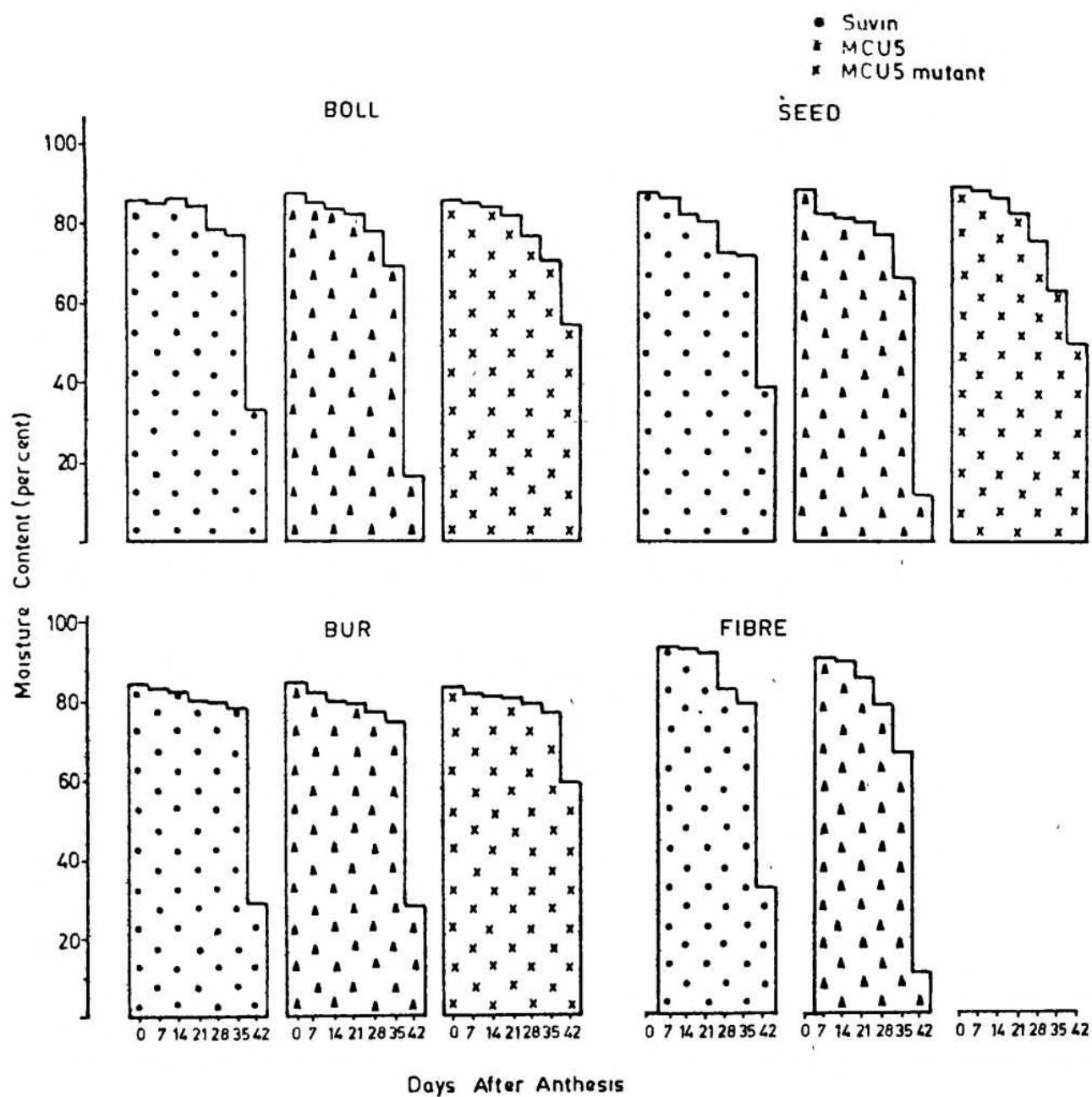


Table 6. Time trend changes in moisture content (per cent) of boll and its components of Suvin. MCU 5 and MCU 5 mutant

Boll/ Component	Genotype	Days after anthesis							Mean
		0	7	14	21	28	35	42	
BOLL	Suvin	85.93	85.58	86.48	84.48	78.78	77.06	33.55	75.98
	MCU 5	87.32	85.60	84.37	82.44	78.17	69.71	16.90	72.07
	MCU 5 mutant	86.31	85.75	84.65	82.39	77.21	71.47	54.90	77.52
	Mean	86.52	85.64	85.16	83.10	78.05	72.75	35.11	
		Genotype (G)		Stage (S)		G x S		S x G	
	SE(m)	0.5207		0.6657		1.0906		1.0759	
	CD(P=0.05)	1.5747		1.8924		3.1454		3.0302	
BUR	Suvin	84.52	83.27	82.91	80.47	80.05	78.54	29.04	71.11
	MCU 5	85.08	82.49	80.27	79.65	77.70	75.39	28.41	72.71
	MCU 5 mutant	83.85	82.08	81.40	81.32	79.55	77.70	59.70	77.94
	Mean	84.48	82.62	81.53	80.48	79.10	77.21	39.05	
		Genotype (G)		Stage (S)		G x S		S x G	
	SE (m)	0.5821		0.9093		1.2623		1.3426	
	CD(P=0.05)	1.7657		2.5925		3.6478		3.7971	
SEED	Suvin	88.75	87.45	83.17	80.94	73.08	73.07	39.25	75.10
	MCU 5	89.39	83.27	82.43	81.25	77.89	67.01	12.13	70.48
	MCU 5 mutant	90.01	89.42	87.54	83.46	76.37	63.87	50.10	77.25
	Mean	89.38	86.71	84.38	81.89	75.78	67.98	33.83	
		Genotype (G)		Stage (S)		G x S		S x G	
	SE(m)	0.8232		0.6431		1.4285		1.2134	
	CD(P=0.05)	2.4972		1.8334		4.1592		3.4239	
FIBRE	Suvin	-	93.79	93.60	92.04	83.21	79.58	32.46	79.11
	MCU 5	-	91.04	90.39	86.18	78.55	66.73	10.15	70.51
	Mean	-	92.42	92.00	89.11	80.88	73.15	21.31	
		Genotype (G)		Stage (S)		G x S		S x G	
	SE(m)	0.9800		1.3200		1.8136		1.7719	
	CD(P=0.05)	3.2773		3.7890		5.6353		5.0862	

increased significantly from 7 and 14 DPA in MCU 5 and Suvin respectively and the maximum DM accumulation occurred between 21 and 35 days after anthesis in both of them. The weight increase between 35 and 42 DPA remained on par.

4.4. Time trend changes in moisture content of the boll and its components

Data on moisture status in the boll and its components during the course of their development are given in Table 6 and Fig. 4.

The mean boll moisture content was 77.52 per cent in MCU 5 mutant which was on par with 75.98 per cent in Suvin and 72.07 per cent in MCU 5. It followed the order as MCU 5 mutant = Suvin > MCU 5.

The mean data on boll moisture per cent remained more or less the same till 14 days after anthesis followed by a significant decrease thereafter till harvest. A maximum decrease of 50 per cent took place between 35 and 42 days of boll age.

It was noticed from the interaction effects between the genotypes within a stage that the boll moisture status in the genotypes remained on par till 28 DPA. In the later stages, it was maintained at a lower level in MCU 5 whereas the mutant

of MCU 5 recorded the highest moisture status on 42 DPA as against the cultivars significantly. Suvin which is known for its fibre length maintained more moisture in the boll over MCU 5 at harvest.

The interaction effects between stages in each of the genotypes showed similar declining trends of boll moisture after 21 DPA as noticed in the means for stages.

The mean bur moisture content in Suvin (74.11 per cent) and MCU 5 (72.71 per cent) were on par but maintained lower moisture than in MCU 5 mutant (77.94 per cent).

The moisture content during bur development established a declining pattern from anthesis till 35 DPA. Later, it decreased rapidly on 42 days after anthesis.

In the interaction effects on the behaviour of the genotypes at specific stages, it was shown that bur moisture was identical till 35 days in the cultivars as well as MCU 5 mutant. At harvest viz., 42 days post anthesis, MCU 5 mutant recorded the highest level of moisture, about twice higher over that of the cultivars.

Considering the changes in bur moisture of a genotype during its development it was noticed that the moisture declined continuously without any effective change till 35 DPA in all of them. It fell sharply in the last stage.

The mean seed moisture content varied significantly in the genotypes in the following order MCU 5 mutant = Suvin > MCU 5.

The stages mean indicated that seed moisture decreased significantly right from anthesis till harvest.

Comparing the genotypes at a particular stage of seed development, it was noticed that the seed moisture did not show any change at anthesis and 21 DPA. In other stages, the differences were found to vary. However, at harvest these differences between genotypes were significant in the order MCU 5 mutant > Suvin > MCU 5.

The interaction effects between stages and genotypes indicated that the moisture decreased significantly during seed development at varying stages. In case of MCU 5 mutant the seed moisture decreased only after 14th day whereas in MCU 5 it occurred after 28 DPA. On the other hand, in Suvin the loss was intermittent and it decreased sharply at harvest as in the other two genotypes.

Fibre moisture in the cultivars showed wide variation in its mean content. It was the highest in Suvin (79.11 per cent) as compared to 70.51 per cent in MCU 5.

The mean of stages revealed that fibre moisture varied little till 21 DPA. Thereafter it decreased progressively till harvest.

Fig.5. Relative growth rate of boll and its components of Suvin, MCU5 and MCU5 Mutant

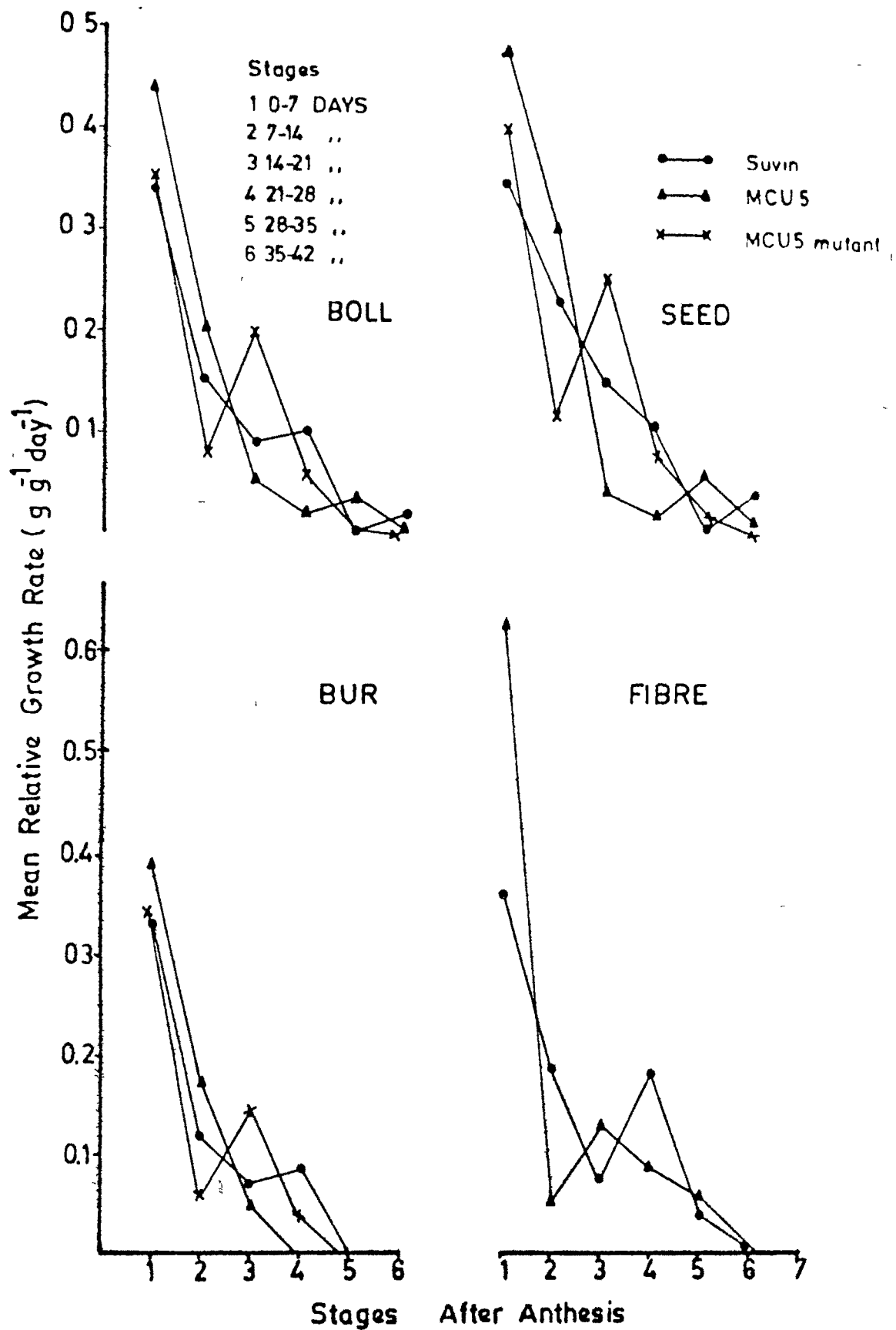


Table 7. Relative growth rate ($g\ g^{-1}\ day^{-1}$) of boll and its components of Suvin, MCU 5 and MCU 5 mutant

Boll/ Component	Genotype	Stages of development (days)						Mean
		0-7	7-14	14-21	21-28	28-35	35-42	
BOLL	Suvin	0.3377	0.1481	0.0936	0.1028	0.0090	0.0185	0.1183
	MCU 5	0.4383	0.1989	0.0548	0.0215	0.0351	0.0077	0.1261
	MCU 5 mutant	0.3489	0.0774	0.1904	0.0588	0.0094	0.0008	0.1144
	Mean	0.3750	0.1415	0.1129	0.0610	0.0180	0.0090	
		Genotype (G)		Stage (S)	G x S	S x G		
	SE(m)	0.0016		0.0044	0.0065	0.0072		
	CD(P=0.05)	0.0048		0.0127	0.0188	0.0204		
BUR	Suvin	0.3256	0.1227	0.0673	0.0856	-0.0007	0.0005	0.1002
	MCU 5	0.3907	0.1771	0.0488	-0.0002	0.0013	0.0007	0.1031
	MCU 5 mutant	0.3394	0.0643	0.1534	0.0371	-0.0039	0.0008	0.0985
	Mean	0.3519	0.1214	0.0898	0.0408	-0.0011	0.0007	
		Genotype (G)		Stage (S)	G x S	S x G		
	SE(m)	0.0018		0.0043	0.0072	0.0076		
	CD(P=0.05)	NS		0.0123	0.0208	0.0216		
SEED	Suvin	0.3538	0.2336	0.1528	0.1105	0.0085	0.0426	0.1503
	MCU 5	0.4800	0.3110	0.0448	0.0213	0.0550	0.0164	0.1548
	MCU 5 mutant	0.3987	0.1244	0.2609	0.0841	0.0223	0.0007	0.1485
	Mean	0.4108	0.2230	0.1528	0.0720	0.0286	0.0199	
		Genotype (G)		Stage (S)	G x S	S x G		
	SE(m)	0.0020		0.0084	0.0096	0.0119		
	CD(P=0.05)	NS		0.0242	0.0274	0.0337		
PIERE	Suvin	0.3555	0.1949	0.0773	0.1769	0.0391	0.0081	0.1420
	MCU 5	0.6280	0.0470	0.1305	0.0897	0.0620	0.0004	0.1596
	Mean	0.4918	0.1210	0.1039	0.1333	0.0506	0.0043	
		Genotype (G)		Stage (S)	G x S	S x G		
	SE(m)	0.0011		0.0088	0.0108	0.0121		
	CD(P=0.05)	0.0035		0.0252	0.0309	0.0346		

The interaction between cultivars and stages indicated that fibre moisture remained on par initially till 14 days in both the elite cultivars. Thereafter Suvin possessed the highest moisture in all the stages of fibre development except showing a parity with MCU 5 on 28 DPA. It is interesting to note that this cultivar ultimately had threefold increase in the level of moisture on 42 DPA over that of MCU 5.

The fibre moisture status between stages showed a significant decline from 21 days of fibre development in both Suvin and MCU 5. A striking feature in the fibre moisture relationship with other boll components was its high status (above 90 per cent) during early fibre development.

4.5. Trends in the relative growth rate (RGR) of boll and its components

Data on this parameter are presented in Table 7 and Fig. 5.

RGR of boll showed that its mean value was significantly higher in MCU 5 ($0.1261 \text{ g g}^{-1} \text{ d}^{-1}$) while it remained on par between Suvin ($0.1133 \text{ g g}^{-1} \text{ d}^{-1}$) and MCU 5 mutant ($0.1144 \text{ g g}^{-1} \text{ d}^{-1}$).

The mean of stages indicated that the boll RGR declined progressively from anthesis till 28-35 stage interval. Further decline was found to be on par between the last two stages.

The interaction of the genotypes at a chosen stage indicated that boll RGR of MCU 5 was significantly higher during 0-14 as well as 28-35 DPA while during 14-21 DPA it varied in the order MCU 5 mutant > Suvin > MCU 5 and this order was altered to Suvin > MCU 5 mutant > MCU 5 on 21-28 DPA. However during 35-42 DPA, there was little difference among them.

The interaction between genotypes and stages were also significant.

The pattern of bur RGR indicated that its mean rate was non-significant among the cottons under study.

The mean of stages was however significant indicating that the bur RGR which was highest in the early stages declined progressively and remained on par in the last two stages.

The interaction effects of the genotypes at a particular stage of bur development exhibited high RGR in MCU 5 at 0-14 DPA. Later, Suvin and MCU 5 had similar RGR on 14-21 DPA. Besides, the rate in the last two stages did not differ among the genotypes.

Bur RGR in relation to stages within a genotype revealed that it decreased in Suvin at a rapid pace till 21 DPA. In the following stage (21-28 DPA) there was little increase in the rate. Thereafter, the rate fell sharply even displaying negative trends. In MCU 5 also, the rate decreased noticeably till 28 DPA which later continued to be on par till harvest. The results depicted negligible rate in later stages in this

cultivar too. In MCU 5 mutant, the rate diminished significantly till 14 DPA and unlike the cultivars, it increased significantly later between 14 and 21 DPA, followed by a significant reduction and with little variation in the last two stages.

RGR of seed also indicated that its mean value did not significantly differ among the cultivars as well as MCU 5 mutant.

The seed RGR however had shown significant difference with regard to the mean of stages. The rate which was highest at anthesis declined progressively till 35 DPA. In the succeeding intervals the RGR was on par.

Considering the RGR of seed of the genotypes at a chosen stage, it was found to be significantly higher in MCU 5 till 14 DPA and also at 28-35 DPA. In Suvin, maintenance of such high rates was not noticed. MCU 5 mutant on the other hand had the highest rate on 14-21 DPA as compared to the cultivars.

RGR in each genotype in relation to stages of seed development indicated that in Suvin it declined significantly from anthesis till 35 DPA. This was followed by a significant increase in the next stage (35-42 DPA). A similar declining

trond was noticeable in MCU 5, which however remained on par between 14 and 35 days of seed development. Later, it fell sharply. In MCU 5 mutant, the rate declined progressively till 14 DPA. There was a prominent mid-stage raise in the rate during 14-21 DPA. It declined in the subsequent stages leading to a negligible minimum on 42 DPA.

The mean data on RGR of fibre indicated that MCU 5 had the highest value of $0.1596 \text{ g g}^{-1} \text{ d}^{-1}$ as against Suvin ($0.1420 \text{ g g}^{-1} \text{ d}^{-1}$) and the difference between the cultivars was significant.

The mean of stages indicated that the fibre RGR which was highest initially fell sharply even at 14 days of fibre development. In the subsequent stage (14-21 DPA), its decrease was on par with the earlier stage. The rate however increased significantly in the next stage (21-28 DPA). Later, it dropped significantly.

The interaction effects in the fibre RGR between the cultivars with regard to the stages of development showed that MCU 5 had the highest rate in 0-7 and 14-21 DPA, while Suvin maintained higher RGR on 7-14 and 21-28 DPA respectively. However, the rate was maintained on par between them from 28-35 stage interval onwards.

Fig.6. Time trend changes in fibre length and fibre dry weight / seed / unit fibre length of Suvin and MUC 5

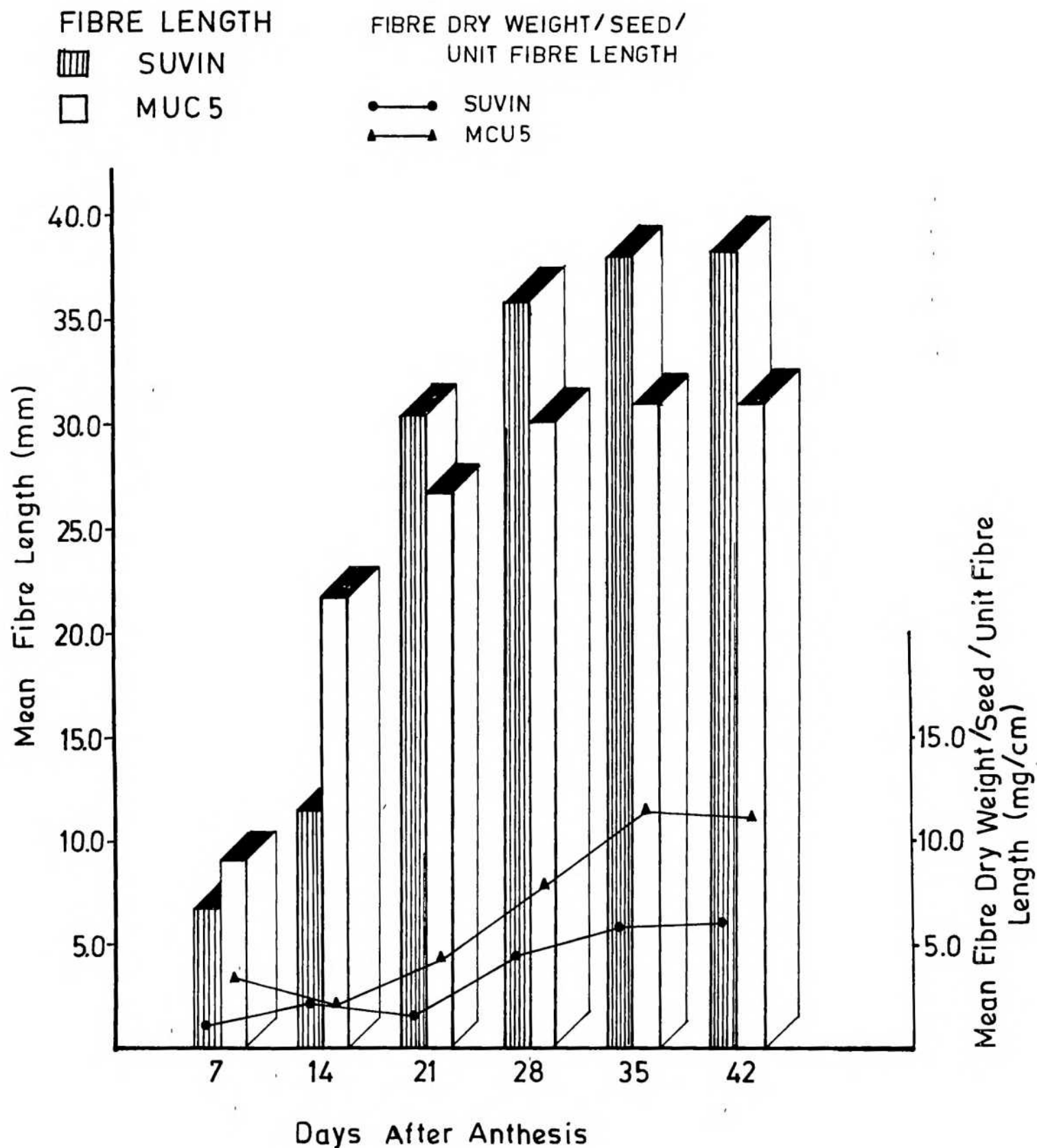


Table 8a. Time trend changes in fibre length (mm) and fibre dry weight/seed/unit fibre length (mg/cm) of Juvin and MCU 5

Genotype	Days after anthesis						Mean
	7	14	21	28	35	42	
Fibre length (mm)							
Suvin	6.70	11.58	30.35	35.83	38.03	38.20	26.78
MCU 5	9.18	21.68	26.78	30.13	31.10	31.14	25.00
Mean	7.94	16.63	28.57	32.98	34.57	34.67	
	Genotype (G)		Stage (S)		G x S		S x G
SS(m)	0.1210		0.1844		0.2983		0.2804
CD(P=0.05)	0.4046		0.5292		0.9271		0.8048
Fibre dry weight per seed per unit length (mg/cm)							
Suvin	0.978	2.144	1.538	4.536	5.798	6.094	3.513
MCU 5	3.231	2.139	4.510	7.860	11.379	11.237	6.726
Mean	2.105	2.142	3.024	6.198	8.589	8.661	
	Genotype (G)		Stage (S)		G x S		S x G
SS(m)	0.1563		0.2553		0.3197		0.3345
CD(P=0.05)	0.5227		0.7328		0.9933		0.9602

Table 8. Number, length and width of fibre initials
at 24 hr post-anthesis in Guvin and MCU 5

Cultivar	No. of fibre initials/ L.S. of ovule	Fibre length (μ)	Fibre width (μ)
Guvin	106.6	19.8	12.8
MCU 5	161.2	51.9	16.7

Considering the RGR of fibre in the cultivars individually during the developmental stages, it was noticed that the rate declined significantly till 14-21 and 7-14 DPA in Suvin and MCU 5 respectively. It is interesting to note that the rate in the subsequent stage of fibre development increased significantly which later fell sharply and continued to decline in the later stages. The mid-stage increase as seen from the results occurred one week earlier in MCU 5. The rate showed no variation in the last two stages in Suvin, while in MCU 5 it was on par between 21-28 and 28-35 DPA.

4.6. Fibre initiation, elongation and wall thickness characteristics

The mean data on these parameters are given in Table 8; 8a and Fig. 6.

Investigations on number, length and width of fibre initials, the day after anthesis brought out considerable variations in Suvin and MCU 5. MCU 5 recorded higher number as well as greater expansion of fibre initials at this phase as compared to Suvin. A high fibre density in MCU 5 is indicative of major thrust on fibre weight per boll in this cultivar.

The time course changes in fibre elongation indicated that the elongation capacity of both the cultivars differed significantly. The mean elongation over the stages was high in Suvin (26.78 mm) followed by MCU 5 (25.00 mm).

The fibre elongation occurred at a significant rate till 35 days after anthesis. It however slowed down in the later stage and became almost constant.

Considering the interaction effects between the cultivars at chosen stages of fibre development, it was noticed that MCU 5 had significantly more fibre elongation during the initial phases till 14 DPA. However, in later stages, Suvin possessed distinctly higher rate of elongation upto 42 DPA.

Increase in fibre length between stages within a genotype showed that it was significantly superior till 35 DPA in both the cultivars. In the subsequent stage, it remained on par with 35 DPA.

Fibre dry weight per seed per unit fibre length was considered as it is a parameter indicating relative fibre wall thickness.

The mean value for the cultivars indicated that MCU 5 had maximum wall thickness (6.726 mg per cm) as compared to Suvin (3.513 mg per cm).

Data on mean of stages showed that the thickness did not vary till 14 DPA. Thereafter it increased significantly over stages till 35 DPA. Between 35 and 42 DPA, there was very little increase in thickness.

Table 9. Seed number/boll at different stages of boll development in Suvin, MCU 5 and MCU 5 mutant

Genotype	Days after anthesis							Mean
	0	7	14	21	28	35	42	
Suvin	19.00	19.00	19.50	18.00	17.00	17.38	17.00	18.13
MCU 5	26.50	27.63	24.50	23.88	23.38	23.13	23.38	24.63
MCU 5 mutant	36.38	34.13	34.50	32.00	32.38	31.88	31.00	33.16
Mean	27.29	26.92	26.17	24.63	24.25	24.13	23.79	

	Genotype (G)	Stage (S)	G x S	S x G
SE(m)	0.2211	0.4339	0.6866	0.7139
CD(P=0.05)	0.6707	1.2369	1.9705	2.0303

The interaction effects between cultivars and stages point out that in all the stages of fibre development, MCU 5 had maximum thickness, except in the 14th day when it was on par with Suvin.

In the fibre developmental stages, MCU 5 recorded a reduction in this character on 14 DPA. Later it increased significantly in all the stages. In Suvin, on the other hand, wall thickness increased till 14 DPA and remained more or less the same till 21 DPA. Later it increased in a similar pattern as noticed in MCU 5.

4.7. Seed number per boll

Data on seed number per boll are presented in Table 9. It showed significant difference among the genotypes under investigation. It varied in the order MCU 5 mutant > MCU 5 > Suvin.

Data on mean seed number over stages indicated that the seed number did not vary upto 14 DPA. Between 14 and 21 DPA the number of seeds decreased significantly and later it remained more or less the same till harvest.

The interaction effects involving the genotypes in relation to a stage have shown that in all the stages significant difference existed among them. MCU 5 mutant maintained highest seed number followed by MCU 5 and Suvin respectively.

Fig.7. Time trend changes in dry weight of seed coat and kernel and seed coat/ kernel ratio of Suvin, MCU5 and MCU5 mutant

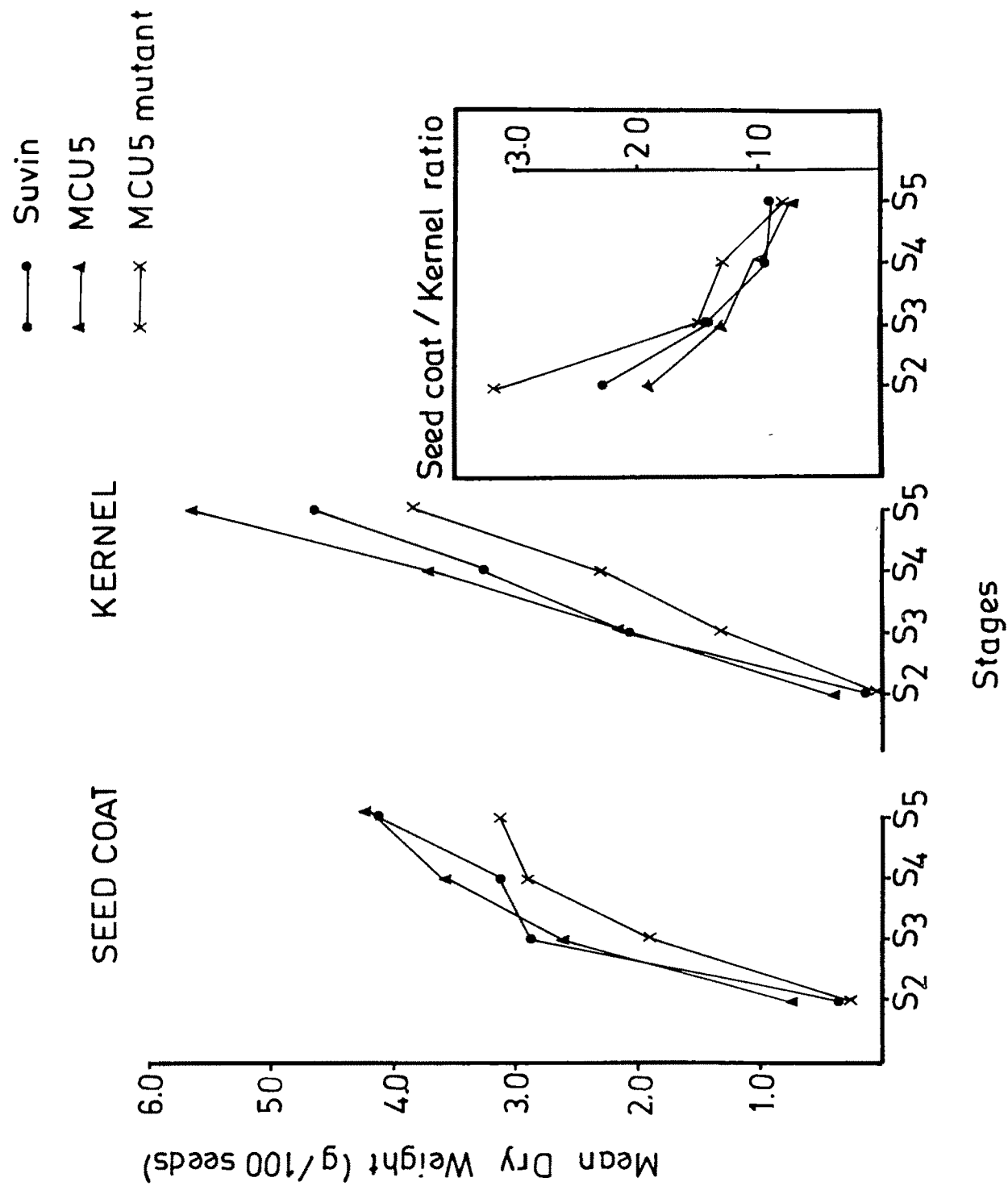


Table 10. Time trend changes in dry weight of seed coat and kernel (g/100 seeds) and seed coat/kernel ratio of Suvin, MCU 5 and MCU 5 mutant

Genotype	Stages of development*				Mean
	S ₂	S ₃	S ₄	S ₅	
Dry weight of seed coat					
Suvin	0.360	2.881	3.122	4.161	2.631
MCU 5	0.761	2.641	3.562	4.190	2.789
MCU 5 mutant	0.281	1.913	2.922	3.106	2.056
Mean	0.467	2.478	3.202	3.819	
	Genotype (G)	Stage (S)	G x S	S x G	
SE(m)	0.0271	0.0450	0.0695	0.0753	
CD(P=0.05)	0.0822	0.1325	0.2046	0.2182	
Dry weight of kernel					
Suvin	0.160	2.061	3.262	4.645	2.532
MCU 5	0.405	2.139	3.702	5.661	2.977
MCU 5 mutant	0.090	1.315	2.261	3.842	1.877
Mean	0.218	1.838	3.075	4.716	
	Genotype (G)	Stage (S)	G x S	S x G	
SE(m)	0.0327	0.0374	0.0636	0.0636	
CD(P=0.05)	0.0993	0.1100	0.1872	0.1842	
Seed coat - Kernel ratio					
Suvin	2.271	1.399	0.957	0.904	1.385
MCU 5	1.890	1.311	0.961	0.740	1.226
MCU 5 mutant	3.143	1.466	1.299	0.815	1.681
Mean	2.435	1.392	1.073	0.820	
	Genotype (G)	Stage (S)	G x S	S x G	
SE(m)	0.0297	0.0318	0.0629	0.0608	
CD(P=0.05)	0.0901	0.0936	0.1854	0.1763	

* S₂ - Fibre elongation; S₃ - Secondary thickening; S₄ - Maturation
 S₅ - Post-maturation stages in Suvin and MCU 5
 S₅ seed developmental stages in MCU 5 mutant

As in stages mean, the interaction between each genotype and stages indicated that the seed number did not show any marked difference between the stages except a distinct reduction in seed number between 7 and 14 as well as 14 and 21 DPA in MCU 5 and its mutant respectively. Such reduction in seed number was not noticed in Suvin.

4.7.1. Dry weight of seed coat, kernel and their ratio

The results are presented in Table 10 and Fig. 7.

A significant difference among the genotypes with regard to the seed coat dry weight was noticed from the mean content. It was high in MCU 5 followed by Suvin and MCU 5 mutant.

The seed coat weight progressively increased in all the stages of its development.

The interaction between genotypes and stages revealed that the seed coat weight was maintained high in all the chosen stages of MCU 5 except at thickening stage where Suvin had the highest weight. The cultivars and MCU 5 mutant showed significant difference among them during secondary thickening and maturation stages. In all the chosen stages, MCU 5 mutant had the lowest seed coat weight. The weight however remained on par with Suvin during seed developmental stage corresponding to fibre elongation in the cultivar. Similarly MCU 5 and Suvin did not show any variation in seed coat weight at post maturation stage.

Comparing the stages within a genotype, it was noticed that in all the chosen stages seed coat weight distinctively increased in the cultivars while little difference existed between the last two stages in MCU 5 mutant, though the weight increment occurred in a way similar to the cultivars.

With regard to the kernel dry weight, the mean weight showed significant variation among the genotypes.

The mean of stages also showed significant trends with regard to weight accumulation in kernel.

Interaction effects involving genotypes within a stage indicated that as in seed coat, MCU 5 recorded highest kernel weight, though the gain during secondary thickening stage was on par with Suvin. Likewise, MCU 5 mutant maintained the lowest weight in all the chosen stages, however it remained on par with Suvin during seed development corresponding to fibre elongation stage. The weight accumulation during maturation and post maturation stages differed significantly among them.

Stages and genotypes interactions have shown that at all the stages, the weight accumulation in kernel was significant.

Seed coat-kernel ratio in the cultivars and MCU 5 mutant brought out significant differences among them. It was high in MCU 5 mutant (1.681 g) followed by Suvin (1.385 g) and least in MCU 5 (1.226 g).

Table 11. Correlation coefficients between boll characters and fibre length and dry weight in Suvin and MCU 5

1. Fibre length										
Character	Suvin				MCU 5					
	7	14	Days after anthesis 21	28	35	42	7	14	Days after anthesis 21	28
Fresh weight										
Boll	-0.055	-0.828*	-0.208	-0.116	0.115	0.176	0.518	0.185	0.321	-0.671
Bur	0.140	-0.561	-0.008	-0.125	0.078	-0.108	0.222	0.169	0.049	-0.506
Seed	-0.009	-0.767*	-0.150	-0.361	0.219	0.321	-0.017	-0.157	0.124	-0.635
Fibre	-0.158	-0.143	-0.389	-0.330	0.006	0.493	0.371	0.522	0.075	-0.635
Dry weight										
Boll	-0.263	-0.884**	-0.179	-0.100	0.276	0.190	-0.061	-0.020	0.021	-0.109
Bur	-0.342	-0.727*	0.032	-0.074	-0.335	0.199	0.368	-0.140	-0.103	-0.422
Seed	-0.184	-0.788*	-0.147	0.200	0.555	0.141	-0.470	0.405	0.325	0.046
Fibre	0.138	-0.275	-0.402	-0.570	0.044	0.173	0.057	-0.093	0.026	0.141
No. of seeds	-0.177	-0.055	0.414	-0.141	-0.714*	0.350	0.389	-0.093	-0.408	-0.528
Moisture										
Boll	0.321	0.457	0.210	0.102	-0.243	0.096	0.476	0.098	0.136	0.118
Bur	0.333	0.738*	-0.089	0.400	0.129	-0.126	-0.096	0.148	0.482	0.105
Seed	0.377	0.084	-0.023	-0.369	-0.377	0.472	0.631	-0.673	-0.216	0.167
Fibre	-0.396	0.263	0.252	0.330	-0.080	0.107	0.161	0.396	0.158	-0.125
2. Fibre dry weight										
Fresh weight										
Boll	0.734*	-0.034	0.510	0.439	0.910**	0.506	0.517	0.302	0.140	0.370
Bur	0.179	-0.192	0.319	0.525	0.870**	0.451	0.280	0.188	-0.080	0.130
Seed	0.671	-0.313	0.202	-0.259	0.728*	0.507	0.458	0.267	0.508	0.550
Fibre	0.771*	0.858**	0.946**	0.260	0.810**	-0.141	0.086	0.212	0.065	0.292
Dry weight										
Boll	0.794*	0.005	0.396	0.524	0.931**	0.789*	0.848**	0.145	0.900**	0.580
Bur	0.735*	-0.055	0.338	0.516	-0.318	0.264	0.624	0.140	0.712*	0.205
Seed	0.639	-0.301	0.140	-0.042	0.681	0.667	0.447	-0.173	0.660	0.131
No. of seeds	-0.504	0.549	0.222	0.478	0.205	-0.300	0.246	0.571	0.311	-0.121
Moisture										
Boll	-0.281	-0.664	-0.386	-0.830*	-0.555	-0.641	-0.611	-0.101	-0.632	-0.243
Bur	-0.503	-0.073	0.329	-0.157	0.820*	-0.054	-0.303	-0.029	-0.671	0.056
Seed	-0.495	0.031	0.297	-0.125	-0.084	0.048	-0.322	0.516	-0.044	0.349
Fibre	0.143	-0.934**	-0.789*	-0.767*	-0.914**	-0.882**	-0.832*	-0.836**	-0.772*	-0.742*

**Significant at 1 per cent level

*Significant at 5 per cent level

The mean of stages showed that the ratio decreased significantly thus indicating greater storage of dry matter in the kernel with the development.

Comparing the genotypes in the chosen stages, it was observed that in most of the stages except post-maturation stage, MCU 5 mutant recorded highest ratio, while during post-maturation stage, Suvin had the highest ratio, which however was similar to the rest. Further, in most of the stages, MCU 5 possessed lowest seed coat-kernel ratio.

Interaction effects involving genotype and stages established that the seed coat-kernel ratio progressively declined in MCU 5. In Suvin alone, the ratio did not differ in the last two stages. In MCU 5 mutant, the declining ratio remained on par between thickening and maturation phases.

4.8. Correlation studies

The correlation coefficients between various boll character and fibre length and dry weight were worked out during different stages of boll development and are presented in Table 11.

In Suvin, fibre length had a negative relationship with the fresh and dry weight of the boll and its components in most of the stages, particularly during early stages of fibre

development. In this context, a level of significance could be observed only on 14 DPA with most of the characters whereas in other stages, the negative association was non-significant. Similarly seed number also registered a negative relationship with fibre length in most of the stages. In MCU 5 too, the relationship was mostly non-significant and unlike Suvin, this trend was noticeable even in later stages.

In both the cultivars, it was noticed that the moisture content had a positive relationship with the fibre length, though the relationship had not attained a level of significance. The most important character was boll and bur moisture which had tended to maintain a positive relationship with fibre length in most of the stages in both the cultivars.

Fibre dry weight had a positive relationship with the fresh and dry weights of boll and its components as well as with the number of seeds per boll in both the cultivars. Unlike the fibre length, it had a negative relationship with the moisture content of boll and its components, and this was mostly significant in the case of fibre moisture only.

4.9. Time trend changes in biochemical and nutritional status

Five chosen stages of fibre development viz., anthesis (S_1), fibre elongation (S_2), secondary thickening (S_3), maturation (S_4) and post-maturation (S_5) were considered for the

Fig.8. Time trend changes in reducing sugar and cellulose content of seed coat, kernel and lint of Suvin and MCU5 and seed coat and kernel of MCU5 mutant

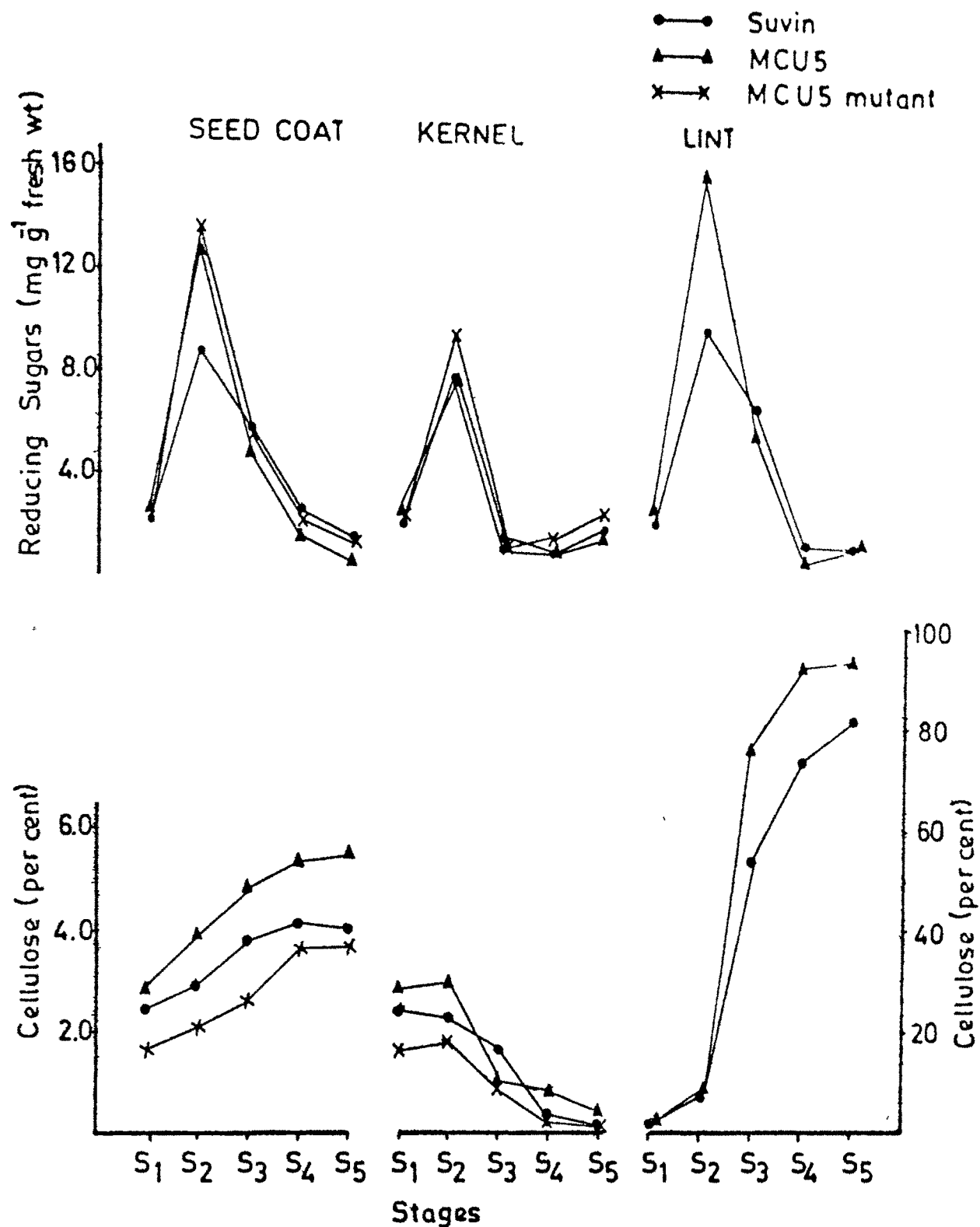


Table 12. Time trend changes in reducing sugar content (mg g^{-1} fresh weight) of seed coat, kernel and lint of Suvin and MCU 5 and seed coat and kernel of MCU 5 mutant

a) Genotype		b) Stage		c) Component							
Genotype	Mean	Stage		Mean		Component	Mean				
Suvin (G_1)	4.03	Fibre elongation (S_2)		10.38		Seed coat (C_1)	4.73				
MCU 5 (G_2)	4.46	Secondary thickening (S_3)		4.19		Kernel (C_2)	2.88				
		Maturation (S_4)		1.18		Lint (C_3)	5.14				
		Post maturation (S_5)		1.24							
SE(m)	0.2463			0.3484			0.3016				
CD(P=0.05)	NS			1.0167			0.8805				
d) Genotype x Stage				e) Genotype x Component		f) Stage x Component					
	S_2	S_3	S_4	S_5	C_1	C_2	C_3	C_1	C_2	C_3	
G_1	8.73	4.50	1.44	1.44	4.63	2.88	4.59	S_2	10.56	7.88	12.75
G_2	12.02	3.88	0.92	1.03	4.83	2.88	5.68	S_3	5.38	1.20	6.00
								S_4	1.91	0.92	0.72
								S_5	1.05	1.60	1.07
SE(m)	0.4927				0.4267			0.6034			
CD(P=0.05)	1.4378				NS			1.7610			
g) Genotype		h) Stage		i) Component							
Genotype	Mean	Stage		Mean		Component	Mean				
Suvin (G_1)	3.76	Fibre elongation (S_2)		10.01		Seed coat (C_1)	5.05				
MCU 5 (G_2)	3.86	Secondary thickening (S_3)		3.25		Kernel (C_2)	3.15				
MCU 5 mutant (G_3)	4.69	Maturation (S_4)		1.56							
		Post maturation (S_5)		1.58							
SE(m)	0.2140			0.2474			0.1749				
CD(P=0.05)	0.6245			0.7220			0.5106				
j) Genotype x Stage				k) Genotype x Component		l) Stage x Component					
	S_2	S_3	S_4	S_5	C_1	C_2	C_1	C_2			
G_1	8.25	3.45	1.65	1.55	4.63	2.88	S_2	11.63	8.38		
G_2	10.12	3.13	1.18	1.00	4.83	2.88	S_3	5.32	1.18		
G_3	11.64	3.17	1.84	2.09	5.68	3.69	S_4	2.04	1.08		
							S_5	1.19	1.97		
SE(m)	0.4285				0.3030		0.3499				
CD(P=0.05)	1.2506				NS		1.0211				

determination of biochemical and nutritional levels. The ovules were drawn for analysis at anthesis, while the following components - seed coat (C_1), kernel (C_2) and lint (C_3) were separated for estimation purpose from S_2 to S_5 stages of fibre development. With regard to growth substances and enzymes, the seed-cotton was used for analysis, while oil content was determined in the kernel in these developmental stages. The chosen stages in MCU 5 were considered for estimating various chemical and nutritional events in the seed coat (C_1) and kernel (C_2) of the seeds in MCU 5 mutant.

The data for S_2 to S_5 stages were alone considered for statistical scrutiny in two groups viz., (i) the cultivars for seed coat, kernel and lint and (ii) cultivars and MCU 5 mutant together for seed coat and kernel only. The results are therefore given based on these statistical inferences.

4.9.1. Reducing sugar content

Data on mean reducing sugar content are presented in Table 12 and Fig. 8.

The mean sugar content ranged between 2 to 2.4 mg in the ovules during anthesis among the genotypes viz., 2.00, 2.33 and 2.40 mg in Suvin, MCU 5 mutant and MCU 5 respectively (Annexure I).

The mean sugar content over the stages (S_2 to S_5) was high in MCU 5 mutant, while it did not vary between the cultivars (Table 12 g).

The stages mean indicated that the sugar level declined rapidly upto maturation phase and thereafter remained the same during post-maturation phase (Table 12 h).

Among the components, sugar content varied significantly as lint = seed coat > kernel (Table 12 c).

The interaction effects between the genotypes and stages indicated that in the cultivars and MCU 5 mutant, sugars declined at a faster rate upto maturation stage and thereafter was maintained on par during post-maturation stage. Similarly, it significantly differed among the genotypes at fibre elongation stage only (S_2) in the order MCU 5 mutant > MCU 5 > Suvin (Table 12 j).

The interaction between genotypes and components was found to be non-significant.

The significant stages and components interaction effects point out that sugar level declined in all the components from elongation stage onwards. This declining trend continued upto maturation stage with no subsequent change in seed coat and lint. In kernel, the declining level was found to remain on par between S_3 to S_5 . Similarly, sugars in these components differed significantly at fibre elongation stage in the order as lint > seed coat > kernel, whereas during secondary thickening stage (S_3), it varied little between

Table 13. Time trend changes in cellulose content (per cent) of seed coat, kernel and lint of Suvin and MCU 5 and seed coat and kernel of MCU 5 mutant

a) Genotype		b) Stage		c) Component	
Genotype	Mean	Stage	Mean	Component	Mean
Suvin (G ₁)	19.67	Fibre elongation (S ₂)	4.60	Seed coat (C ₁)	4.32
MCU 5 (G ₂)	24.53	Secondary thickening (S ₃)	23.57	Kernel (C ₂)	1.22
		Maturation (S ₄)	29.43	Lint (C ₃)	60.76
		Post-maturation (S ₅)	30.78		
SE(m)	0.5036		0.7122		0.6168
CD(P=0.05)	1.4698		2.0786		1.8000

d) Genotype x Stage				e) Genotype x Component			f) Stage x Component		
	S ₂	S ₃	S ₄	S ₅	C ₁	C ₂	C ₃		
G ₁	4.07	20.00	26.00	28.58	3.74	1.13	54.13	S ₂	3.40
G ₂	5.13	27.13	32.87	32.97	4.90	1.30	67.38	S ₃	4.30
								S ₄	4.78
								S ₅	4.80
SE(m)			1.0072			0.8723			1.2336
CD(P=0.05)			2.9396			2.5458			3.6003

g) Genotype		h) Stage		i) Component	
Genotype	Mean	Stage	Mean	Component	Mean
Suvin (G ₁)	2.44	Fibre elongation (S ₂)	2.67	Seed coat (C ₁)	3.99
MCU 5 (G ₂)	3.10	Secondary thickening (S ₃)	2.48	Kernel (C ₂)	1.06
MCU 5 mutant (G ₃)	1.89	Maturation (S ₄)	2.41		
		Post-maturation (S ₅)	2.33		
SE(m)	0.0573		0.0661		0.0468
CD(P=0.05)	0.1672		0.1930		0.1365

j) Genotype x Stage				k) Genotype x Component		l) Stage x Component	
	S ₂	S ₃	S ₄	S ₅	C ₁	C ₂	
G ₁	2.60	2.75	2.25	2.13	3.74	1.13	S ₂
G ₂	3.45	2.95	3.05	2.95	4.90	1.30	S ₃
G ₃	1.95	1.75	1.93	1.90	3.03	0.74	S ₄
							S ₅
SE(m)			0.1146		0.0810		0.0935
CD(P=0.05)			0.3344		0.2364		0.2730

seed coat and lint and they both had significantly higher sugar than kernel. In the later stages, the sugar level was found to be the same in these components (Table 12 f).

4.9.2. Cellulose content

Mean data on cellulose content are given in Table 13 and Fig. 8.

Cellulose content in the ovules during anthesis was 2.75, 2.45 and 1.60 per cent in MCU 5, Savin and MCU 5 mutant respectively (Annexure II).

The mean cellulose content of the genotypes over the stages S_2 to S_5 was found to be significantly high in MCU 5, followed by Savin and MCU 5 mutant (Table 13 g).

The stages mean indicated that in the cultivars, cellulose level increased progressively upto maturation stage, without any significant addition in the later stage (Table 13 b).

The components mean showed that lint had highest cellulose content followed by seed coat and kernel (Table 13 c).

Interaction between genotypes and stages in the cultivars showed that in both Savin and MCU 5 there was progressive increase in cellulose till maturation stage and the content was markedly high in MCU 5 from secondary thickening stage onwards (S_3) (Table 13 d).

Interaction effects between genotypes and components revealed that cellulose content varied little between seed coat and kernel but was maintained high in lint. Among the cultivars, it was significantly higher in the lint of MCU 5. Inclusion of MCU 5 mutant in this context indicated that cellulose level in seed coat varied significantly among the genotypes remaining in the order MCU 5 > Suvin > MCU 5 mutant (4.90 > 3.74 > 3.03 per cent) and in the kernel it was on par between MCU 5 and Suvin but was significantly lower in MCU 5 mutant (1.30 = 1.13 > 0.74 per cent) (Table 13 e and k).

Interaction effects between stages and components showed that within the components over stages the cellulose level varied little in seed coat and kernel while there was significant increase in the lint. Also, lint had significantly higher cellulose content in all the chosen stages, whereas between seed coat and kernel the content remained on par till secondary thickening stage (Table 13 f).

The per cent increase of cellulose in lint between different stages was worked out. In Suvin, it was shown that the per cent increase between elongation and secondary thickening stage was 47.50 while the increase was 67.00 in MCU 5. In between secondary thickening and maturation stage, the increase was 19.00 in Suvin as compared to 17.00 only in MCU 5. When a comparison was made between maturation and post-maturation

Fig. 9. Time trend changes in free amino acid content of seed coat, kernel and lint of Suvin and MCU5 and seed coat and kernel of MCU5 mutant

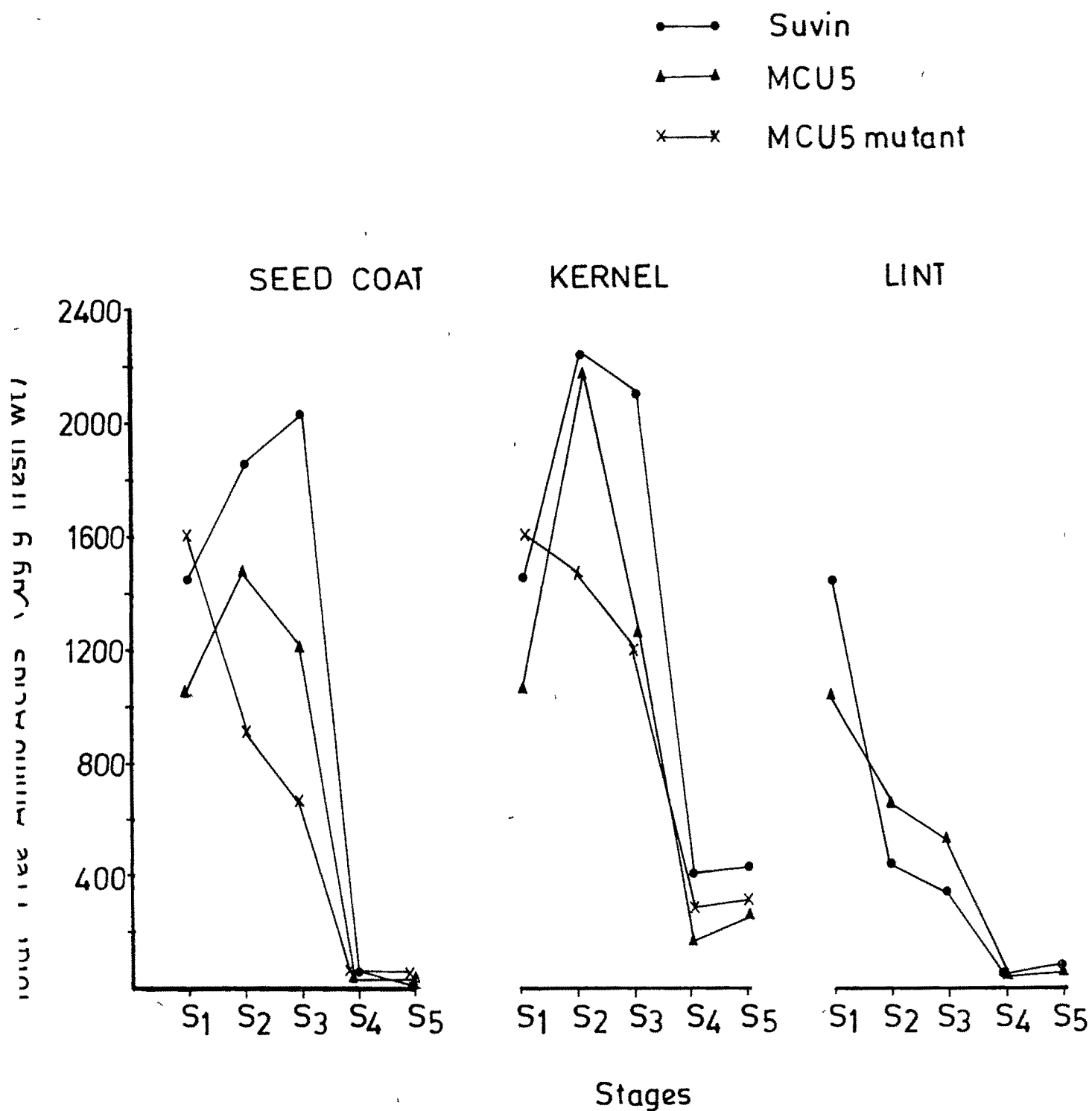


Table 14. Time course changes in total free amino acid content ($\mu\text{g g}^{-1}$ fresh weight) of seed coat, kernel and lint of Suvin and MCU 5 and seed coat and kernel of MCU 5 mutant

a) Genotype		b) Stage		c) Component							
Genotype	Mean	Stage		Mean	Component	Mean					
Suvin (G_1)	837.17	Fibre elongation (S_2)		1477.50	Seed coat (C_1)	838.88					
MCU 5 (G_2)	658.17	Secondary thickening (S_3)		1242.50	Kernel (C_2)	1130.63					
		Maturation (S_4)		124.67	Lint (C_3)	273.50					
		Post-maturation (S_5)		146.00							
SE(m)	7.0698			9.9983		8.6588					
CD(P=0.05)	20.6333			29.1799		25.2705					
d) Genotype x Stage				e) Genotype x Component			f) Stage x Component				
	S_2	S_3	S_4	S_5	C_1	C_2	C_3		C_1	C_2	C_3
G_1	1513.33	1495.00	167.67	172.67	989.50	1293.75	228.25	S_2	1670.00	2215.00	547.50
G_2	1441.67	990.00	81.67	119.33	688.25	967.50	318.75	S_3	1617.50	1672.50	437.50
								S_4	45.00	292.50	36.50
								S_5	23.00	342.50	72.50
SE(m)			14.1397			12.2453				17.3175	
CD(P=0.05)			41.2666			35.7379				50.5411	
g) Genotype		h) Stage		i) Component							
Genotype	Mean	Stage		Mean	Component	Mean					
Suvin (G_1)	1141.63	Fibre elongation (S_2)		1695.00	Seed coat (C_1)	700.50					
MCU 5 (G_2)	827.88	Secondary thickening (S_3)		1412.50	Kernel (C_2)	1027.92					
MCU 5 mutant (G_3)	623.13	Maturation (S_4)		170.00							
		Post-maturation (S_5)		179.33							
SE(m)	7.5130			8.6752		6.1343					
CD(P=0.05)	21.9267			25.3188		17.9031					
j) Genotype x Stage				k) Genotype x Component		l) Stage x Component					
	S_2	S_3	S_4	S_5	C_1	C_2	C_1	C_2			
G_1	2050.00	2067.50	230.00	219.00	989.50	1293.75	S_2	1421.67	1968.33		
G_2	1835.00	1222.50	107.50	146.50	688.25	967.50	S_3	1306.67	1518.33		
G_3	1200.00	947.50	172.50	172.50	423.75	822.50	S_4	46.67	293.33		
							S_5	27.00	331.67		
SE(m)			15.0260		10.6250			12.2687			
CD(P=0.05)			43.8534		31.0090			35.8061			

stages, the increase was found to be 8.00 in Suvin and 0.50 in MCU 5. These distribution pattern clearly indicated that cellulose deposition in MCU 5 occurred at a higher rate during elongation phase while in Suvin it was relatively higher at thickening and also in later stages. Thus cellulose deposition extended for a longer period in Suvin, though the rate of deposition was relatively low.

4.3.3. Total free amino acid content

Mean data on the total free amino acid content during the chosen fibre developmental stages are presented in Table 14 and Fig. 9.

The amino acid content in the ovules of the cotton genotypes during anthesis was high in MCU 5 mutant followed by Suvin and MCU 5 (Annexure III).

The mean amino acid content in the genotypes over the developmental stages (S_2 to S_5) was significantly higher in Suvin, followed by MCU 5 and its mutant (Table 14 g).

The stages mean indicated that the content declined till maturation phase with little variation at post-maturation phase. It was noticed that the decline occurred rapidly between secondary thickening and maturation stages (Table 14 h).

Among the components, amino acid level differed significantly and was high in kernel, followed by seed coat and lint (Table 14 c).

The interaction effects for genotypes and stages indicated that the amino acid content declined rapidly after secondary thickening stage in Suvin whereas in MCU 5 and its mutant it was noticed from the fibre elongation stage itself. It remained on par in the genotypes in later stages. Among the genotypes, the content varied significantly in the order Suvin > MCU 5 > MCU 5 mutant till secondary thickening stage (S_3). During maturation stage (S_4) the amino acid content was in the order Suvin > MCU 5 mutant > MCU 5, whereas at post-maturation (S_5) it was significantly higher in Suvin and remained the same between MCU 5 and its mutant (Table 14 j).

The genotypes and components interaction has shown that in the seed coat and kernel, the amino acid level was in the order Suvin > MCU 5, while in the lint fraction, the content was high in MCU 5 (318.75 μ g) as compared to 223.25 μ g in Suvin. Among the components, the amino acid level was in the order kernel > seed coat > lint (Table 14 e).

The stages and components interaction revealed that the amino acid content declined significantly in all components till maturation stage. In all the chosen stages, the amino acid level

Table 14a. Changes in amino acid composition ($\mu\text{g g}^{-1}$ fresh weight) of ovule, seed coat, kernel and lint of Suvin and MCU 5 and ovule, seed coat and kernel of MCU 5 mutant

Genotype	Amino acid**	Stages of development*													
		Ovule	Seed coat					Kernel				Lint			
		S ₁	S ₂	S ₃	S ₄	S ₅	S ₂	S ₃	S ₄	S ₅	S ₂	S ₃	S ₄	S ₅	
SUVIN	ASP	130	120	70	Tr	Tr	110	100	Tr	Tr	130	60	Tr	-	
	Glu	130	90	50	Tr	Tr	95	70	Tr	-	105	70	20	-	
	Ser	50	90	80	Tr	-	40	50	Tr	-	20	20	Tr	-	
	Arg	75	95	40	Tr	-	50	60	Tr	-	40	Tr	Tr	-	
	Thr	50	85	Tr	Tr	-	30	30	Tr	-	Tr	Tr	Tr	-	
	Total	435	480	240	Tr	-	325	310	Tr	-	295	150	20	-	
MCU 5	ASP	145	105	90	Tr	Tr	115	90	Tr	Tr	140	75	Tr	-	
	Glu	105	85	60	Tr	Tr	110	80	Tr	Tr	100	75	Tr	-	
	Ser	30	55	45	Tr	-	65	45	40	-	25	25	Tr	-	
	Arg	50	100	90	20	-	40	55	40	-	55	35	Tr	-	
	Thr	30	80	20	Tr	-	20	20	Tr	-	Tr	Tr	Tr	-	
	Total	360	425	305	20	-	350	290	80	-	320	210	Tr	-	
MCU 5 mutant	ASP	90	65	25	Tr	-	70	45	Tr	-					
	Glu	85	50	35	Tr	-	60	40	Tr	-					
	Ser	65	75	70	Tr	-	85	60	Tr	-					
	Arg	95	100	60	Tr	-	80	Tr	Tr	-					
	Thr	70	80	40	Tr	-	90	65	Tr	-					
	Total	405	370	230	Tr	-	385	210	Tr	-					

*S₁ = Anthesis; S₂ = Fibre elongation; S₃ = Secondary thickening; S₄ = Maturation
 S₅ = Post maturation stages in Suvin and MCU 5. Seed developmental stages in MCU 5 mutant

** ASP = Aspartate; Glu = Glutamate; Ser = Serine; Arg = Arginine; Thr = Threonine
 Tr = Trace

differed significantly among the components till thickening stage. Later the content was the same between seed coat and lint and was maintained at a higher level in the kernel (Table 14 f).

4.9.3.1. Amino acid composition

Data on the time course changes in the content of aspartic acid, glutamic acid, serine, arginine and threonine during the course of fibre and seed development are given in Table 14a. It was noticed that most of these amino acids were detectable upto secondary thickening stage only. In the remaining stages, they were present mostly in traces.

Aspartic acid emerged out as the prominent amino acid during anthesis in MCU 5, whereas it was present in equal proportion with glutamic acid in Suvin. MCU 5 mutant recorded low aspartate content at this stage. It declined in seed coat and kernel during fibre elongation and secondary thickening stages. MCU 5 mutant had low concentration of it, both in the seed coat and kernel during these stages. In the developing fibre, the level of aspartate remained high in MCU 5 as well as Suvin.

Glutamic acid, another amino acid constituent of major importance was present in higher concentrations during anthesis in the cultivars. It declined and remained more or less equal in

Fig.10. Time trend changes in auxin, gibberellin and abscisic acid like substances in seed cotton of Suvin and MCU5 and seed of MCU5 mutant

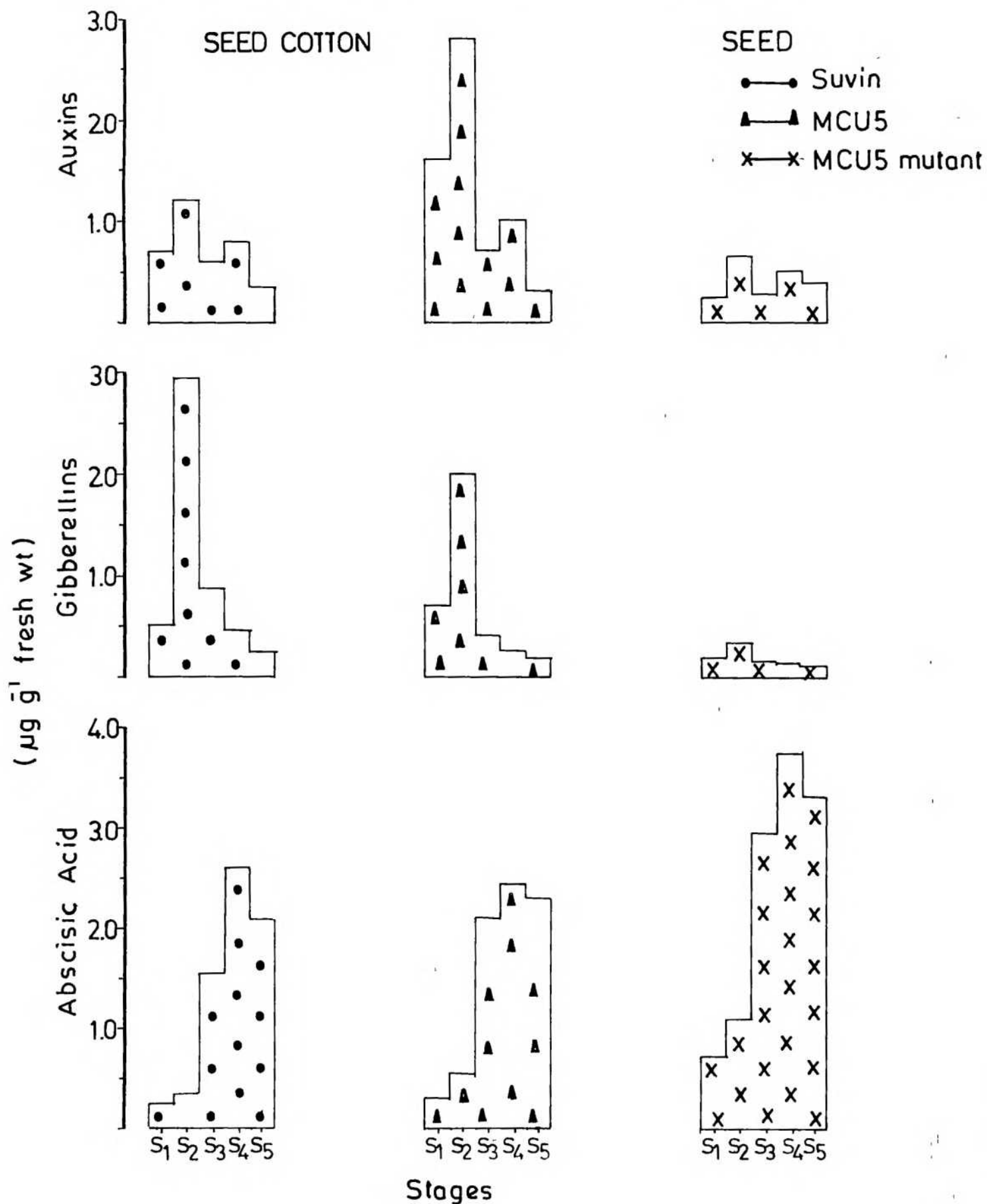


Table 15. Time trend changes in endogenous auxin, gibberellin and abscisic acid like substances ($\mu\text{g g}^{-1}$ fresh weight) in seed-cotton of Suvin and MCU 5 and seed of MCU 5 mutant

Genotype	Stages of development*					Mean
	S ₁	S ₂	S ₃	S ₄	S ₅	
Auxin like substances						
Suvin	0.70	1.22	0.58	0.84	0.34	0.74
MCU 5	1.58	2.78	0.70	1.00	0.30	1.27
MCU 5 mutant	0.24	0.63	0.26	0.50	0.40	0.41
Mean	0.84	1.54	0.51	0.78	0.35	
Gibberellin like substances						
Suvin	0.50	2.93	0.87	0.46	0.23	1.00
MCU 5	0.68	2.00	0.38	0.26	0.20	0.70
MCU 5 mutant	0.21	0.33	0.17	0.14	0.11	0.19
Mean	0.46	1.75	0.47	0.29	0.18	
Abscisic acid like substances						
Suvin	0.25	0.36	1.56	2.61	2.06	1.37
MCU 5	0.31	0.55	2.09	2.43	2.28	1.53
MCU 5 mutant	0.72	1.09	2.93	3.74	3.30	2.36
Mean	0.43	0.67	2.19	2.93	2.55	

*S₁ = Anthesis; S₂ = Fibre elongation

S₃ = Secondary thickening; S₄ = Maturation

S₅ = Post-maturation stages in Suvin and MCU 5

Seed developmental stages in MCU 5 mutant

Savin and MCU 5 in the seed coat and kernel during fibre elongation stages. MCU 5 mutant recorded low level of this amino acid in these seed developmental stages. Glutamate in the lint was found more or less equal in the cultivars. It continued to exist upto maturation phase in Savin as compared to MCU 5.

The other amino acid constituents were serine, arginine and threonine. The relative concentration of these amino acids was generally low in the cultivars.

4.9.4. Growth substances

Data on growth substances in the seed-cotton of Savin and MCU 5 and seed of MCU 5 mutant are presented in Table 15 and Fig. 10. The data pertain to only one replication and hence could not be statistically analysed.

There was considerable difference in the auxin like substances in the cultivars and in MCU 5 mutant. The mean auxin content was higher in MCU 5 (1.27 μg) followed by Savin (0.74 μg) and was low in MCU 5 mutant (0.41 μg). The auxin content increased at fibre elongation phase which later declined during secondary thickening stage. It again registered a rise of lower magnitude at maturation phase. The content later declined during post-maturation stage in all these genotypes.

In all the stages, MCU 5 had marked auxin activity except at post-maturation phase as compared to its mutant and Suvin. In MCU 5 mutant, the auxin status was lower till maturation stage. It was interesting to note that during anthesis and fibre elongation stages, auxin activity in MCU 5 was about twice to that of Suvin.

Gibberellin like substances exhibited different time course trend regarding its endogenous activity. Among the cultivars, gibberellins occurred at a higher level in Suvin (1.00 μg), followed by MCU 5 (0.70 μg) and MCU 5 mutant (0.19 μg). Further, GA activity increased during fibre elongation phase and later declined linearly with the developmental stages. In Suvin, GA like substances were recorded at a higher level in all stages except anthesis. At anthesis, MCU 5 had comparatively more activity. It is of interest to note that higher content of gibberellins during fibre elongation phase was more characterised in Suvin as compared to MCU 5. There was little GA activity in the case of MCU 5 mutant and that too very low in all the seed developmental stages.

Abscissic acid like substances were found to be high in MCU 5 mutant (2.36 μg) followed by MCU 5 (1.53 μg) and Suvin (1.37 μg). The activity increased with the advancement of the chosen stages but decreased at post-maturation stage. It was

Fig.11. Time trend changes in total phenolic content of seed coat, kernel and lint of Suvin and MCU5 and seed coat and kernel of MCU5 mutant

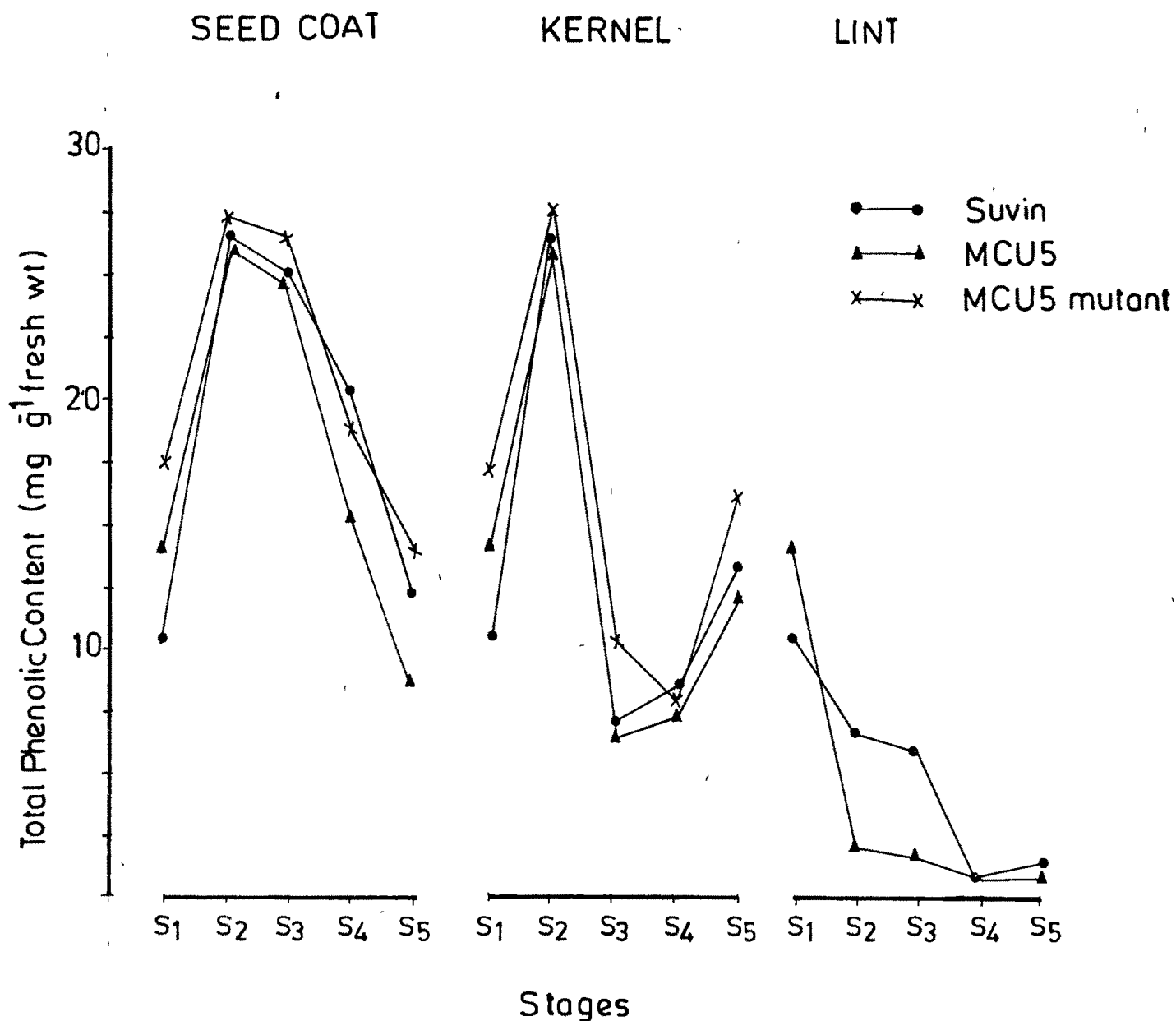


Table 16. Time trend changes in total phenolic content (mg g^{-1} fresh weight) of seed coat, kernel and lint of Suvin and MCU 5 and seed coat and kernel of MCU 5 mutant

a) Genotype		b) Stage		c) Component			
Genotype	Mean	Stage		Mean	Component	Mean	
Suvin (G_1)	1.28	Fibre elongation (S_2)		1.89	Seed coat (C_1)	1.99	
MCU 5 (G_2)	1.10	Secondary thickening (S_3)		1.17	Kernel (C_2)	1.34	
		Maturation (S_4)		0.89	Lint (C_3)	0.26	
		Post-maturation (S_5)		0.82			
SE(m)	0.0231			0.0327		0.0283	
CD(P=0.05)	0.0675			0.0954		0.0827	
d) Genotype x Stage				e) Genotype x Component		f) Stage x Component	
	S_2	S_3	S_4	S_5	C_1	C_2	C_3
G_1	1.98	1.26	0.99	0.91	2.10	1.38	0.37
G_2	1.80	1.09	0.78	0.72	1.87	1.29	0.14
SE(m)	0.0463				0.0401		0.0567
CD(P=0.05)	NS				NS		0.1653
g) Genotype		h) Stage		i) Component			
Genotype	Mean	Stage		Mean	Component	Mean	
Suvin (G_1)	1.74	Fibre elongation (S_2)		2.65	Seed coat (C_1)	2.04	
MCU 5 (G_2)	1.58	Secondary thickening (S_3)		1.66	Kernel (C_2)	1.40	
MCU 5 mutant (G_3)	1.85	Maturation (S_4)		1.30			
		Post maturation (S_5)		1.27			
SE(m)	0.0389			0.0449		0.0318	
CD(P=0.05)	0.1135			0.1311		0.0927	
j) Genotype x Stage				k) Genotype x Component		l) Stage x Component	
	S_2	S_3	S_4	S_5	C_1	C_2	C_3
G_1	2.64	1.59	1.45	1.29	2.10	1.38	0.43
G_2	2.60	1.56	1.13	1.03	1.87	1.29	0.38
G_3	2.72	1.84	1.33	1.49	2.15	1.54	0.08
							0.14
SE(m)	0.0778				0.0550		0.0635
CD(P=0.05)	NS				NS		0.1854

observed that the content was comparatively lower during anthesis and fibre elongation stages, particularly in the cultivars. In the cultivars, the activity remained relatively at a higher level in MCU 5 except at maturation stage. MCU 5 mutant though followed similar trend as found in the cultivars, it had high level of abscisic acid in all the seed developmental stages.

To sum up, the results clearly indicated a sort of specification in the relative activity of phytohormones with regard to fibre development in Suvin and MCU 5. It was demonstrated that auxin activity occurred more abundantly in MCU 5, while endogenous gibberellins had higher activity in Suvin. MCU 5 mutant had a low status of these growth substances in the seed with little variation in their growth promoting activities. Mutant however had high inhibitory activity of abscisic acid like substances during the seed developmental stages.

4.9.5. Total phenolic content

Mean data on phenolics are presented in Table 16 and Fig. 11.

The phenolic content at anthesis was more in MCU 5 mutant followed by MCU 5 and Suvin (Annexure IV).

The mean phenolics in the genotypes over the developmental stages (S_2 to S_5) was in the order MCU 5 mutant = Suvin > MCU 5 (Table 16g).

The stages mean indicated that phenolics declined upto maturation stage with little variation later (Table 16 h).

Among the components, phenolic content varied significantly in the order as seed coat > kernel > lint (Table 16 c).

Interaction effects between genotypes and stages as well as between genotypes and components were non-significant.

Interaction effects between stages and components revealed that in all the components the phenolic content varied with the advancement of stages in the following order:

Seed coat	$S_2 = S_3 > S_4 > S_5$
Kernel	$S_2 > S_3 = S_4 < S_5$
Lint	$S_2 = S_3 > S_4 = S_5$

Within the components, lint had the lowest phenolics in all the developmental stages, whereas between seed coat and kernel a significant difference in the phenolics could be observed from secondary thickening (S_3) onwards. In all these stages, seed coat had significantly higher phenolic content except on post-maturation stage (S_5) (Table 16 f).

Fig.12. Time trend changes in IAA oxidase and peroxidase activity in seed cotton of Suvin and MCU5 and seed of MCU5 mutant

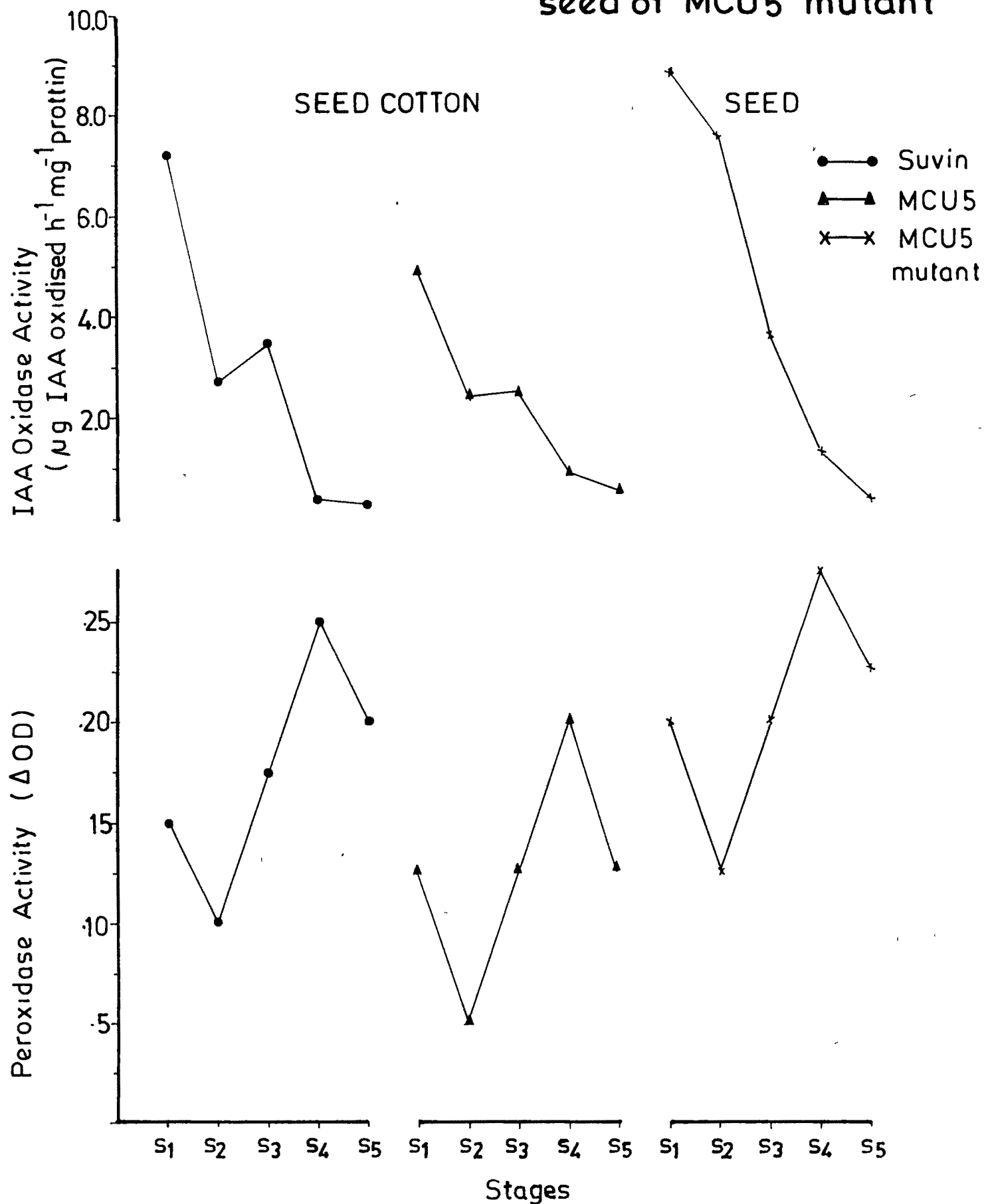


Table 17. Time trend changes in IAA oxidase activity (μg IAA oxidised $\text{h}^{-1} \text{mg}^{-1}$ protein) and peroxidase activity (ΔOD) in seed cotton of Suvin and MCU 5 and seed of MCU 5 mutant

Genotype	Stages of development*					Mean
	S ₁	S ₂	S ₃	S ₄	S ₅	
IAA oxidase activity (μg IAA oxidised $\text{h}^{-1} \text{mg}^{-1}$ protein)						
Suvin	7.16	2.73	3.48	0.44	0.36	2.83
MCU 5	4.92	2.40	2.48	0.93	0.60	2.27
MCU 5 mutant	8.93	7.53	3.59	1.35	0.36	4.35
Mean	7.00	4.22	3.18	0.91	0.44	
	Genotype (G)		Stage (S)		G x S	
SE(m)	0.167		0.216		0.374	
CD(P=0.05)	0.356		0.460		0.797	
Peroxidase activity (Δ OD)						
Suvin	0.150	0.100	0.175	0.250	0.200	0.175
MCU 5	0.125	0.050	0.125	0.200	0.125	0.125
MCU 5 mutant	0.200	0.125	0.200	0.275	0.225	0.205
Mean	0.158	0.092	0.167	0.242	0.183	
	Genotype (G)		Stage (S)		G x S	
SE(m)	0.011		0.014		0.025	
CD(P=0.05)	0.037		0.043		NS	

*S₁ = Anthesis; S₂ = Fibre elongation
 S₃ = Secondary thickening; S₄ = Maturation
 S₅ = Post-maturation stages in Suvin and MCU 5
 Seed developmental stages in MCU 5 mutant

4.9.6. Enzyme status

Data on IAA oxidase and peroxidase activity are given in Table 17 and Fig. 12.

The distribution of IAA oxidase showed a pattern of significant difference in its mean level of activity in Suvin, MCU 5 and MCU 5 mutant in the order MCU mutant > Suvin > MCU 5.

The stages mean indicated that the oxidase activity decreased from anthesis with the advancement of boll age.

Considering the interaction between genotypes and stages, it was noticed that IAA oxidase activity differed significantly among the genotypes during anthesis, but the activity in later stages was mostly on par between the cultivars or between the cultivars and MCU 5 mutant. Among the cultivars, Suvin had the highest activity of this enzyme during anthesis and secondary thickening stages. The activity was relatively higher in MCU 5 from maturation stage onwards, which however remained on par between the cultivars. MCU 5 mutant recorded the highest oxidase activity during anthesis and the next stage as compared to the cultivars.

Comparing the stage intervals with regard to the enzyme activity, the results revealed that IAA oxidase activity decreased markedly during fibre elongation stage in both the cultivars. Later, it increased considerably in Suvin during

secondary thickening stage, whereas it remained on par with the early stage in MCU 5. The activity declined at a faster rate during maturation phase and this trend remained on par with the post-maturation stage in both the cultivars. In MCU 5 mutant, this enzyme showed overall higher activity which declined right from anthesis and continued to decline significantly in all the chosen stages.

Peroxidase activity had characteristic identify to IAA oxidase during initial stages of fibre development, but depicted a different pattern in its activity in the later stages. The results clearly established significant difference in this enzyme system among the genotypes under study.

The mean peroxidase activity in the genotypes was low in MCU 5 ($0.125 \triangle OD$) as against Suvin ($0.175 \triangle OD$) and was prominently on the higher side in MCU 5 mutant ($0.205 \triangle OD$).

The stages mean point out that during anthesis, the enzyme remained at a higher level and declined distinctly during fibre elongation stage. The enzyme activity later increased markedly during secondary thickening and maturation stages and had considerable decline during post-maturation stage in the cultivars as well as MCU 5 mutant.

The interactions between genotypes and stages were found to be non-significant.

Fig 13 Time trend changes in nitrogen, phosphorous, potassium and calcium content of seed coat, kernel and lint of Suvin and MCU5 and seed coat and kernel of MCU5 mutant

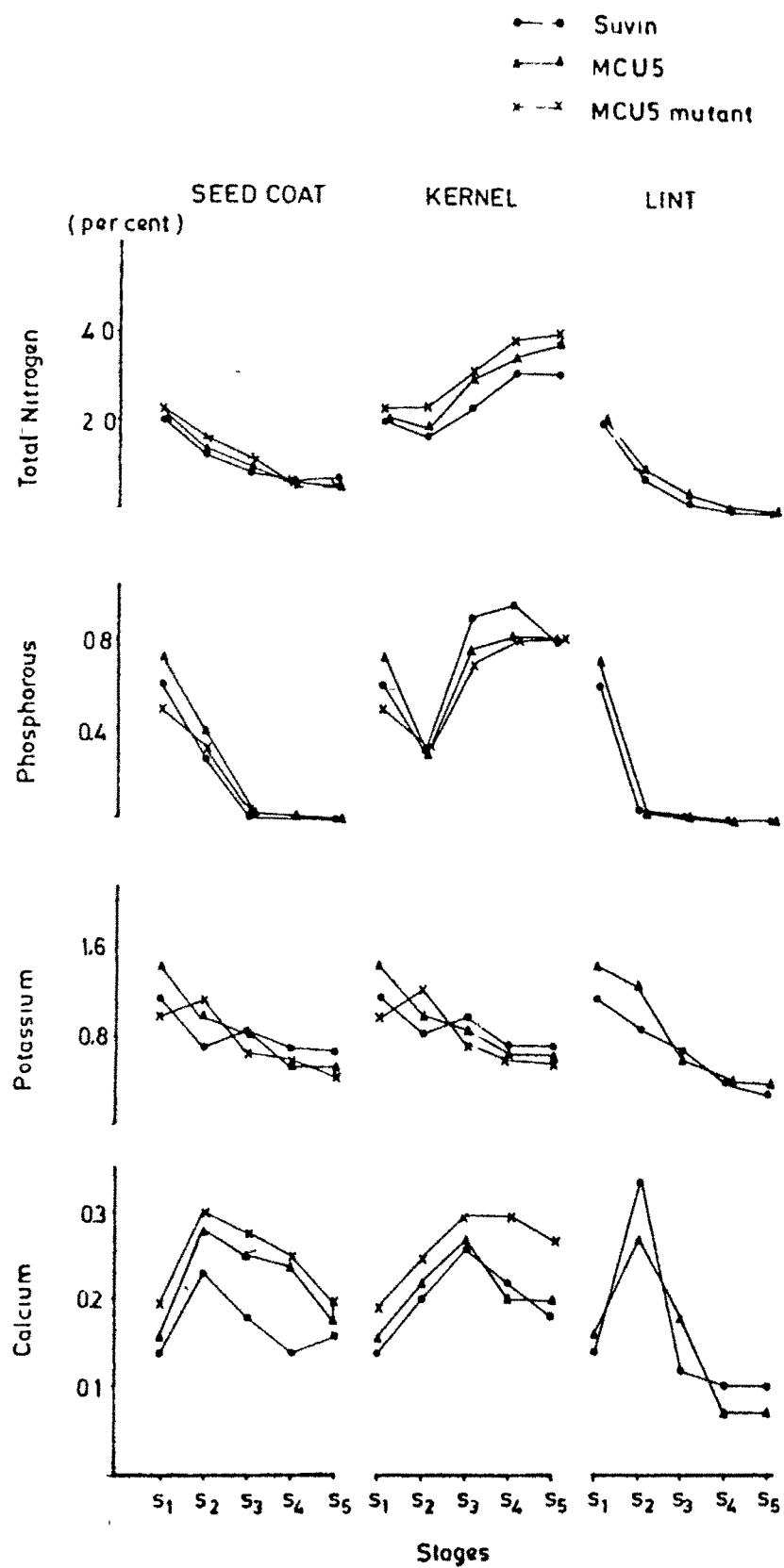


Table 18. Time trend changes in total nitrogen content (per cent) of seed coat, kernel and lint of Suvin and MCU 5 and seed coat and kernel of MCU 5 mutant

a) Genotype		b) Stage		c) Component							
Genotype	Mean	Stage		Mean	Component	Mean					
Suvin (G_1)	1.26	Fibre elongation (S_2)		1.33	Seed coat (C_1)	0.87					
MCU 5 (G_2)	1.45	Secondary thickening (S_3)		1.33	Kernel (C_2)	2.86					
		Maturation (S_4)		1.35	Lint (C_3)	0.34					
		Post maturation (S_5)		1.40							
SE(m)	0.1114			0.1575		0.1364					
CD(P=0.05)	NS			NS		0.3981					
d) Genotype x Stage				e) Genotype x Component			f) Stage x Component				
	S_2	S_3	S_4	S_5	C_1	C_2	C_3		C_1	C_2	C_3
G_1	1.23	1.16	1.31	1.32	0.88	2.62	0.27	S_2	1.32	1.93	0.86
G_2	1.44	1.50	1.39	1.49	0.86	3.09	0.41	S_3	0.92	2.72	0.36
								S_4	0.60	3.36	0.09
								S_5	0.66	3.51	0.07
SE(m)	0.2227				0.1929				0.2728		
CD(P=0.05)	NS				NS				0.7962		
g) Genotype		h) Stage		i) Component							
Genotype	Mean	Stage		Mean	Component	Mean					
Suvin (G_1)	1.75	Fibre elongation (S_2)		1.72	Seed coat (C_1)	0.92					
MCU 5 (G_2)	1.98	Secondary thickening (S_3)		1.96	Kernel (C_2)	3.04					
MCU 5 mutant (G_3)	2.22	Maturation (S_4)		2.08							
		Post maturation (S_5)		2.17							
SE(m)	0.1473			0.1701		0.1203					
CD(P=0.05)	NS			NS		0.3510					
j) Genotype x Stage				k) Genotype x Component			l) Stage x Component				
	S_2	S_3	S_4	S_5	C_1	C_2		C_1	C_2		
G_1	1.49	1.63	1.93	1.95	0.88	2.62	S_2	1.43	2.00		
G_2	1.66	2.01	2.03	2.21	0.86	3.09	S_3	1.04	2.88		
G_3	2.01	2.24	2.27	2.35	1.03	3.40	S_4	0.60	3.55		
							S_5	0.63	3.71		
SE(m)	0.2946				0.2083			0.2405			
CD(P=0.05)	NS				NS			0.7019			

4.9.7. Total nitrogen content

Mean data on total nitrogen content are given in Table 18 and Fig. 13.

Total nitrogen in the ovules at anthesis was high in MCU 5 mutant, followed by MCU 5 and Suvin (Annexure V).

The mean nitrogen content of genotypes and stages (S_2 to S_5) were found to be non-significant.

Among the components, nitrogen content varied in the order Kernel > seed coat > lint (Table 18 c).

Interaction effects between genotypes and stages as well as genotypes and components were found to be non significant.

Interaction effects between stages and components indicated that the nitrogen content declined in seed coat and lint whereas it increased in the kernel in the chosen stages. However, the trend was on par in between the stages in seed coat and lint, while in kernel, the increase in nitrogen was significant between S_2 and S_3 stages. The content was significantly high in kernel in all the stages while the difference was not marked between seed coat and lint in any of the chosen stages (Table 18 f).

Table 19. Time trend changes in phosphorus content (per cent) of seed coat, kernel and lint of Suvin and MCU 5 and seed coat and kernel of MCU 5 mutant

a) Genotype		b) Stage		c) Component		
Genotype	Mean	Stage	Mean	Component	Mean	
Suvin (G ₁)	0.37	Fibre elongation (S ₂)	0.36	Seed coat (C ₁)	0.16	
MCU 5 (G ₂)	0.34	Secondary thickening (S ₃)	0.41	Kernel (C ₂)	0.73	
		Maturation (S ₄)	0.35	Lint (C ₃)	0.17	
		Post-maturation (S ₅)	0.29			
SE(m)	0.0039		0.0056			0.0048
CD(P=0.05)	0.0115		0.0163			0.0141

d) Genotype x Stage					e) Genotype x Component			f) Stage x Component		
	S ₂	S ₃	S ₄	S ₅		C ₁	C ₂	C ₃		
G ₁	0.35	0.45	0.39	0.29		0.15	0.76	0.19	S ₂	0.36 0.32 0.42
G ₂	0.38	0.37	0.30	0.29		0.17	0.69	0.15	S ₃	0.18 0.85 0.21
									S ₄	0.08 0.92 0.04
									S ₅	0.03 0.82 0.03
SE(m)			0.0079				0.0068			0.0097
CD(P=0.05)			0.0231				0.0200			0.0283

g) Genotype		h) Stage		i) Component		
Genotype	Mean	Stage	Mean	Component	Mean	
Suvin (G ₁)	0.46	Fibre elongation (S ₂)	0.33	Seed coat (C ₁)	0.16	
MCU 5 (G ₂)	0.43	Secondary thickening (S ₃)	0.49	Kernel (C ₂)	0.72	
MCU 5 mutant (G ₃)	0.44	Maturation (S ₄)	0.49			
		Post maturation (S ₅)	0.42			
SE(m)	0.0052		0.0060			0.0043
CD(P=0.05)	0.0152		0.0176			0.0125

j) Genotype x Stage					k) Genotype x Component		l) Stage x Component	
	S ₂	S ₃	S ₄	S ₅		C ₁	C ₂	
G ₁	0.31	0.54	0.56	0.42		0.15	0.76	S ₂ 0.35 0.32
G ₂	0.37	0.49	0.44	0.43		0.17	0.69	S ₃ 0.18 0.80
G ₃	0.33	0.45	0.47	0.42		0.16	0.71	S ₄ 0.09 0.89
								S ₅ 0.02 0.82
SE(m)			0.0105				0.0074	0.0085
CD(P=0.05)			0.0305				0.0216	0.0249

4.9.8. Phosphorus content

Data on phosphorus content are presented in Table 19 and Fig. 13.

A perusal of data point out that the phosphorus content was high in MCU 5, followed by Savin and MCU 5 mutant in the ovules at anthesis (Annexure VI).

The mean phosphorus content of genotypes over the chosen stages was in the order Savin > MCU 5 mutant = MCU 5 (Table 19 g).

The stages mean indicated that the phosphorus content increased significantly till thickening stage and later declined (Table 19 h).

Among the components, the phosphorus status was in the order kernel > Lint = Seed coat (Table 19 e).

Interaction effects between genotypes and stages showed that the phosphorus content increased significantly till thickening stage and later continued to remain in the same level till maturation in seed coat and lint, while it declined significantly in kernel at this stage. Later it declined significantly in seed coat and lint only. Similarly, among the genotypes the trend was in the following order (Table 19 j).

Table 20. Time trend changes in potassium content (per cent) of seed coat, kernel and lint of Suvin and MCU 5 and seed coat and kernel of MCU 5 mutant

a) Genotype		b) Stage		c) Component							
Genotype	Mean	Stage		Mean	Component	Mean					
Suvin (G_1)	0.73	Fibre elongation (S_2)		0.98	Seed coat (C_1)	0.75					
MCU 5 (G_2)	0.76	Secondary thickening (S_3)		0.83	Kernel (C_2)	0.84					
		Maturation (S_4)		0.60	Lint (C_3)	0.66					
		Post-maturation (S_5)		0.56							
SE(m)	0.0092			0.0130		0.0112					
CD(P=0.05)	0.0268			0.0379		0.0328					
d) Genotype x Stage				e) Genotype x Component			f) Stage x Component				
	S_2	S_3	S_4	S_5	C_1	C_2	C_3		C_1	C_2	C_3
G_1	0.83	0.88	0.64	0.57	0.74	0.87	0.59	S_2	0.87	0.95	1.14
G_2	1.14	0.78	0.57	0.55	0.75	0.81	0.72	S_3	0.83	0.97	0.69
								S_4	0.65	0.74	0.43
								S_5	0.62	0.70	0.37
SE(m)			0.0184			0.0159			0.0225		
CD(P=0.05)			0.0536			0.0464			0.0656		
g) Genotype		h) Stage		i) Component							
Genotype	Mean	Stage		Mean	Component	Mean					
Suvin (G_1)	0.81	Fibre elongation (S_2)		1.01	Seed coat (C_1)	0.74					
MCU 5 (G_2)	0.78	Secondary thickening (S_3)		0.84	Kernel (C_2)	0.83					
MCU 5 mutant (G_3)	0.78	Maturation (S_4)		0.67							
		Post-maturation (S_5)		0.62							
SE(m)	0.0127			0.0147		0.0104					
CD(P=0.05)	NS			0.0430		0.0303					
j) Genotype x Stage				k) Genotype x Component			l) Stage x Component				
	S_2	S_3	S_4	S_5	C_1	C_2		C_1	C_2		
G_1	0.80	0.96	0.75	0.71	0.74	0.87	S_2	0.97	1.05		
G_2	1.02	0.84	0.64	0.62	0.75	0.81	S_3	0.78	0.91		
G_3	1.22	0.73	0.64	0.55	0.74	0.82	S_4	0.64	0.71		
							S_5	0.58	0.66		
SE(m)			0.0254		0.0180			0.0207			
CD(P=0.05)			0.0742		NS			NS			

- S₂ MCU 5 > MCU 5 mutant = Suvin
- S₃ Suvin > MCU 5 > MCU 5 mutant
- S₄ Suvin > MCU 5 mutant = MCU 5
- S₅ MCU 5 = MCU 5 mutant = Suvin

Interaction between genotypes and components were also significant.

Interaction between stages and components indicated that in seed coat, the phosphorous content declined significantly at all stages while in kernel it increased significantly upto maturation and later declined. In the lint, the decline in phosphorus continued significantly till maturation stage with little difference in the subsequent stage. In all the chosen stages, the phosphorus content differed significantly in these components, except at post-maturation stage, when seed coat and lint phosphorus were found to be alike (Table 19 f).

4.9.9. Potassium content

Data on potassium content are given in Table 20 and Fig. 13.

At anthesis, potassium remained high in MCU 5 (1.47 per cent) followed by Suvin (1.19 per cent) and MCU 5 mutant (1.04 per cent) (Annexure VII).

Mean of cultivars over the stages was non-significant.

The stages mean indicated that potassium content declined progressively till post-maturation stage (Table 20 h).

Table 21. Time trend changes in calcium content (per cent) of seed coat, kernel and lint of Suvin and MCU 5 and seed coat and kernel of MCU 5 mutant

a) Genotype		b) Stage		c) Component	
Genotype	Mean	Stage	Mean	Component	Mean
Suvin (G_1)	0.19	Fibre elongation (S_2)	0.26	Seed coat (C_1)	0.21
MCU 5 (G_2)	0.20	Secondary thickening (S_3)	0.21	Kernel (C_2)	0.22
		Maturation (S_4)	0.16	Lint (C_3)	0.16
		Post-maturation (S_5)	0.15		
SE(m)	0.0051		0.0073		0.0063
CD(P=0.05)	0.0150		0.0212		0.0183

d) Genotype x Stage				e) Genotype x Component			f) Stage x Component				
	S_2	S_3	S_4	S_5	C_1	C_2	C_3		C_1	C_2	C_3
G_1	0.26	0.19	0.15	0.15	0.18	0.22	0.17	S_2	0.26	0.21	0.31
G_2	0.26	0.23	0.17	0.15	0.24	0.22	0.15	S_3	0.22	0.27	0.15
								S_4	0.19	0.21	0.09
								S_5	0.17	0.19	0.09
SE(m)	0.0103				0.0089				0.0013		
CD(P=0.05)	NS				0.0260				0.0367		

g) Genotype		h) Stage		i) Component	
Genotype	Mean	Stage	Mean	Component	Mean
Suvin (G_1)	0.20	Fibre elongation (S_2)	0.25	Seed coat (C_1)	0.23
VCU 5 (G_2)	0.23	Secondary thickening (S_3)	0.26	Kernel (C_2)	0.24
VCU 5 mutant (G_3)	0.27	Maturation (S_4)	0.23		
		Post-maturation (S_5)	0.20		
SE(m)	0.0079		0.0092		0.0065
CD(P=0.05)	0.0232		0.0267		NS

j) Genotype x Stage				k) Genotype x Component		l) Stage x Component			
	S_2	S_3	S_4	S_5	C_1	C_2		C_1	C_2
G_1	0.22	0.22	0.18	0.17	0.18	0.22	S_2	0.27	0.22
G_2	0.25	0.26	0.22	0.19	0.24	0.22	S_3	0.24	0.28
G_3	0.28	0.29	0.28	0.24	0.26	0.28	S_4	0.21	0.24
							S_5	0.18	0.22
SE(m)	0.0159				0.0112			0.0130	
CD(P=0.05)	NS				NS			0.0378	

Among the components, the potassium status was high in kernel, followed by seed coat and lint (Table 20 c).

Interaction effects between genotypes and stages indicated that the potassium content declined significantly in all the stages in MCU 5 mutant, while in MCU 5 the declining trend was the same between S_4 and S_5 stages. In Suvin, the content increased significantly at S_3 and later declined. Among them, the stage differences were well marked till secondary thickening stage only (Table 20 j).

Interaction between genotypes and components indicated that the potassium content varied little in the seed coat of the cultivars. It was high in the kernel of Suvin while in lint it was found to be high in MCU 5 (Table 20 e).

Interaction between stages and components indicated that the potassium content declined with little variation between stages in seed coat, while in the case of lint, potassium declined significantly in all the stages. In the kernel, potassium content increased till S_3 without any change and later declined. In all the stages, the level of potassium significantly differed among these components (Table 20 f).

4.9.10. Calcium content

Mean data on calcium content are presented in Table 21 and Fig. 13.

The mean calcium content was highest in MCU 5 mutant followed by MCU 5 and Suvin in the ovules at the time of anthesis (Annexure VIII).

The mean calcium content in the genotypes over the stages (S_2 to S_5) revealed that calcium was significantly higher in MCU 5 mutant over MCU 5 and Suvin (Table 21 g).

Mean of stages indicated that the calcium content remained without any change till secondary thickening stage (S_3) and later declined (Table 21 h).

Among the components, the calcium level was in the order kernel = seed coat > lint (Table 21 c).

Interaction effects between genotypes and stages were not significant.

Interaction between genotypes and component point out that the calcium content was high in the seed coat in MCU 5 while the level in kernel and lint was similar in both the cultivars (Table 21 e).

Interaction between stages and components was significant. It was noticed that the calcium content declined significantly till maturation stage (S_4) and thereafter it remained on par both in seed coat and lint. In kernel, on the other hand, calcium content increased significantly till

Fig 14 Time trend changes in zinc, manganese and iron content of seed coat, kernel and lint of Suvin and MCU5 and seed coat and kernel of MCU5 mutant

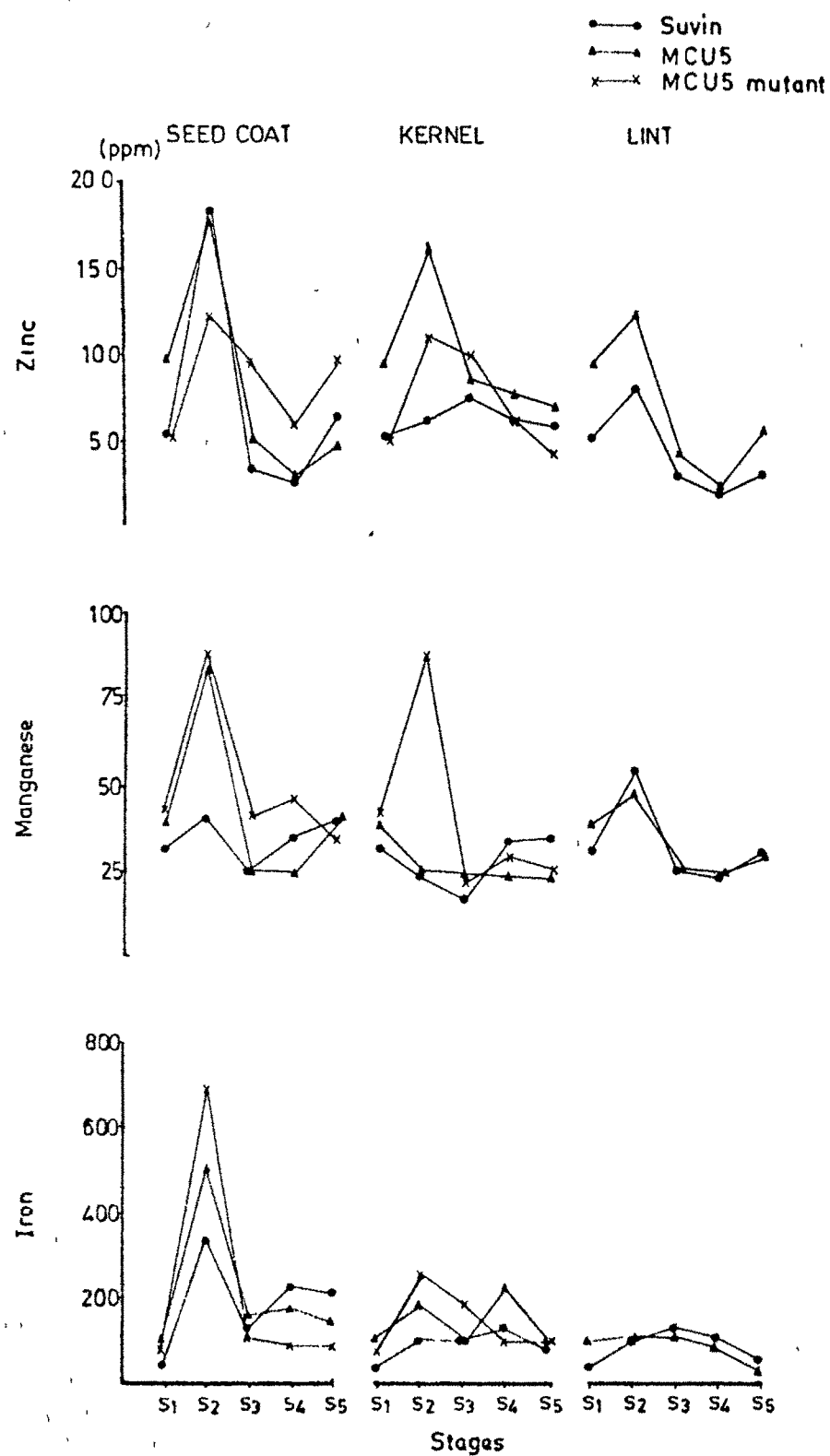


Table 22. Time trend changes in zinc content (ppm) of seed coat, kernel and lint of Suvin and MCU 5 and seed coat and kernel of MCU 5 mutant

a) Genotype		b) Stage		c) Component		
Genotype	Mean	Stage	Year	Component	Mean	
Suvin (G ₁)	62.58	Fibre elongation (S ₂)	133.08	Seed coat (C ₁)	77.16	
MCU 5 (G ₂)	80.57	Secondary thickening (S ₃)	54.59	Kernel (C ₂)	84.22	
		Maturation (S ₄)	42.08	Lint (C ₃)	53.35	
		Post-maturation (S ₅)	56.54			
SE(m)	2.3580		3.3347			2.8879
CD(P=0.05)	6.8818		9.7323			8.4284

d) Genotype x Stage				e) Genotype x component			f) Stage x Component		
	S ₂	S ₃	S ₄	S ₅	C ₁	C ₂	C ₃		
G ₁	110.33	48.33	38.33	53.33	77.13	67.81	42.81	S ₂	180.50 113.75 105.00
G ₂	155.83	60.83	45.83	59.75	77.19	100.63	63.88	S ₃	43.15 81.98 38.13
								S ₄	28.75 13.75 23.75
								S ₅	55.63 67.50 46.50
SE(m)		4.7160				4.0842			5.7759
CD(P=0.05)		13.7636				11.9196			16.8569

g) Genotype		h) Stage		i) Component		
Genotype	Mean	Stage	Mean	Component	Mean	
Suvin (G ₁)	72.47	Fibre elongation (S ₂)	137.04	Seed coat (C ₁)	82.72	
MCU 5 (G ₂)	88.91	Secondary thickening (S ₃)	75.17	Kernel (C ₂)	83.33	
MCU 5 mutant (G ₃)	87.71	Maturation (S ₄)	54.90			
		Post-maturation (S ₅)	65.00			
SE(m)	3.1183		3.6007			2.5460
CD(P=0.05)	9.1007		10.5086			NS

j) Genotype x Stage				k) Genotype x Component		l) Stage x Component	
	S ₂	S ₃	S ₄	S ₅	C ₁	C ₂	
G ₁	124.25	56.25	46.25	63.13	77.13	67.81	S ₂ 160.75 113.33
G ₂	170.00	69.38	56.25	60.00	77.19	100.63	S ₃ 61.58 88.75
G ₃	116.88	99.88	62.20	71.88	93.85	81.56	S ₄ 38.97 70.83
							S ₅ 69.58 60.42
SE(m)		6.2366			4.4099		5.0922
CD(P=0.05)		18.2015			12.8704		14.8615

secondary thickening (S_3) and decreased subsequently. The calcium content in the components differed significantly in the order lint > seed coat > kernel at fibre elongation stage (S_2) and at secondary thickening (S_3) stage it varied as kernel > seed coat > lint. Later it was on par in seed coat and kernel but was significantly lower in the lint (Table 21 f).

4.9.11. Zinc content

Mean data for zinc content are given in Table 22 and Fig. 14.

This nutrient element was maintained high in MCV 5 (97.75 ppm) followed by Suvin (55.00 ppm) and MCV 5 mutant (53.75 ppm) at anthesis (Annexure IX).

Mean zinc level in the genotypes over the chosen stages (S_2 to S_5) was in the order MCV 5 = MCV 5 mutant > Suvin (Table 22 g).

Stages mean indicated that the zinc level decreased significantly till maturation stages and later remained unaltered (Table 22 h).

Components mean of Zn content was in the order kernel = seed coat > lint (Table 22 c).

Interaction between genotypes and stages point out that the zinc content declined rapidly immediately after fibre elongation stage and thereafter it remained the same in Suvin

and MCU 5. In MCU 5 mutant, the decline in zinc content was noticed from secondary thickening stage only. Comparing the zinc content between genotypes within a stage it was found to be in the order as MCU 5 > Suvin = MCU 5 mutant at fibre elongation stage. During secondary thickening stage, MCU 5 mutant had the highest zinc content, whereas it did not differ between the cultivars. In rest of the stages, no difference could be noticed among them with regard to zinc content (Table 22 j).

Interaction between genotypes and components indicated that the zinc content in seed coat was more or less the same between the cultivars. In kernel and lint, significantly higher zinc content was recorded in MCU 5 (100.63 and 63.88 ppm respectively) as compared to 67.81 and 42.81 ppm respectively in Suvin (Table 22 e).

Interaction between stages and components indicated that zinc content declined significantly till secondary thickening stage (S_3) in seed coat and lint. Later, it was found to be on par between S_3 and S_4 stages. There was significant increase in its content at post-maturation stage (S_5). In kernel too, zinc level decreased significantly till secondary thickening stage. However, it did not show any variation in later stages. Considering the content in the components within a stage, zinc content was significantly higher in the seed coat at fibre elongation stage. On the other hand, kernel and lint

Table 23. Time trend changes in manganese content (ppm) of seed coat, kernel and lint of Suvin and MCU 5 and seed coat and kernel of MCU 5 mutant

a) Genotype		b) Stage		c) Component							
Genotype	Mean	Stage		Mean	Component	Mean					
Suvin (G ₁)	32.56	Fibre elongation (S ₂)		46.67	Seed coat (C ₁)	39.07					
MCU 5 (G ₂)	33.54	Secondary thickening (S ₃)		24.03	Kernel (C ₂)	26.25					
		Maturation (S ₄)		27.35	Lint (C ₃)	33.85					
		Post-maturation (S ₅)		34.16							
SE(m)	0.2876			0.4067		0.5522					
CD(P=0.05)	0.8394			1.1871		1.0210					
d) Genotype x Stage		e) Genotype x Component			f) Stage x Component						
	S ₂	S ₃	S ₄	S ₅	C ₁	C ₂	C ₃		C ₁	C ₂	C ₃
G ₁	40.83	22.78	30.53	36.10	35.00	27.70	34.99	S ₂	62.50	25.00	52.50
G ₂	52.50	25.28	24.17	32.22	43.13	24.79	32.71	S ₃	25.00	21.25	25.85
								S ₄	28.33	29.15	24.58
								S ₅	40.43	29.58	32.48
SE(m)		0.5752				0.4981				0.7045	
CD(P=0.05)		1.6788				1.4538				2.0560	
g) Genotype		h) Stage		i) Component							
Genotype	Mean	Stage		Mean	Component	Mean					
Suvin (G ₁)	31.35	Fibre elongation (S ₂)		59.72	Seed coat (C ₁)	43.75					
MCU 5 (G ₂)	33.96	Secondary thickening (S ₃)		26.12	Kernel (C ₂)	31.94					
MCU 5 mutant (G ₃)	48.22	Maturation (S ₄)		32.24							
		Post-maturation (S ₅)		33.33							
SE(m)	0.9493			1.0962		0.7751					
CD(P=0.05)	2.7706			3.1992		2.2622					
j) Genotype x Stage		k) Genotype x Component			l) Stage x Component						
	S ₂	S ₃	S ₄	S ₅	C ₁	C ₂		C ₁	C ₂		
G ₁	32.93	21.25	33.73	37.50	35.00	27.70	S ₂	72.22	47.22		
G ₂	54.58	25.00	23.75	32.50	43.13	24.79	S ₃	30.28	21.95		
G ₃	91.65	32.10	39.25	29.98	53.11	43.33	S ₄	34.50	29.98		
							S ₅	38.05	28.60		
SE(m)		1.8987				1.3426			1.5502		
CD(P=0.05)		5.5412				3.9182			4.5244		

possessed more or less same content. During thickening and maturation stages, it was significantly higher in kernel, but was on par between seed coat and lint. At post-maturation stage, zinc content was found to be same in all these components (Table 22 f).

4.9.12. Manganese content

Mean data on manganese content are presented in Table 23 and Fig. 14.

Manganese status during the time of anthesis was more or less same in MCU 5 mutant and MCU 5 and was higher than Suvin (Annexure X).

The mean manganese content in the genotypes over the stages was significantly higher in MCU 5 mutant (43.22 ppm) while it was 33.96 and 31.35 ppm in MCU 5 and Suvin which was on par between them (Table 23 g).

The stages mean indicated that the level of manganese declined rapidly during secondary thickening stage (S_3) and later it increased and remained on par during maturation and post-maturation phase (Table 23 h).

Among the components, the manganese status varied significantly in the order seed coat > lint > kernel (Table 23 c).

Interaction effects between genotypes and stages indicated that the manganese content declined significantly from fibre elongation stage (S_2) onwards till secondary thickening (S_3) in all the genotypes. Later it increased significantly in Suvin and MCU 5 mutant, while in MCU 5 there was little change in the content at this stage. During post-maturation stage (S_5), manganese content remained without any change in Suvin, increased significantly in MCU 5 and declined in MCU 5 mutant. Among the genotypes, manganese content significantly varied in the chosen stages in the following order (Table 23 f).

$$S_2 = \text{MCU 5 mutant} > \text{MCU 5} > \text{Suvin}$$

$$S_3 = \text{MCU 5 mutant} > \text{MCU 5} = \text{Suvin}$$

$$S_4 = \text{MCU 5 mutant} = \text{Suvin} > \text{MCU 5}$$

$$S_5 = \text{Suvin} = \text{MCU 5} = \text{MCU 5 mutant}$$

Interaction between genotypes and components indicated that the manganese content was maintained high in seed coat, followed by lint and kernel. Among the cultivars, the kernel and lint of Suvin had the highest manganese level (Table 23 e).

Interaction between stages and components point out that the manganese content in seed coat declined significantly till secondary thickening stage (S_3) and later increased progressively till post-maturation stage. More or less similar changes were noticed in kernel also. In lint, it declined till

Table 24. Time trend changes in iron content (ppm) of seed coat, kernel and lint of Suvin and MCU 5 and seed coat and kernel of MCU 5 mutant

a) Genotype		b) Stage		c) Component							
Genotype	Mean	Stage		Mean	Component	Mean					
Suvin (G ₁)	147.25	Fibre elongation (S ₂)		226.65	Seed coat (C ₁)	239.07					
MCU 5 (G ₂)	164.45	Secondary thickening (S ₃)		124.70	Kernel (C ₂)	132.24					
		Maturation (S ₄)		166.37	Lint (C ₃)	96.24					
		Post-maturation (S ₅)		107.67							
SE(m)	15.8703			22.4401		19.4371					
CD(P=0.05)	NS			65.5029		56.7272					
d) Genotype x Stage				e) Genotype x Component		f) Stage x Component					
	S ₂	S ₃	S ₄	S ₅	C ₁	C ₂	C ₃		C ₁	C ₂	C ₃
G ₁	183.90	123.33	161.68	120.07	228.35	109.16	104.23	S ₂	425.03	149.93	105.00
G ₂	269.40	126.07	171.05	95.27	249.79	155.31	88.24	S ₃	145.00	105.00	124.10
								S ₄	205.83	175.85	107.43
								S ₅	180.43	91.18	48.40
SE(m)			31.7407			27.4882				38.8742	
CD(P=0.05)			NS			NS				113.4543	
g) Genotype		h) Stage		i) Component							
Genotype	Mean	Stage		Mean	Component	Mean					
Suvin (G ₁)	168.76	Fibre elongation (S ₂)		349.98	Seed coat (C ₁)	241.85					
MCU 5 (G ₂)	202.55	Secondary thickening (S ₃)		134.14	Kernel (C ₂)	143.43					
MCU 5 mutant (G ₃)	206.62	Maturation (S ₄)		164.42							
		Post-maturation (S ₅)		124.03							
SE(m)	18.3793			21.2225		15.0066					
CD(P=0.05)	NS			61.9379		43.7967					
j) Genotype x Stage				k) Genotype x Component		l) Stage x Component					
	S ₂	S ₃	S ₄	S ₅	C ₁	C ₂		C ₁	C ₂		
G ₁	224.18	118.33	184.18	148.35	228.35	109.16	S ₂	511.13	188.83		
G ₂	350.78	131.68	207.50	126.25	249.79	155.31	S ₃	134.95	133.33		
G ₃	475.00	152.43	101.58	97.48	247.41	165.83	S ₄	169.93	158.90		
							S ₅	151.38	96.67		
SE(m)			36.7585			25.9922			30.0132		
CD(P=0.05)			107.2796			NS			87.5794		

maturation stage (S_4) and increased significantly later (Table 23 f). Considering the manganese content among the components within a stage, it was significantly higher in seed coat followed by lint and kernel at fibre elongation (S_2) and post-maturation stages (S_5). During the secondary thickening stage (S_3), the manganese content in seed coat and lint was more or less the same but significantly more than in kernel. On the other hand during maturation stage (S_4) it remained on par between seed coat and kernel but was significantly lower in lint.

4.9.13. Iron content

Mean data on iron content are given in Table 24 and Fig. 14.

Iron content was high in WCU 5 followed by WCU 5 mutant and Juvin during anthesis (Annexure XI).

The mean iron content in the genotypes over the chosen stages was non-significant (Table 24 g).

Stages mean indicated that the iron level declined significantly at secondary thickening stage (S_3) and remained more or less the same in the subsequent stages (Table 24 h).

Components mean indicated that iron content was in the order kernel = lint > seed coat (Table 24 c).

Fig.15. Time trend changes in total protein content of seed coat, kernel and lint of Suvin and MCU5 and seed coat and kernel of MCU5 mutant

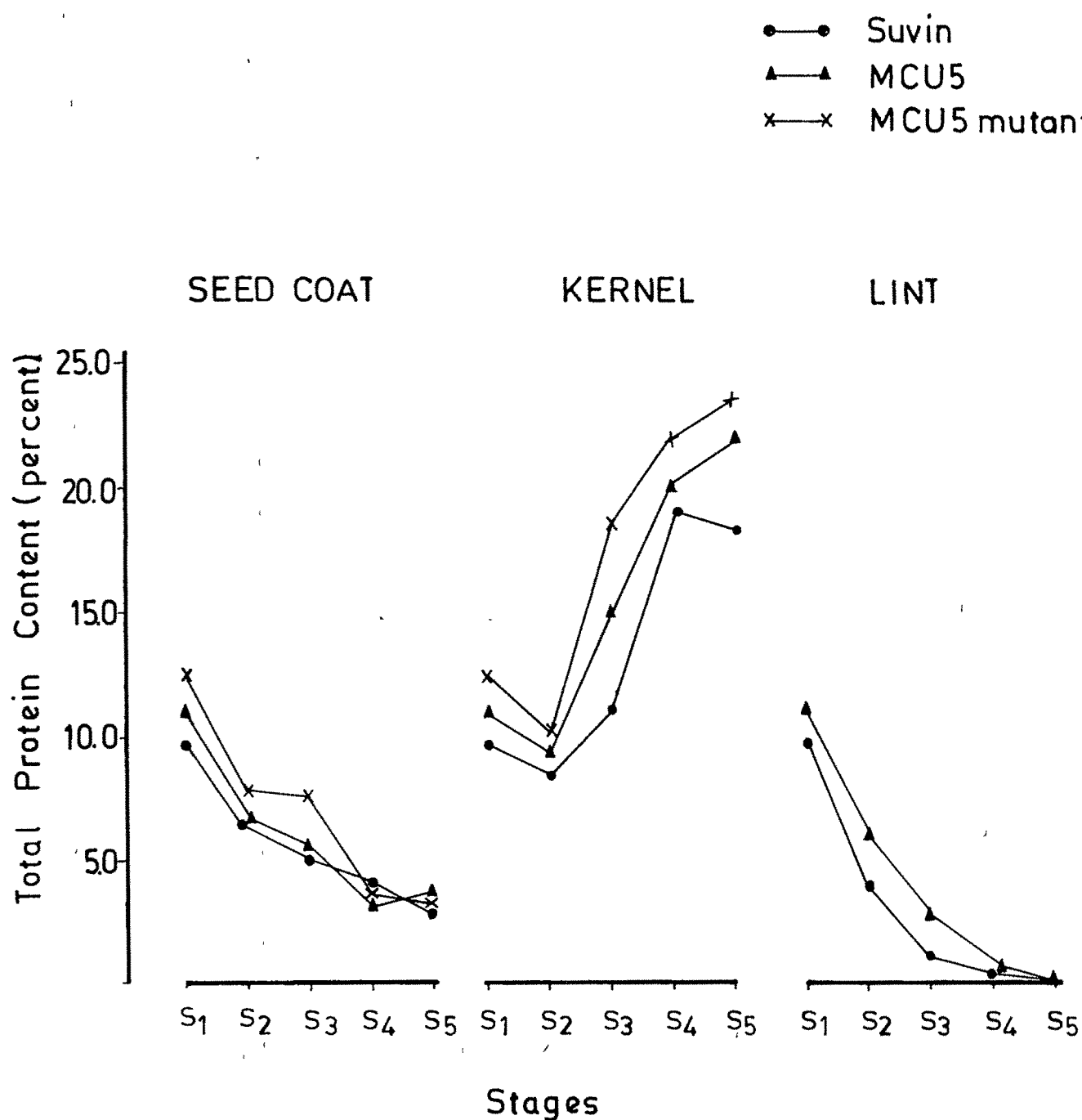


Table 25. Time ~~time~~ changes in total protein content (per cent) of seed coat, kernel and lint of Suvin and MCU 5 and seed coat and kernel of MCU 5 mutant

a) Genotype		b) Stage		c) Component		
Genotype	Mean	Stage		Mean	Component	Mean
Suvin (G ₁)	6.74	Fibre elongation (S ₂)	6.82	Seed coat (C ₁)	4.63	
MCU 5 (G ₂)	7.84	Secondary thickening (S ₃)	6.74	Kernel (C ₂)	15.37	
		Maturation (S ₄)	7.80	Lint (C ₃)	1.97	
		Post-maturation (S ₅)	7.79			
SE(m)	0.3505		0.4957			0.4293
CD(P=0.05)	1.0230		NS			1.2529

d) Genotype x Stage					e) Genotype x Component			f) Stage x Component		
	S ₂	S ₃	S ₄	S ₅		C ₁	C ₂	C ₃		
G ₁	6.29	5.76	7.75	7.13		4.62	14.16	1.43	S ₂	6.51 8.94 5.02
G ₂	7.35	7.72	7.85	8.46		4.64	16.58	2.31	S ₃	5.33 13.07 1.83
									S ₄	3.56 19.44 0.42
									S ₅	3.13 20.03 0.36
SE(m)	0.7010					0.6071				0.8586
CD(P=0.05)	NS					NS				2.5058

g) Genotype		h) Stage		i) Component		
Genotype	Mean	Stage		Mean	Component	Mean
Suvin (G ₁)	9.39	Fibre elongation (S ₂)	8.17	Seed coat (C ₁)	4.95	
MCU 5 (G ₂)	10.61	Secondary thickening (S ₃)	10.49	Kernel (C ₂)	16.44	
MCU 5 mutant (G ₃)	12.08	Maturation (S ₄)	11.93			
		Post-maturation (S ₅)	12.18			
SE(m)	0.5650		0.6124			0.4613
CD(P=0.05)	1.6489		1.9039			1.3462

j) Genotype x Stage					k) Genotype x Component		l) Stage x Component	
	S ₂	S ₃	S ₄	S ₅		C ₁	C ₂	
G ₁	7.44	8.09	11.46	10.51		4.62	14.16	S ₂ 7.00 9.34
G ₂	8.01	10.31	11.54	12.69		4.64	16.58	S ₃ 6.05 14.92
G ₃	9.07	13.07	12.78	13.39		5.58	18.57	S ₄ 3.56 20.29
								S ₅ 3.17 21.19
SE(m)	1.1299					0.7990		0.9226
CD(P=0.05)	NS					NS		2.6926

Interaction effects between genotypes and stages point out that the iron content in Suvin did not vary between the developmental stages while in MCV 5 and its mutant it declined significantly till secondary thickening stage (S_3) and thereafter it was on par in the rest of the stages. Among the genotypes within a stage, the iron content differed significantly in the order MCV 5 mutant > MCV 5 > Suvin at fibre elongation stage (S_2). In the other stages it did not vary (Table 24 j).

Interaction effects involving genotypes and components were non-significant.

Interaction between stages and components has shown that iron status in the chosen stages within a component remained without any variation in kernel and lint. On the other hand in seed coat it declined rapidly till secondary thickening stage and remained on par in later stages. Data among the components within a stage indicated that the iron level varied significantly as seed coat > kernel = lint at fibre elongation stage. During the secondary thickening (S_3) and maturation (S_4) stages, it did not vary among the components. On the other hand, during post-maturation stage (S_5) it was significantly lower in lint as compared to seed coat and kernel (Table 24 f).

4.9.14. Total protein content

Mean data on total protein content are presented in Table 25 and Fig. 15.

Total protein content at anthesis was higher in MCU 5 mutant followed by MCU 5 and Savin (Annexure XII).

The mean protein content in the genotypes over the stages was significantly higher in MCU 5 mutant over the two cultivars which maintained more or less same protein content among themselves (Table 25 g).

The stages mean indicated that total protein content increased significantly till secondary thickening stage (S_3) and thereafter there was no significant increase (Table 25 h).

Among the components, the protein content varied in the order kernel > seed coat > lint (Table 25 c).

Interaction effects between genotypes and stages as well as between genotypes and components were found to be non-significant.

Interaction between stages and components was significant. Considering the protein content within a component over stages it was found that in seed coat, total protein content did not differ between the stages. In kernel, it increased significantly till maturation stage (S_4) only. In lint, it declined rapidly till secondary thickening stage (S_3) and thereafter there was no significant reduction. Among the components within a stage, the protein content varied in the following order (Table 25 f).

Table 27. Correlation coefficients between chemical constituents and fibre length and dry weight in Suvin and MOU 5

Constituent	Suvin		MOU 5	
	Fibre length	Fibre dry weight	Fibre length	Fibre dry weight
Reducing sugars	-0.872	-0.961*	-0.981*	-0.906
Cellulose	0.980*	0.974*	0.997**	0.856
✓ Free amino acids	-0.808	-0.919	-0.789	-0.997**
Phenolics	-0.741	-0.882	-0.834	-0.935
IAA oxidase	-0.537	-0.787	-0.647	-0.964*
Peroxidase	0.904	0.834	0.841	0.787
Nitrogen	-0.993**	-0.945	-0.947	-0.955*
Phosphorous	-0.894	-0.971*	-0.984	-0.902
Potassium	-0.842	-0.981*	-0.995**	-0.870
Calcium	-0.998**	-0.881	-0.906	-0.984*
Zinc	-0.979*	-0.826	-0.940	-0.703
Manganese	-0.935	-0.712	-0.937	-0.629
Iron	-0.096	-0.485	-0.415	-0.676
✓ Protein	-0.998**	-0.932	-0.963*	-0.940
Oil	0.993**	0.945	0.987*	0.874

** Significant at 1 per cent level

* Significant at 5 per cent level

Fig.16. Time trend changes in oil content of kernel of Suvin, MCU5 and MCU5 mutant

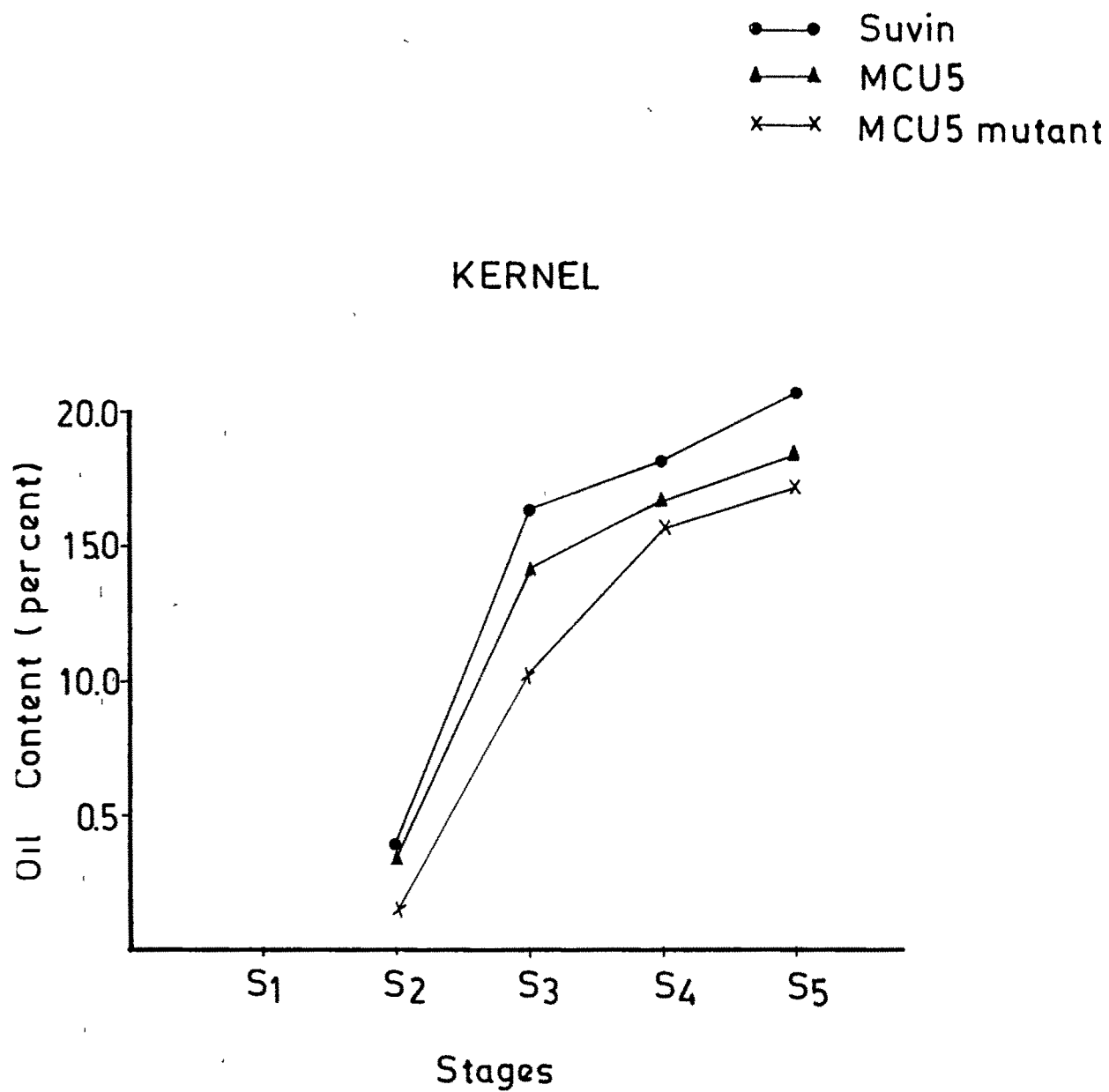


Table 26. Time trend changes in oil content (per cent) of kernel of Suvin, MCU 5 and MCU 5 mutant

Genotype	Stages of development*				Mean
	S ₂	S ₃	S ₄	S ₅	
Suvin	3.80	16.35	18.12	20.59	14.72
MCU 5	3.60	14.05	16.51	18.41	13.14
MCU 5 mutant	1.34	10.10	15.07	17.46	10.99
Mean	2.91	13.50	16.57	18.82	

	Genotype (G)	Stage (S)	G x S
SE(m)	0.646	0.746	1.292
CD(P=0.05)	1.991	2.299	NS

*S₂ = Fibre elongation; S₃ = Secondary thickening
 S₄ = Maturation; S₅ = Post-maturation stages in
 Suvin and MCU 5

Seed developmental stages in MCU 5 mutant

S_2 Kernel = Seed coat = Lint

S_3 Kernel > Seed coat > Lint

S_4 Kernel > Seed coat > Lint

S_5 Kernel > Seed coat > Lint

4.9.15. Oil content

Data on the oil content are presented in Table 26 and Fig. 16.

The mean oil content of the genotypes over the stages showed no difference between Savin and MCU 5 while it was significantly lower in MCU 5 mutant. It was in the order Savin = MCU 5 > MCU 5 mutant (14.72 = 13.14 > 10.99 per cent).

The stages mean indicated rapid accumulation of oil till maturation stage. Further, oil accumulation continued till harvest and this increase was significant only upto maturation stage.

The interaction effects between genotypes and stages were found to be non-significant.

4.9.16. Correlation coefficients between chemical constituents and fibre length and dry weight

Correlation between chemical constituents and fibre length and dry weight are presented in Table 27. It was noticed that in Savin, cellulose and oil content had significant positive relationship with fibre length, while most of other constituents

Table 28. Specific leaf area ($\text{cm}^2 \text{g}^{-1}$) and specific leaf weight (mg cm^{-2}) at anthesis stage of the leaf subtending boll of Suvin, MCU 5 and MCU 5 mutant

Genotype	SLA ($\text{cm}^2 \text{g}^{-1}$)	SLW (mg cm^{-2})
Suvin	166.94	6.01
MCU 5	148.65	6.90
MCU 5 mutant	156.36	6.51
SE(m)	4.4903	0.2364
CD(P=0.05)	13.6213	NS

viz., nitrogen, calcium, zinc and total protein content maintained significant negative relationship with this fibre trait. In MCU 5, cellulose and oil content showed significant positive association with fibre length as noticed in the case of Suvin. Other chemical constituents had negative relationship with fibre length and it was found to be significant with regard to reducing sugars, phosphorus, potassium and total proteins only.

Fibre dry weight also recorded more or less a similar pattern of relationship with the constituents as noticed in the case of fibre length. In Suvin, cellulose and fibre dry weight had significant positive relationship while reducing sugars, phosphorus and potassium had maintained significant negative relationship. In MCU 5, amino acids, IAA oxidase, nitrogen and calcium had significant negative relationship with fibre dry weight. The positive relationship of cellulose and oil content with fibre dry weight in this cultivar was non-significant.

4.10. Physiology of subtending leaf

4.10.1. Specific leaf area (SLA) and specific leaf weight (SLW)

Data on SLA and SLW are presented in Table 28. These parameters were determined in the leaf subtending boll at anthesis to find out the genotypic differences. It was noticed that Suvin recorded maximum specific leaf area ($166.94 \text{ cm}^2 \text{ g}^{-1}$)

Fig .17. Time trend changes in photosynthetic rate of leaf
substending the boll of Suvin, MCU5 and
MCU5 mutant

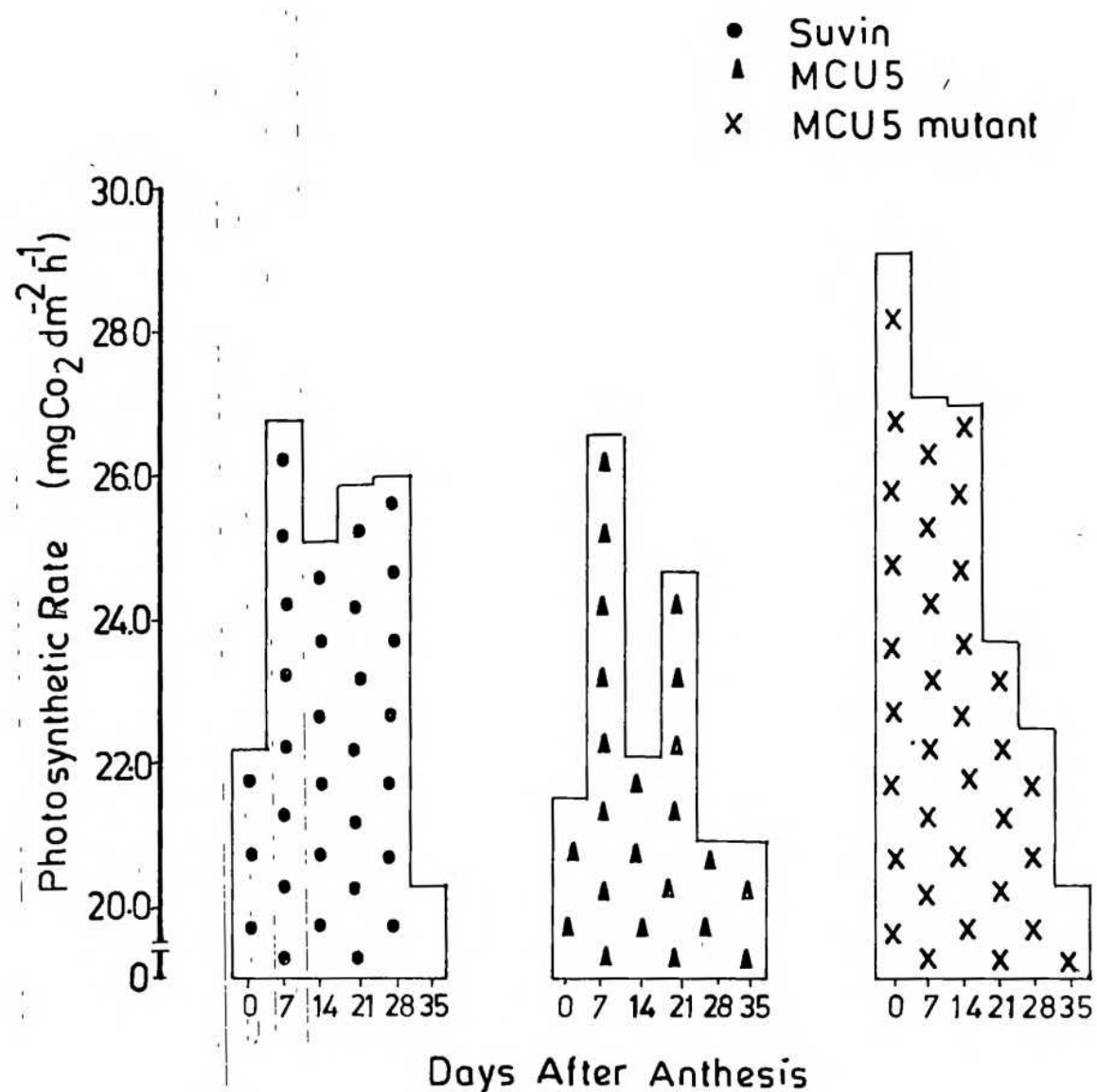


Table 29. Time trend changes in photosynthetic rate
(mg CO₂ dm⁻² h⁻¹) of the leaf subtending boll
of Suvin, MCU 5 and MCU 5 mutant

Genotype	Days after anthesis						Mean
	0	7	14	21	28	35	
Suvin	22.2	26.8	25.1	25.9	26.0	20.3	24.38
MCU 5	21.5	26.6	22.1	24.7	20.9	20.9	22.78
MCU 5 mutant	29.1	27.1	27.0	23.7	22.5	20.3	24.95
Mean	24.3	26.8	24.7	24.8	23.1	20.5	

	Genotype (G)	Stage (S)	G x S
SE(m)	0.2880	0.4074	0.7056
CD(P=0.05)	0.8558	1.2103	2.0963

which was on par with MCU 5 mutant ($156.36 \text{ cm}^2 \text{ g}^{-1}$) while MCU 5 recorded the least SLA ($145.65 \text{ cm}^2 \text{ g}^{-1}$). SLA of MCU 5 was however the same as in MCU 5 mutant. Specific leaf weight on the other hand did not show any significant difference among the genotypes.

4.10.2. Photosynthetic rate of the leaf subtending boll

Photosynthetic rate of leaf subtending the boll was measured at an interval of seven days upto 35 days viz., till the beginning of leaf senescence and data are presented in Table 29 and Fig. 17.

It was observed that the photosynthetic capacity with regard to the mean of genotypes over the stages was equal in MCU 5 mutant and Suvin but was significantly higher than MCU 5. The mean photosynthetic rate was 22.78, 24.38 and 24.95 $\text{mg CO}_2 \text{ dm}^{-2} \text{ h}^{-1}$ in MCU 5, Suvin and MCU 5 mutant respectively.

The stages mean indicated that the photosynthetic rate increased significantly upto 7th day following anthesis. Later it declined till 35 DPA.

Interaction effects between genotypes at a stage denoted that the photosynthetic rate was significantly higher in MCU 5 mutant over the two cultivars at anthesis stage and the rate did not differ between the cultivars. On 7 DPA, the rate did not

Fig.18. Per cent distribution of ^{14}C assimilates in leaf subtending the boll and boll components at fibre elongation stage of Suvin and MCU5 and seed development stage of MCU5 mutant

- 1= ^{14}C activity in ethanol extract
 2= ^{14}C activity in Hcl extract
 3= Total ^{14}C activity

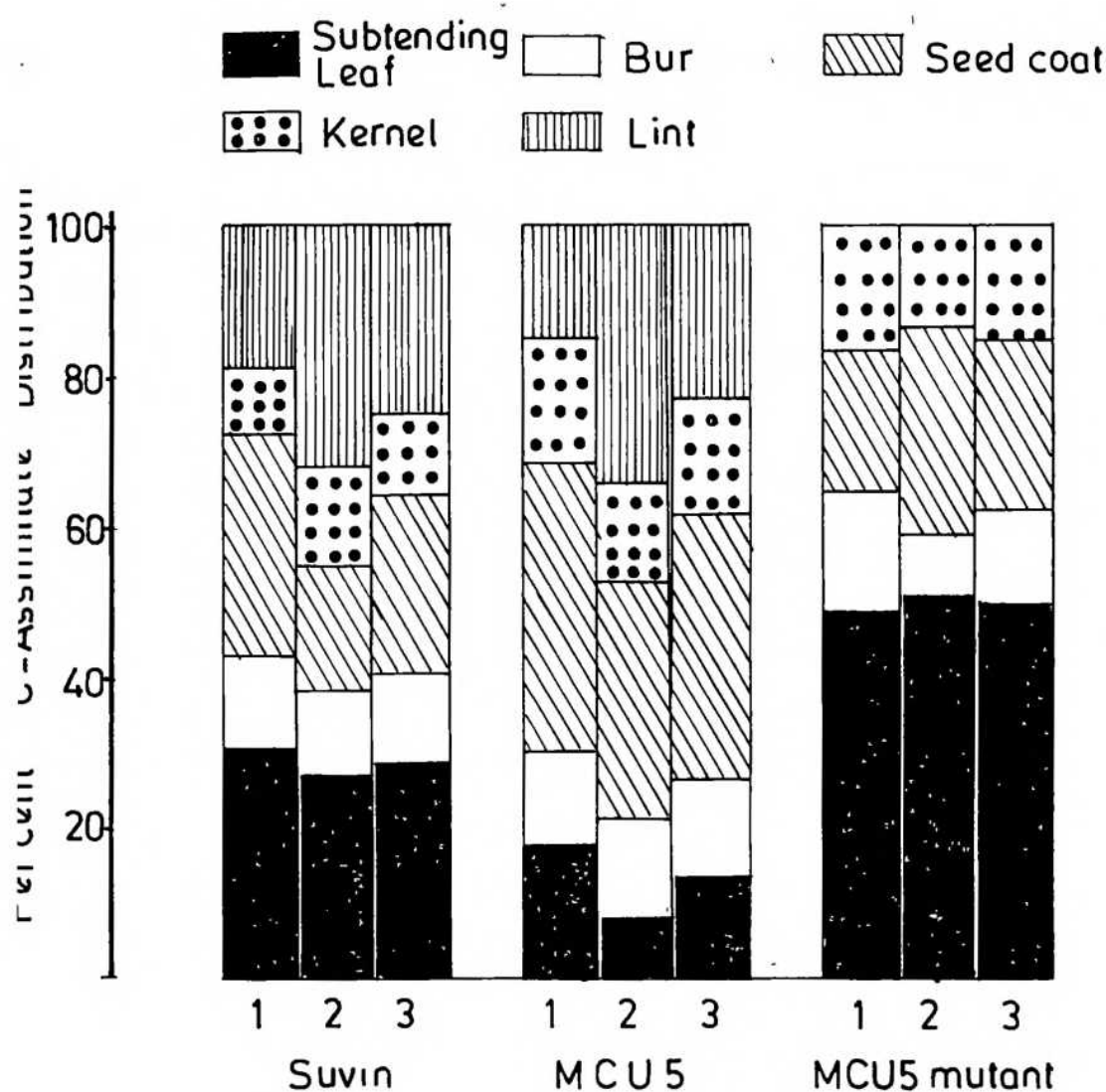


Table 30. Distribution of ^{14}C -assimilates (dpm g^{-1} fresh weight) in the leaf subtending boll and boll components at fibre elongation stage of Suvin and MCU 5 and seed development stage of MCU 5 mutant

Genotype	Extrac- table activity	^{14}C assimilate distribution					Total activity
		Subten- ding leaf	Bur	Seed coat	Kernel	Lint	
Suvin	Ethanol	380	357	846	250	543	2876
	HCl	635	294	382	317	761	2389
	Total	1515	651	1228	567	1304	5265
MCU 5	Ethanol	594	424	1271	561	472	3322
	HCl	213	351	823	346	884	2617
	Total	807	775	2094	907	1356	5939
MCU 5 mutant	Ethanol	1310	433	498	436	-	2677
	HCl	1201	208	637	315	-	2361
	Total	2511	641	1135	751	-	5033

show any difference among the genotypes and on 14 DPA, it was on par between MCU 5 mutant and Suvin, but was significantly lower in MCU 5. The photosynthetic rate on 21 DPA was similar in the genotypes, while on 28 DPA it was in the order Suvin > MCU 5 mutant = MCU 5. On 35 DPA, the rate was found to be the same among the genotypes.

Interaction effects between the stages for a genotype varied in the following order:

Suvin $0 < 7 = 14 = 21 = 28 > 35$

MCU 5 $0 < 7 < 14 = 21 > 28 = 35$

MCU 5
mutant $0 = 7 = 14 > 21 = 28 > 35$

4.10.3. ^{14}C distribution in leaf subtending boll and boll components

The distribution pattern of labelled ^{14}C sucrose in leaf subtending boll and boll components viz., bur, seed coat, kernel and lint of 20 days old bolls was investigated in pot culture experiment. Ethanol and hydrochloric acid extracts of the leaf and boll components were made 20 hr after labelling. The results are presented in Table 30 and Fig. 18.

^{14}C distribution in the ethanol extract of leaf subtending boll was high in MCU 5 mutant followed by Suvin and MCU 5. In the bur component of the boll too, MCU 5 mutant

had high activity. It was lower in Suvin as compared to MCU 5. In seed coat, high ^{14}C activity was noticed in MCU 5 followed by Suvin. MCU 5 mutant had the least ^{14}C incorporation (1271, 846, 498 dpm g^{-1} fresh weight in MCU 5, Suvin and MCU 5 mutant respectively). The distribution pattern in the kernel was however different. MCU 5 had more activity, about twice that of Suvin, while MCU 5 mutant recorded activity lower than MCU 5. Comparing the pattern of distribution of labelled carbon in the lint, it was found that Suvin had relatively more incorporation.

The activity in Hcl extract among the components was comparatively lower except that of lint. This was mainly due to the fact that Hcl was able to extract structural components, while ethanol had extracted all soluble components at this boll age. The activity in the subtending leaf followed similar pattern as noticed in ethanol extract. The absolute activity in the bur was high in MCU 5 followed by Suvin and MCU 5 mutant. With regard to seed coat, MCU 5 had more preferential incorporation followed by MCU 5 mutant. Suvin had the least activity. The distribution of ^{14}C assimilates in kernel was lower than that of seed coat and the activity was maintained higher in MCU 5, while in Suvin and MCU 5 mutant it was equally distributed. With regard to the lint, MCU 5 had shown prominent ^{14}C incorporation (884 dpm) as compared to 761 dpm in Suvin in the Hcl extract.

Table 31. Fibre quality parameters at harvest in Suvin
and MCU 5

Cultivar	2.5 per cent span length	Uniformity ratio (per cent)	Fineness micronaire 10-6 g/in	Matu- rity coeffi- cient	PSI '0' gauge (lb/mg)
Suvin	37.39	47.29	3.79	0.77	10.17
MCU 5	33.41	45.57	3.58	0.74	8.23
SE(m)	0.0920	0.4213	0.0437	0.0036	0.1246
CD(P=0.05)	0.3184	1.4089	0.1461	0.0122	0.4169

The total ^{14}C activity comprising of ethanol and Hcl extractable activity was high in MCU 5 followed by Suvin. It was found to be low in MCU 5 mutant. MCU 5 mutant had high total ^{14}C activity in the subtending leaf while it had low activity in bur and kernel components as compared to the cultivars. Among the cultivars, the total ^{14}C activity was high in the subtending leaf of Suvin about twice to that of MCU 5, while in the boll components, the activity was found to be relatively higher in MCU 5.

A perusal of the results highlighted the following features:

- i) The proportion of ^{14}C distribution was higher in ethanol extract.
- ii) MCU 5 mutant had high ^{14}C activity in the subtending leaf. Between the cultivars it was higher in Suvin.
- iii) MCU 5 had high ^{14}C assimilate incorporation in the seed coat and kernel as compared to Suvin and MCU 5 mutant.

5.1. Quality evaluation of fibre at harvest

The quality parameters of fibre were recorded at harvest in Suvin and MCU 5. The following attributes viz., 2.5 per cent span length, uniformity ratio, fineness, maturity coefficient and bundle strength were considered for the fibre quality evaluation (Table 31).

The results indicated that Suvin recorded significantly more span length (3.98 mm) over MCU 5 at harvest. Fibre length uniformity ratio was also significantly higher in Suvin (47.3 per cent) which was grouped under 'good' category, while MCU 5 had uniformity ratio of 45.6 per cent falling within the average classification.

Based on the micronaire value, both the cultivars had fine quality lint with little difference in the category grouping.

Maturity coefficient, an index signifying the multiple character of fibre maturity is generally represented by the presence of mature, half mature and immature fibres. It was observed that both the cultivars had average maturity coefficient. Suvin had comparatively higher values which was significant (0.77 in Suvin and 0.74 in MCU 5 respectively).

Bundle strength in terms of PSI (lb/mg) remained significantly high in Suvin (10.17) classified under 'very good' category, while MCU 5 was grouped under 'good' category (8.23).

The overall estimate of the results revealed that in most of the quality parameters evaluated at harvest, Suvin has more desirable fibre quality parameters.

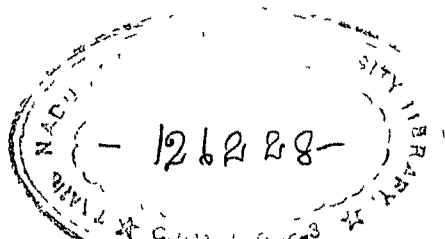


Table 32. Inter-correlation coefficients between fibre quality parameters at harvest in Suvin and MCU 5

Quality parameter	Suvin			MCU 5		
	Uniformity ratio	Micro-naire	Maturity coefficient	Uniformity ratio	Micro-naire	Maturity coefficient
2.5 per cent span length	0.552	-0.407	-0.407	0.726*	0.072	0.403
Uniformity ratio	-	0.134	0.037	-	0.271	0.291
Micronaire	-	-	-0.026	-	-	-0.158
Maturity coefficient	-	-	-0.193	-	-	-
						0.604

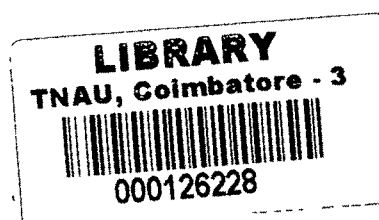
* Significant at 5 per cent level

5.2. Correlation coefficients between fibre quality parameters at harvest

Inter correlation coefficients between fibre quality parameters at harvest are given in Table 52.

In Savin, span length had positive relationship with uniformity ratio only. Uniformity ratio maintained positive relationship with other characters. Micronaire value however had negative relationship with maturity coefficient whereas it had significant positive relationship with bundle strength. Maturity coefficient on the other hand showed non-significant negative relationship with bundle strength.

In HCU 5, span length had positive relationship with other characters of fibre quality and was significant with uniformity ratio only. Uniformity ratio had non-significant positive relationship with micronaire, maturity coefficient and bundle strength. Micronaire value had non-significant negative association with maturity coefficient, whereas this parameter showed positive association with bundle strength. Maturity coefficient and bundle strength were positively related.



Discussion

CHAPTER V

DISCUSSION

The physiological significance of various investigations carried out to unravel the development of fibre and associated boll traits in two elite cotton cultivars are discussed in this chapter. The mutant of MCU 5 has been designated as a 'check' to identify characters leading to lintlessness in this genotype. The time course changes in physiological, chemical, hormonal and nutritional status of fibre and associated boll components were contemplated to bring out the complexity of the developmental events within the boll in relation to fibre dry weight per boll and the main quality parameter viz., fibre length in view of their economic importance. The data obtained in the study are discussed in the light of limited literature available on these aspects.

5.1. Flowering

The flowering trends indicated that flower initiation occurred 7 days earlier in MCU 5 as compared to Suvin and MCU 5 mutant. However, irrespective of flower initiation as well as its duration the total number of flowers per plant was high in MCU 5 mutant. Among the cultivars, MCU 5 produced

more number of flowers per plant. These flowering trends could be related to species and varietal variations as opined by McClelland and Neely (1931).

In respect of rate of flowering, Suvin had gradual increase in flowers per plant which continued for a longer duration. This signified a strong indeterminate flowering habit in this genotype. MCU 5 on the other hand, possessed more number of flowers immediately after initiation and it ceased earlier too, indicating synchrony in flowering. Its mutant also had high rate of flowering initially, but unlike MCU 5 the flowering was continued for a longer duration. Differences in flowering responses were attributed to variations in day and night temperatures (Bhatt and Rao, 1982). In the present investigation, maximum number of flowers during the course of flowering corresponded with a higher accumulated degree days and heliothermal units in MCU 5 mutant which was closely followed by MCU 5. In Suvin, the number of flowers at maximum flowering intensity was comparatively lower and correspondingly cumulative heat units were of lower order. These findings indicated that peak flower production in the genotypes were related to accumulated heat units.

The fresh and dry weight of flower was significantly higher in Suvin, whereas its mean boll weight was found to be

lower as against MCU 5 and its mutant. This clearly indicated that greater flower weight in Suvin was contributed largely by its epicalyx bracts and petals. It was possible that excessive development of bracts did not lead to any substantial increase in boll growth as the assimilate contribution from bracts to the boll was well below 10 per cent (Benedict and Kohel, 1975; Constable and Rawson, 1980b).

5.2. Changes in the physiological parameters of boll and its components

The culmination of flowering is indicated by the formation of boll, which serves as a major sink.

In the developing boll, accumulation of fresh weight is considered important, as it initiates the actual expansion of boll through the absorption and incorporation of assimilates in addition to the moisture content. MCU 5 recorded high mean fresh weight of boll followed by its mutant. Suvin, on the other hand, had low fresh weight, indicating limitations on its sink size. The fresh weight of boll at harvest was high in MCU 5 mutant followed by MCU 5 and Suvin. A high fresh weight in the boll of mutant at this stage was indicative of higher moisture status, whereas higher boll desiccation considerably decreased final boll weight in MCU 5.

Boll expansion was rapid immediately after anthesis particularly in MCU 5 and maximum boll size was reached between 21 and 23 days after anthesis in all the genotypes. This volume expansion may be related to intense cell division activity as noticed in similar march of events in cereal grains (Evers, 1970).

Maximum size of various boll components viz., bur, seed and fibre was mostly reached between 21 and 35 days post anthesis (DPA). The bur weight reached the maximum on 28th day while seed and fibre recorded maximum weight on 35 days after anthesis. These trends indicated a situation of high metabolic activity in the economic components of boll for a longer period and this was conspicuously evident in Suvin.

The major gain in fresh weight of fibre during the course of its development was most significant in MCU 5, though the fibre desiccation was rapid. This could have imposed restrictions on the elongation of fibre. These two events viz., high fibre weight and its early dehydration along with a few other interrelated boll characters - early desiccation of bur and seed ultimately led to earliness in the boll duration of MCU 5 as compared to Suvin. Similar findings on boll development in cotton were reported by Nemon and Malik (1970) and Mutascars (1976).

In the parallel events in MCU 5 mutant, maximum fresh weight was invested in the bur and seed, identifying them as alternative sink components of boll in the absence of fibre. This readily provided evidence that boll under genetic compulsions could distribute assimilate in alternative sink components. Normally the sink strength has a feed back effect on the photosynthetic rate of the source. In MCU 5 mutant, the source activity as represented by higher photosynthetic rate at earlier stage had probably ended in the diversion of the assimilates to the development of bur and seed. Redistribution of assimilates for alternative sink development has been reported by Fondy and Geiger (1980) and Peoples and Matthews (1981).

Dry matter (DM) in boll showed a continuous accumulation till harvest in MCU 5, while in Suvin and MCU 5 mutant, this was observed till 28 and 35 days after anthesis respectively and later it tended to level off in MCU 5 mutant. There was a greater investment of DM in MCU 5 than that of Suvin while in the case of MCU 5 mutant, DM accumulation was lower than MCU 5.

While apportioning the total dry matter of the boll into its components, it was noticed that the dry matter partitioning between bur and seed was almost equal in all the

genotypes, and it was more pronounced in the case of mutant. These differences of boll dry matter and also its partitioning into various boll components could be related to sink size. The basic difference between bur and seed DM investments in the present study was that bur had comparatively higher dry matter partitioning at earlier stages of boll development. Seeds on the other hand, showed distinct lag period on DM accumulation till 7 and 14 DPA in cultivars and MCU 5 mutant respectively. After this initial lag phase, seeds of MCU 5 continued to accumulate dry matter significantly till harvest, while in Suvin and MCU 5 mutant, the DM distribution was similar to that of entire boll. The DM partitioning in various boll components is in agreement with the findings of Marani (1979).

Fibre dry weight per boll was significantly higher in MCU 5 in all the stages and was about twice higher than that of Suvin at harvest. However, it showed a distinct lag period till 14 days in both the cultivars. This type of lag phase in DM accumulation has been reported during wheat grain development too (Evers, 1970). Fibre dry weight increased rapidly once the lag period as mentioned above was over and slowed down at fibre maturity. Schubert et al. (1973) noticed maximum rate of fibre weight between 20 and 30 days after anthesis. In the present investigation, the rate of

dry weight accumulation in fibre varied with boll age. In Suvin high rates were observed between 21 and 28 DPA whereas in MCU 5 it was delayed further (28-35 DPA), though the rate of weight gain between 21 and 28 days after anthesis was also equally higher in this cultivar. These trends showed that on a comparative basis MCU 5 had better assimilate partitioning towards fibre and this was evident from high fibre dry weight per seed as well as boll.

The relative dry matter distribution in different boll components at harvest of Suvin, MCU 5 and MCU 5 mutant is presented in Table 33.

Table 33. Relative distribution of dry matter in various boll components and fibre dry weight/seed at harvest

Genotype	Per cent distribution of DM			Fibre dry weight/seed (mg)
	Bur	Seed	Fibre	
Suvin	41.21	45.01	13.78	23.2
MCU 5	32.67	45.67	21.66	34.9
MCU 5 mutant	44.61	55.39	-	-

It is interesting to note that the distribution of DM into the bur and seed was distinctly higher in MCU 5 mutant. This indicate DM investment exclusively in bur and seed in the

absence of fibre. Among the cultivars, dry matter in the boll components of Suvin was more or less equally distributed between bur and seed with low partitioning towards fibre. In MCU 5, on the other hand, seed received more dry matter, followed by bur and fibre. This brought out the pattern of DM distribution in boll components and also emphasised on the priority received by seeds. Leffler (1976) observed a proportionate DM partitioning between seed and fibre. In the present investigation, the dry matter accumulation was more directed towards the seed component of the boll.

Distribution of dry matter within the seed components viz., seed coat and kernel varied significantly among the genotypes. MCU 5 alone possessed greater capacity for higher DM in these seed components as compared to Suvin. A low DM in these components of seed as well as high seed coat/kernel ratio in MCU 5 mutant indicated uneven development of these structural components that could be probably limiting the physiological functions of seed in this genotype. Seed coat received more dry matter during initial stages of seed development. This was attributed to newly formed fibres (Stewart, 1980). More fibre initials observed at one day post anthesis in MCU 5 could therefore be related to higher dry matter investment in the seed coat than that of Suvin. Kernel weight on the other hand increased during later stages

of seed development in all the genotypes and is in agreement with the findings of Baranov and Maltzer (1937).

Moisture status of the boll and its components decreased right from anthesis and continued till harvest. The decline of moisture status was well marked in later stages of boll development, when boll desiccation became rapid. MCU 5 mutant possessed highest mean boll and bur moisture status and among the cultivars the mean moisture content in boll and its components was maintained significantly at a higher level in Suvin only. In the boll components, the moisture content was found to be relatively high in fibre followed by seed and was low in bur during early boll development till 21 DPA. This indicated that high moisture in fibre and seed during early stages of boll development provided high metabolic activity for their growth and a favourable fibre elongation in Suvin was the outcome of higher moisture status in the fibre. Kaufman (1969) and Fraser et al. (1982) also attributed the metabolic activity of growing organs to changes in the moisture status.

Relative growth rate (RGR) serves as a useful parameter in determining the growth rates of boll and its components in the genotypes. It was observed that initially RGR was maintained high and with the advancement of boll age the rate

declined. The results also depicted that the growth of entire boll differed significantly among the genotypes, while as far as the individual boll components were concerned the growth rate was significant for the fibre only. However, an useful inference could be derived from the results. There was significant increase in RGR of seed in Suvin during later boll age indicative of seed growth when RGR of other boll components was low. Similar growth rate of seeds with the completion of pod formation in groundnut has been reported by Duncan et al. (1978). In this context, it may be mentioned that in MCU 5 mutant, a significant increase in RGR of boll, bur and seed was noticed on 14-21 DPA. It confirmed the parallel and active growth events occurring in these boll components in the absence of fibre.

RGR of fibre was initially high in MCU 5 but Suvin had high RGR in later stages, excepting at 14-21 and 28-35 DPA. Though the rate declined concomitantly with fibre development, there was a significant increase in the rate in mid-boll age: 14-21 DPA in MCU 5 and 21-28 DPA in Suvin. The increase in RGR during the mid course of fibre development was indicative of intense fibre growth rates and was found to be earlier in MCU 5. During this intensive fibre growth period, the RGR of seed and bur was maintained lower in these cultivars. These findings as discussed earlier indicated that higher growth

rates in fibre at specific stages was predominant over that of other boll components. With fibre attaining maturity, the rate declined correspondingly and the decline was more pronounced in MCU 5 due to earliness in boll development. In the present study, considerable fluctuations in RGR was noticed during the development of fibre and this could be attributed to varietal and environmental variations as opined by Gipson and Joham (1969) and Gipson and Ray (1969).

Fibre development

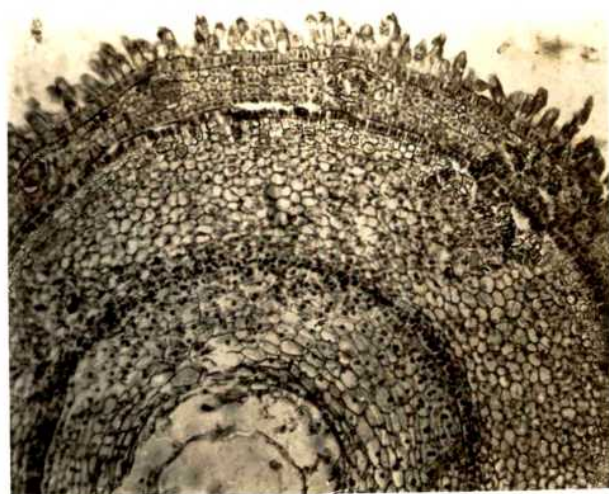
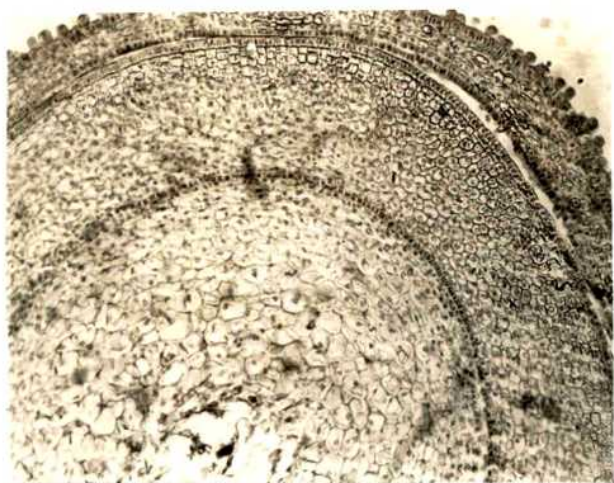
Seeds nourish the fibres and in this context seed number per boll significantly varied between Suvin and MCU 5. It was higher in MCU 5, hence this cultivar possessed more fibre density per boll. Seeds per boll increased in MCU 5 mutant at the expense of fibre. The number of seeds in a boll is a function of ovules per flower and fertilization efficiency. The former is primarily a function of genetics and environmental component (Stewart, 1980). Considering the above observations, it can be said that number of seeds per boll showed species difference, remaining high in hirsutum cotton viz., MCU 5 and its mutant than that of Suvin belonging to barbadense group. The seed size did not vary perceptively among these genotypes (Table 34).

Table 34. Seed size at harvest in Suvin, MCU 5 and MCU 5 mutant

Genotype	Seed length (mm)	Seed width (mm)
Suvin	8.94	4.20
MCU 5	9.14	4.21
MCU 5 mutant	8.88	3.88

The number, length and width of fibre initials in Suvin and MCU 5 were recorded at random in a microscopic field from the transverse section of ovary at 24 hr post anthesis (Plate 2). It was noticed that the fibre initials of ovule was high in MCU 5 as compared to Suvin. Similarly, the length and width of these initials were also more in MCU 5 showing variations on fibre differentiation in these cultivars. An interesting feature of the investigation was that Suvin possessed fibre initials mostly on the upper half of the ovule, whereas the initials were spread on the entire ovule in MCU 5. These observations confirmed the earlier findings of Flint (1950) that the proliferation of fibres is not uniform. Stewart (1975) also indicated that the fibres began to expand on the day of anthesis. High fibre weight per seed and also per boll in MCU 5 could also be

PLATE 2 : Showing fibre initials in Suvin and MCU 5
and the L.S. of ovule of Suvin, MCU 5 and
MCU 5 mutant at 24 hrs post-anthesis



traced to the high fibre intensity at early stages of development. These fibre initials may not involve fuzz hairs as fuzz initiation occurs 4 to 8 days after anthesis (Ramsey, 1973; Beasley, 1979). Suvin on the other hand showed sparse fibre initials per ovule which ultimately resulted in the lower fibre dry weight per seed and also per boll in this cultivar. GA and ABA were reported to exert hormonal regulations on fibre initiation (Beasley, 1977; Dhindsa et al., 1976). In the present investigation, the variation in fibre differentiation as well as expansion of fibre initials in the cultivars could be regarded as phytohormone regulation at anthesis. Also, it is quite possible that greater size of fibre initials at anthesis in MCU 5 was indicative of earliness for boll characters.

Fibre length is the essential economic attribute of the boll. On a comparative basis, fibre elongation was significantly higher in Suvin. However, it was interesting to note that MCU 5 possessed greater fibre length till 14 days after anthesis and Suvin surpassed MCU 5 thereafter till harvest. Greater fibre elongation at earlier boll age in MCU 5 was the outcome of greater expansion of fibre initials as noticed at post-anthesis stage. In both the cultivars, the rate of elongation which was greater during early stages of

boll development declined at later stages. Genotypic differences on fibre elongation were related to evolutionary process by Popova et al. (1979a). Evidently, Suvin and MCU 5 showed variations on the rate of fibre elongation. The boll duration relative to the production of half of the total fibre length was comparatively shorter in MCU 5 i.e., 14 DPA than that of Suvin (21 DPA). The investigation therefore demonstrated that fibre growth was an accelerated event in MCU 5, whereas in Suvin it was distinctly a gradual phenomenon.

Fibre dry weight per seed per unit fibre length which is indicative of relative fibre thickness was higher in MCU 5. This could be traced to more of cellulose deposition (Meinert and Delmer, 1977). The weight per unit length increased continuously in Suvin, whereas in MCU 5 it was low on 14 DPA and later increased significantly. These findings are in agreement with the observations made by Beasley (1979). On the whole fibre thickness was inversely related to fibre elongation as noticed in both the cultivars.

5.3. Contribution of current photosynthate from subtending leaf to the boll

The investigations on the physiology of leaf subtending the boll elucidated certain trends in photo-assimilate production and translocation. These were further confirmed by ^{14}C labelling in subtending leaf during fibre

elongation phase. The data on the area of the subtending leaf has shown that at the time of anthesis MCU 5 mutant had maximum leaf area while Suvin possessed the minimum area. MCU 5 had a higher leaf area than that of Suvin at this stage (Table 35).

Table 35. Subtending leaf area, photosynthetic rate and source strength at anthesis

Genotype	Subtending leaf area (dm ²)	Photosynthetic rate (mg CO ₂ dm ² h ⁻¹)	Source strength (mg CO ₂ dm ⁻² h ⁻¹)
Suvin	0.339	22.2	7.53
MCU 5	0.569	21.5	12.23
MCU 5 mutant	0.818	29.5	24.13

SLA and SLW at anthesis indicated higher photosynthetic efficiency in MCU 5. However trends in photosynthetic rate per unit leaf area was lower in MCU 5. The lower photosynthetic rate per unit leaf area in case of larger leaves had already been observed by many workers (Dunstone and Evans, 1973; Hart *et al.*, 1978; Mahon, 1982). The total amount of photosynthate for the entire subtending leaf when calculated, it was clear that MCU 5 produced larger quantity of photoassimilates

and contributed more towards the boll dry matter as compared to Suvin.

MCU 5 mutant possessed not only greater area of the subtending leaf, but had higher rate of photosynthesis per unit area irrespective of larger leaf area. In spite of this fact, it is evident from ^{14}C studies that about 50 per cent of the assimilates stagnated in the leaf itself. This stagnation of assimilate in the leaf of the mutant may be due to unfavourable vascular connections. Moreover, this trend had amply reflected the lower sink strength in the mutant which did not have fibre initiation. Presumably, higher photo-assimilates in the leaf of mutant contributed its own share for greater leaf area development.

The pattern of ^{14}C incorporation in different boll components as well as the subtending leaf during fibre elongation period indicated that a greater proportion of assimilates accumulated in the subtending leaf of MCU 5 mutant. This brought out distinctly the phenomenon of limited assimilate translocation in this genotype. Limitation of assimilate translocation ultimately led to the structural development of the source as noticed in mung bean (Kuo et al., 1978). Among the cultivars, photosynthetic rate per unit leaf area as well as ^{14}C activity was higher in Suvin. However, assimilate

translocation from the leaf to the boll was restricted, as observed from low DM in the boll components of Suvin. MCU 5 on the other hand possessed high source strength and also efficient translocation of assimilates towards the boll indicating a well maintained source-sink relationship in the cultivar.

^{14}C activity in the soluble components remained high in the bur of MCU 5 mutant indicating a preferential bur growth in this genotype and this could be related to its lintless nature. Redistribution of assimilates as found in bur components was substantiated by similar findings in Phaseolus vulgaris (Wien et al., 1976). Further high activity in seed coat as compared to the kernel of the genotypes pointed out two possible inferences: (i) seed coat acting as the site of unloading of current photosynthates and (ii) its proximity to the actively growing fibre in the cultivars. Lint of Suvin and MCU 5 had sizable carbon incorporation, particularly in the case of Suvin. High assimilate partitioning towards developing fibre has been reported by Benedict et al. (1973, 1976).

Activity of ^{14}C in the structural components of boll was relatively lower indicating reduced assimilate incorporation in these components of the developing boll at this boll age. However, lint of Suvin and MCU 5 had more incorporation and this could be regarded as a favourable assimilate partitioning towards lint development.

5.4. Chemical composition of the boll components

Sugar depletion and cellulose deposition were the important chemical events in boll. Reducing sugar content was found to increase at a higher proportion in the seed coat than in the kernel component of seed during early boll development in the cultivars as well as MCU 5 mutant. Probably there was a high sugar requirement in the seed coat of the cultivars for early fibre growth. Further, the seed coat has been identified as an active site for photoassimilate unloading (Thorne and Rainbird, 1983; Wolswinkel and Ammerlan, 1983).

Considering the seed coat, kernel and lint together in the cultivars, it was noticed that sugar content increased at a higher rate at fibre elongation stage and declined later at a faster rate. Rapid sugar depletion with a concomitant increase in cellulose content of lint was observed. Meinert and Delmer (1977) showed that after 16 DPA, cellulose synthesis was active. In the present study, it was noticed that the pattern of sugar decline was high in all the developmental phases of fibre, indicating a high cellulose turnover right from fibre elongation phase. In seed coat, the cellulose increased gradually at a low order. Sugar and cellulose inter-relationship was indicated by Jack and Forest (1940),

Dastur and Ahad (1945), Conner et al. (1972) and Singh and Singh (1979). However, the species difference on sugar and cellulose relationship was not highlighted. In the present investigation, MCU 5 cotton accumulated high cellulose content in each of the chosen stage, while in Suvin, the rate of cellulose deposition was relatively lower but continued for a longer boll development period.

The maximum fibre length attained was also found to correspond with the boll age having low sugar content (Krieg et al., 1972). This invariably occurred at maturation stage in both the cultivars. Kernel cellulose, on the other hand declined with boll maturation. A low sugar content in kernel as well as rapid kernel expansion without any increment in cellulose content could be considered as dilution effect.

In MCU 5 mutant reducing sugars accumulated at a higher level in the seed. The cellulose content, on the other hand, was very low thus indicating the greater utilization of reducing sugars for seed development. The disturbance in cellulose enzymes and the consequent inhibition on cellulose synthesis was suggested for the lintless character in certain genotypes of cotton (Santhanam and Bhardwaj, 1962).

Free amino acids, protein and oil content are also considered for discussion in relation to fibre development.

Occurrence of relatively low free amino acid content in MCU 5 and its mutant could be due to high incorporation in protein. Further, MCU 5 possessed more free amino acids in the lint than that of seed coat and kernel. This was more concerned with higher cellulose deposition in the lint of this cultivar in the presence of higher auxin activity. Singh and Singh (1976) opined that the amino acid content played a major role in fibre development.

The composition of the amino acids revealed that relatively higher proportion of glutamate and aspartate were needed as pre-requisite for lint production (Santhanam and Bhardwaj, 1962, 1964). In the present investigation, it is seen that a high content of glutamate and aspartate coupled with high auxin activity resulted in high rate of cellulose deposition in MCU 5. In Suvin, though these amino acids were prevalent in substantial amount, a low auxin activity limited the extent of cellulose deposition in the lint. The low level of these amino acids in MCU 5 mutant, a non-lint type further confirms the statement of Santhanam and Bhardwaj (1962, 1964). Perhaps, these two amino acids are metabolized to other amino acids in the mutant (Flinn and Pate, 1968).

In general, oil and protein content increased in the kernel progressively with boll age. The increase in these

constituents exhibited a concomitant depletion of sugar and amino acid content. Suvin and MCU 5 accumulated more of oil and protein, whereas in the mutant, a shift towards high protein and low oil content was noticed. El-Nockrashy et al. (1976) reported that high oil content was associated with sugar depletion in cotton. Thus, high cellulose turnover in MCU 5 as compared to that of Suvin could be due to sugar depletion directed towards both cellulose and oil synthesis. In MCU 5 mutant, there was maximum accumulation of protein and sugar in the seed with low oil content. It is quite possible that MCU 5 mutant not only lacked mechanism for the conversion of sugar to cellulose, but the utilization of sugar for oil synthesis also appeared to be less efficient.

Total nitrogen, phosphorus and potassium are considered together to understand the role of these major nutrients in relation to boll and fibre development. Accumulation of these nutrients in seed could be ascribed to the sink size which varied in the order MCU 5 > MCU 5 mutant > Suvin. However, the content of the nutrients per unit weight showed variations among them. Nitrogen accumulated at a higher proportion in seeds particularly in kernel in all these genotypes. The greater N content due to higher dry matter accumulation in the boll had been reported earlier (Longnecker et al., 1963). Nitrogen has been reported to increase the fibre length

(Gomaa et al., 1981). In the present investigation, the cultivars possessed substantial nitrogen in the lint, which declined with the advancement of fibre growth.

The higher phosphorous content in the lint of Suvin may provide better energy source for fibre growth as reported by Basra (1982). Since phosphorous is involved in the energetics, it may play a great role in cellulose synthesis in the lint of MCU 5 too (Tarchevskii et al., 1980; Bhatt, 1983).

Potassium content was reported to be involved in the transport of photoassimilates from the leaves to the bolls (Ashley and Goodson, 1972). High lint weight in MCU 5 therefore might have been mediated through the high K status in the lint of MCU 5 as compared to Suvin.

The content of major nutrients in the lint declined with the advancement of fibre growth. This could be due to redistribution of the nutrients to the seeds as reported earlier (Leffler, 1976).

Among the secondary and micronutrients, calcium, and manganese accumulated more in MCU 5 mutant. High manganese content may be involved in the enhanced oxidase activity in this genotype, since manganese serves as a substrate for the oxidase enzymes (Morgan et al., 1966; Taylor et al., 1968). This has possibly resulted in low IAA level as observed in

the present investigation. Among the cultivars, Suvin, preferred to accumulate secondary and micronutrients at a lower level. Further, low zinc content may be related to low auxin activity in this cultivar as against MCU 5, where relatively higher auxin production was noticed and these differences might be attributed to zinc dependent auxin synthesis as shown by Skoog (1940).

Investigations on the level of phytohormones in relation to fibre development in the cultivars revealed a high endogenous auxin status in MCU 5 particularly at anthesis and fibre elongation phases. The existence of higher amount of auxin therefore increased number of fibre initials as well as lint weight through higher cellulose deposition. High fibre dry weight in MCU 5 could also be related to the mobilization of metabolites by high auxin activity as reported by Crane (1969). Further, comparatively lower level of GA presumably limited the overall fibre elongation in this cultivar.

The endogenous phytohormone activity in Suvin differed from that of MCU 5. Gibberellins were relatively higher than that of auxin content from fibre elongation onwards. This GA enriched hormonal balance thus favoured more of fibre elongation in this cultivar. Bhardwaj and Lad (1977) also reported the dependence of fibre growth in cotton on the endogenous status of gibberellin.

The present investigation showed a typical hormonal balance in seed-cotton with regard to fibre dimensions - length and weight in Suvin and MCU 5. More GA content favoured fibre elongation, whereas a shift towards auxin increased fibre weight. The additive effect of these two phytohormones may therefore regulate fibre development in these cotton cultivars.

The level of the phytohormones remained at a low ebb in the mutant of MCU 5 and led to the inability of this genotype to produce fibres. van Overbeek (1938) suggested that lower auxin content be related to lower rate of production in crop plants.

Abscisic acid in all these genotypes was found to be minimum during the phases of anthesis and fibre elongation, particularly in the cultivars. It increased till boll maturity and then declined. A similar decline in ABA content with the maturity of barley grains was reported by Goldbach and Michael (1976). The low ABA content during early stages of fibre development may be indicative of high IAA level (Milborrow, 1966) and this was true in the present investigation too. In all the stage of seed development, ABA remained high in the mutant genotype leading to inhibition of fibre initiation. It might be possible that GA, IAA and ABA can interrelate among themselves in determining the events of fibre development.

Presumably this inter-relationship was mediated by ABA (Brenner et al., 1982).

IAA oxidase and peroxidase activities were investigated during boll development to bring out the significance of these enzymes on auxin degradation in relation to fibre development. The enzyme activity present at all phases of fibre development indicating that auxin degradation was inseparable from the fibre growth process. The low auxin content in MCU 5 mutant on the other hand suggested the significance of the oxidase activity in this genotype.

Among the cultivars, the activity of oxidase enzymes were relatively higher in Suvin in which they preferably intervened and restricted the activities of auxin as reflected on low lint production. The regulation of IAA by oxidases as suggested by Galston and Davies (1969) was well defined in the present investigation.

The activity of these enzymes considerably decreased in the cultivars during fibre elongation and also in the seed developmental stage in MCU 5 mutant. There was a parallel increase in auxin content at these stages. The total phenolics increased at this stage and may be involved in the regulation of IAA oxidase activity as reported by Morgan (1964). High phenolic content at fibre elongation stage therefore kept the IAA content at an enhanced level.

Increase in the activity of these oxidase enzymes during secondary thickening phase was not significant. However, relatively higher IAA oxidase activity at this stage in the cultivars could be responsible for the low IAA content (Jasdanwala et al., 1977). This could further be traced to low phenolics content at this secondary thickening phase. All these events resulted in shortening of auxin mediated cell expansion in Suvin and only to lesser extent in the case of MCU 5.

The activity of oxidase enzymes showed variations in later stages. However, the decline in the activity in one or other later stages was possibly the result of higher boll desiccation.

5.5. Fibre quality parameters

The distinguishing features of cotton lint quality at harvest viz., length, fineness and strength are the outcome of genetic and environmental effects. In the present investigation, Suvin and MCU 5 showed differences in lint quality.

The length is an important quality parameter of fibre. Suvin possessed more span length which per se signified the impact of long boll duration as well as high endogenous gibberellin activity. Similarly, increase of lint length by exogenous application of GA was reported by Bhatt and Ramanujam (1971).

Suvin had low lint weight and seed population per boll and the reverse was true with MCU 5. A negative association between lint weight and length was shown by Scholl and Miller (1976) and is in agreement with the variations noticed in the cultivars in the present investigation.

Micronaire or fibre fineness and strength are the most important properties on the quality of lint. Though there were variations on the fineness of the lint between the cultivars, the micronaire values are within the accepted technological norms and did not show any specificity to the cultivars as normally expected.

It has also been observed that MCU 5 possessed significantly lower fibre strength. Considering low maturity coefficient to that of preponderance of immature fibres, a low fibre strength could be expected. It could be further related to short boll maturation period. Comparatively a longer boll maturation period in Suvin provided adequate fibre maturity leading to higher strength.

In summation, an overall estimate of quality parameters project Suvin as an ideal cotton to possess quality lint as compared to MCU 5. Quality of lint in the present investigation showed varietal variations and Suvin had optimum physiological events of the developing boll due to longer boll duration.

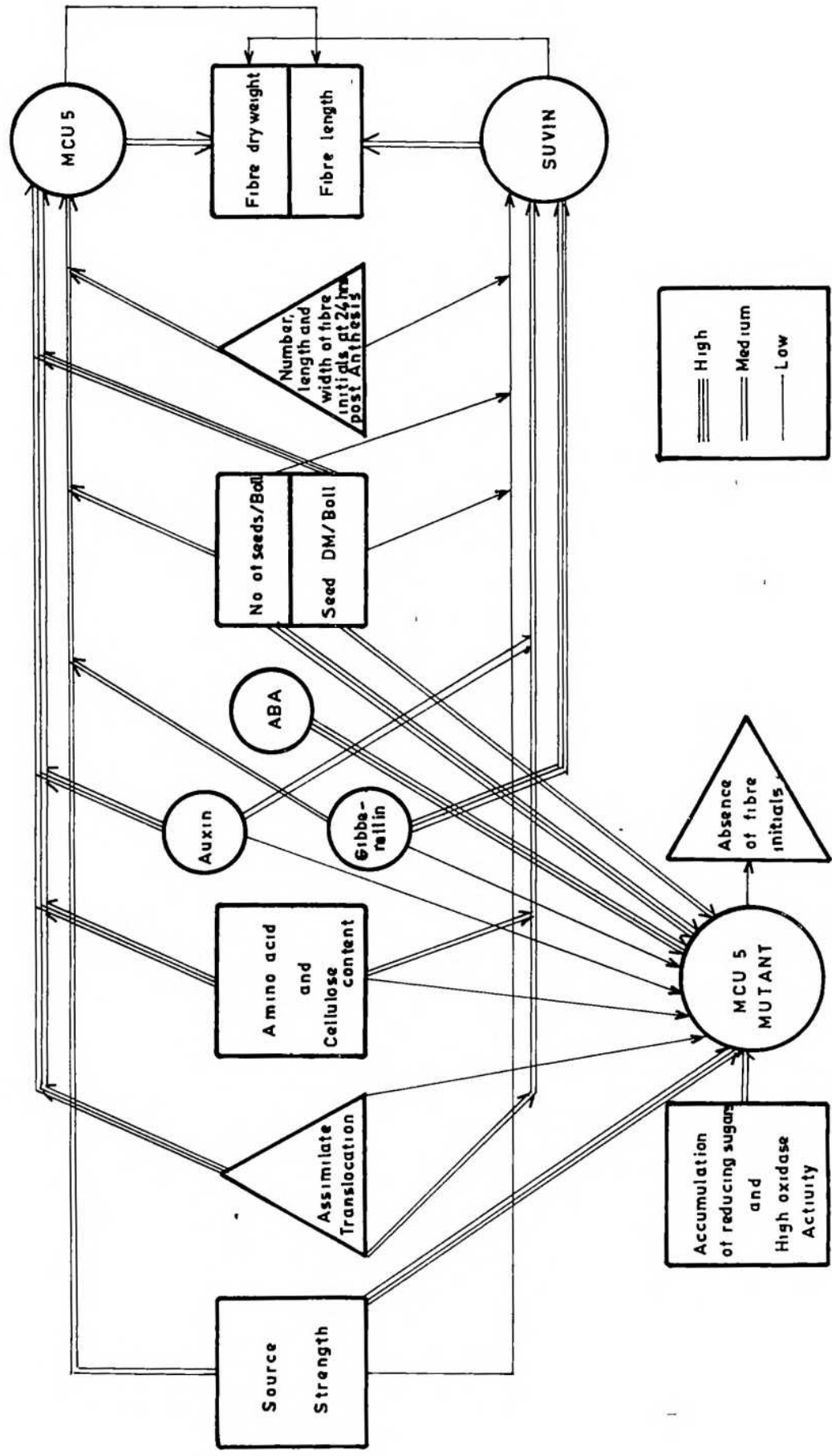
5.6. Correlation studies

Fibre length and weight were related to boll weight, seed number, moisture status of boll, its components, and chemical constituents of lint. Correlation coefficients showed that weight of boll and its components as well as seed number per boll had mostly negative association with fibre length in both the cultivars. Bala Kotaiah and Butany (1971) observed similar trends between boll number and fibre length and related this to the difficulty in simultaneous improvement for other characters. Moisture content of boll and its components on the other hand showed a positive association with fibre length. This signified the importance of moisture for better fibre growth.

With regard to fibre weight in Suvin and MCU 5, fibre dry weight per boll showed positive association with the weight of boll and its components as well as seed number. This clearly denoted that fibre dry weight unlike its length was mostly inter-dependent on the simultaneous development of other boll components. A similar observation was reported by Leffler (1980).

Among the chemical constituents of lint, correlation coefficient revealed the existence of varying levels of inter-relationship among the characters under study. Cellulose and oil content alone showed positive relationship with fibre

FIG 13. Flow diagram on certain physiological events leading to non-fibre development in MCU 5 mutant and fibre development in Suvin and MCU5



length and weight and this could be regarded as their progressive accumulation in seed during boll development. Major and micronutrients had negative association with these fibre characters. The depletion of nutrients in the lint as the fibre developed was also indicative of their redistribution within the boll as reported earlier by Leffler (1976).

The inter-correlation coefficients between various fibre quality parameters indicated variations between Suvin and MCU 5. Much of these variations were traced to differential rate of fibre development in relation to boll growth and its duration. According to De Langhe (1980), a major part of the difference in fibre properties was traced to fibre differentiation events as noticed in Suvin and MCU 5.

The inter-related events of fibre development in the cultivars and its non-development in MCU 5 mutant are presented in Fig. 19.

Recapitulation and integration of physiological events

Among the cultivars, MCU 5 possessed higher source strength of the leaf subtending boll as well as the partitioning of assimilates towards the boll, thus having an ideal source-sink relationship. This has resulted into greater sink size due to high DM investment in this cultivar. MCU 5 also possessed more

number of fibre initials at one day post-anthesis. Therefore, high lint weight in later stages of fibre development was the consequence of the initial impetus on fibre intensity. This was further substantiated by more number of seeds per boll. These events in turn limited the fibre elongation but increased the thickening considerably. Endogenous levels of phytohormones also varied in their activity. High auxin activity with an interplay of high content of aspartate and glutamate as well as potassium content directed more of lint weight through higher cellulose deposition. It was also recorded that a low endogenous gibberellin activity limited elongation of fibres in this cultivar as compared to Suvin. Above all, this cultivar exhibited earliness for all the boll characters. This probably culminated into low fibre maturity coefficient and strength as observed in quality evaluation.

Suvin had low source strength as well as a reduced supply of assimilate, which had additive physiological impediments on the quantum of lint produced per boll. This was further manifested by the reduced sink size which bore low seed number with low fibre initials. Also, a low fibre weight per seed was the outcome of low auxin input. However, comparatively higher gibberellin and phosphorus content resulted in favourable fibre elongation in the presence of more boll and fibre moisture

for a longer boll duration. An event related to fibre development in this cultivar was that there was low fibre size and intensity at post-anthesis and fibre elongation continued at a lower rate till 14 DPA. However, the rate of elongation increased in subsequent stages and ultimately ended with greater fibre length at harvest. A low fibre intensity and expansion at one day post-anthesis could be the result of limitations imposed by more growth of floral structures and also low growth promoting phytohormones at this stage as compared to MCU 5. However the overall impact of high gibberellin content in fibre elongation was conspicuous. A long boll duration led to better fibre quality output in this cultivar.

MCU 5 mutant had maximum source strength of subtending leaf. However, the translocation of assimilate was highly impaired. The DM investment occurred in alternative sink component with an increase in seed number per boll. Added to this, limitations on the dry weight partitioning in the seed components, high oxidase activity, low synthesis of cellulose, free amino acids, auxins and gibberellins and a high level of ABA led to complete absence of fibre initials. This genotype also had high accumulation of sugar and protein as well as secondary and micronutrients in seed in the absence of fibre.

The present investigation elucidated the source-sink relationship and the developmental events of the boll and its components in three cotton genotypes. The activity of auxins, gibberellins and abscisic acid emphasised the relative role of phytohormones in fibre development. This signifies the possibility of either genetic manipulation or the exogenous chemical regulation which can throw further light on the physiology of fibre development in cotton.

Summary

CHAPTER VI

SUMMARY

The present investigations embody the results of various field, pot culture and laboratory studies conducted to understand the physiology of fibre development in two elite cotton cultivars. A mutant of MCU 5 was employed to identify characters leading to lintlessness in this genotype. Time course changes in physiological, chemical, hormonal and nutritional status of the developing boll were observed. The experimental approach also encompasses the source-sink relationship as well as assimilate partitioning by ^{14}C labelling of the source leaf at chosen boll age. During fibre ontogeny, investigations were also extended to cover the developmental events of the associated boll components. The summary of results of this study is given below.

1. Two elite cotton cultivars viz., MCU 5 (Fuzzy, linted) and Suvin (linted) belonging to Gossypium hirsutum L. and Gossypium barbadense L. respectively were employed for the study. MCU 5 mutant (lintless) was designated as a 'Check'. The genotypes were grown in field during summer and winter as well as in pot culture during winter season of 1983 to collect data on various developmental events of boll and its components.

2. Data on the growth parameters indicated that MCU 5 mutant had more of plant height as well as number of leaves per plant, followed by MCU 5 and Suvin.

3. Source strength was maximum in MCU 5 mutant.

However, constraints in assimilate translocation in this mutant was evident from ^{14}C labelling at source leaf. Among the cultivars, MCU 5 alone possessed ideal source-sink relationship as observed from effective assimilate partitioning in the boll.

4. Mean number of flowers per plant was higher in MCU 5 mutant, followed by MCU 5 and Suvin. MCU 5 initiated flowers early and showed a shorter duration of flower production indicative of accelerated flowering events. In Suvin and MCU 5 mutant, flower initiation was delayed by seven days and the flowering duration was also longer. Accumulated degree days and heliothermal units were related to maximum flowering intensity. Fresh and dry weights of flowers were significantly higher in Suvin due to rapid development of epicalyx and petals of the flower, which however did not substantially contribute to the boll.

5. Data on fresh weight of boll and its components indicated that the weight continued to increase till 21 to 35 days post anthesis and later declined sharply due to desiccation. Fresh weight grain was rapid in MCU 5.

6. Dry matter (DM) continued to accumulate in the boll till harvest in MCU 5, whereas it tended to level off on 35 days after anthesis in Suvin and MCU 5 mutant. Dry matter

distribution in the seed and its components viz., seed coat and kernel was high in MCU 5. Fibre dry weight was also high in MCU 5. Besides, there was an initial lag period in the fibre dry matter accumulation followed by a rapid phase and the rate of weight increment declined at fibre maturity in both the cultivars. In MCU 5 mutant, DM investment in bur and seed as well as more seed number per boll indicated that they acted as alternative sinks in the absence of fibre. A high seed coat-kernel ratio was indicative of uneven seed development leading to limitations on the physiological functions of the seed in this genotype.

7. Boll and fibre moisture remained higher in Suvin thus providing conducive moisture profile for greater fibre elongation as compared to MCU 5. Further, moisture content in the boll and its components showed positive relationship with fibre length, whereas fibre dry weight maintained negative relationship in both the cultivars.

8. Relative growth rate of boll and its components' declined right from anthesis till harvest with fluctuations in between. MCU 5 mutant showed a rise in RGR at early boll age indicating the greater expansion of bur and seed in the absence of fibre. Fibre growth rate of cultivars also possessed similar increasing trends at early boll age as noticed in MCU 5 mutant. Correspondingly, there was low RGR of bur and seed.

9. At 24 hours post-anthesis period, MCU 5 possessed more of fibre initials per ovule and these initials were poised for greater expansion. Suvin on the other hand had lower fibre intensity and smaller size of fibre initials. A notable feature was that these initials were sparse in the lower half of the ovule at this stage. Further, elongation of the fibre was maintained high in MCU 5 till 14 days post-anthesis and subsequently it was Suvin which possessed more elongation till harvest. Among these cultivars, the relative wall thickness was higher in MCU 5.

10. Sugar depletion in the seed components and lint of the cultivars were related to cellulose synthesis. There was high rate of cellulose deposition in the lint of MCU 5 than that of Suvin. However, cellulose deposition in the lint of Suvin continued for a longer period. MCU 5 mutant had restricted cellulose synthesis and showed a tendency to possess more of reducing sugars in the seed indicative of interruption in the cellulose mechanism.

11. Protein progressively accumulated in the kernel with a concomitant decrease in amino acid content. High amino acid content in the lint of MCU 5 resulted with more of cellulose deposition. In this context, glutamate and aspartate emerged out as major amino acids related to fibre production. MCU 5 mutant lacked these amino acids in enough quantity for fibre initiation.

This genotype accumulated more of protein but less of oil. This pointed out the normal incorporation of amino acid into protein, whereas restricted oil synthesis was associated with that of sugar accumulation.

12. The content of major nutrients decreased in the lint with the advancement of boll age, indicative of their redistribution within the boll. Nitrogen accumulated more in the kernel. A high content of phosphorus in the lint of Suvin provided energy for greater fibre elongation whereas in MCU 5 it was perhaps involved in cellulose deposition of the lint. Presence of higher quantity of potassium in the lint of MCU 5 suggested greater assimilate translocation towards significant cellulose deposition. Secondary and trace elements tended to accumulate in the seeds of MCU 5 mutant perhaps due to the absence of fibre.

13. Endogenous levels of auxins and gibberellins considerably varied in the genotypes. MCU 5 had relatively higher auxin activity, while Suvin possessed more of gibberellins. A high ABA content and low level of auxins and gibberellins were noticed in MCU 5 mutant. Higher fibre dry weight in MCU 5 was due to high auxins activity whereas greater fibre elongation in Suvin was related to the presence of higher content of gibberellins. The absence of fibre initials in MCU 5 mutant was the results of high ABA and low activity of growth promoting substances.

14. The activity of IAA oxidase and peroxidase enzymes declined at active fibre elongation phase under the regulation of phenolic content in both the cultivars. A trend in the increase of the activity of oxidase enzymes at secondary thickening stage in Suvin and MCU 5 indicated slow down of IAA mediated cell expansion phase. In MCU 5 mutant, the enzyme activity was considerably high.

15. Fibre quality parameters evaluated at harvest indicated that on the whole, fibre quality was superior in Suvin. Greater span length in this cultivar reflected on higher gibberellin activity.

16. The study revealed that Suvin possessed optimum physiological events culminating into better quality fibre under the influence of more of boll and fibre moisture as well as longer boll duration as compared to MCU 5. Further studies on the auxin metabolism in relation to fibre development could through further light on this intricate problem.

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Annexures

Annexure I. Time trend changes in reducing sugar content
(mg g⁻¹ fresh weight) of seed coat, kernel and
lint of Suvin and MCU 5 and seed coat and
kernel of MCU 5 mutant

Genotype	Component	Stages of development				
		S ₁	S ₂	S ₃	S ₄	S ₅
Suvin	Seed coat		8.70	5.90	2.40	1.50
	Kernel	2.00	7.80	1.00	0.90	1.80
	Lint		9.70	6.60	1.03	1.03
MCU 5	Seed coat		12.45	4.85	1.43	0.60
	Kernel	2.40	7.80	1.40	0.93	1.40
	Lint		15.80	5.40	0.40	1.10
MCU 5 mutant	Seed coat		13.75	5.20	2.28	1.48
	Kernel	2.33	9.53	1.13	1.40	2.70

Annexure II. Time trend changes in cellulose content (per cent) of seed coat, kernel and lint of Suvin and MCU 5 and seed coat and kernel of MCU 5 mutant

Genotype	Component	Stages of development				
		S ₁	S ₂	S ₃	S ₄	S ₅
Suvin	Seed coat		2.90	3.80	4.15	4.10
	Kernel	2.45	2.30	1.70	0.35	0.15
	Lint		7.00	54.50	73.50	81.50
MCU 5	Seed coat		3.90	4.80	5.40	5.50
	Kernel	2.75	3.00	1.10	0.70	0.40
	Lint		8.50	75.50	92.50	93.00
MCU 5 mutant	Seed coat		2.10	2.60	3.70	3.70
	Kernel	1.60	1.80	0.90	0.15	0.10

Annexure III. Time trend changes in total free amino acid content ($\mu\text{g g}^{-1}$ fresh weight) of seed coat, kernel and lint of Suvin and MCU 5 and seed coat and kernel of MCU 5 mutant

Genotype	Component	Stages of development				
		S ₁	S ₂	S ₃	S ₄	S ₅
Suvin	Seed coat	1445	1860	2035	50	13
	Kernel		2240	2100	410	425
	Lint		440	350	43	80
MCU 5	Seed coat	1055	1480	1200	40	33
	Kernel		2190	1245	175	260
	Lint		655	525	30	65
MCU 5 mutant	Seed coat	1610	925	685	50	35
	Kernel		1475	1210	295	310

Annexure IV. Time trend changes in total phenolic content
(mg g⁻¹ fresh weight) of seed coat, kernel and
lint of Suvin and MCU 5 and seed coat and kernel
of MCU 5 mutant

Genotype	Component	Stages of development				
		S ₁	S ₂	S ₃	S ₄	S ₅
Suvin	Seed coat	1.03	2.63	2.50	2.05	1.23
	Kernel		2.65	0.68	0.85	1.35
	Lint		0.65	0.59	0.08	0.15
MCU 5	Seed coat	1.40	2.60	2.48	1.53	0.85
	Kernel		2.60	0.63	0.72	1.20
	Lint		0.20	0.16	0.08	0.12
MCU 5 mutant	Seed coat	1.58	2.70	2.63	1.87	1.38
	Kernel		2.73	1.05	0.79	1.60

Annexure V. Time trend changes in total nitrogen content
(per cent) of seed coat, kernel and lint of Suvin
and MCU 5 and seed coat and kernel of MCU 5 mutant

Genotype	Component	Stages of development				
		S ₁	S ₂	S ₃	S ₄	S ₅
Suvin	Seed coat	2.01	1.23	0.88	0.68	0.74
	Kernel		1.74	2.38	3.18	3.16
	Lint		0.72	0.23	0.07	0.05
MCU 5	Seed coat	2.12	1.40	0.95	0.51	0.57
	Kernel		1.91	3.06	3.54	3.85
	Lint		1.00	0.48	0.11	0.04
MCU 5 mutant	Seed coat	2.29	1.66	1.28	0.61	0.58
	Kernel		2.35	3.20	3.95	4.11

Annexure VI. Time trend changes in phosphorus content (per cent) of seed coat, kernel and lint of Suvin and MCU 5 and seed coat and kernel of MCU 5 mutant

Genotype	Component	Stages of development				
		S ₁	S ₂	S ₃	S ₄	S ₅
Suvin	Seed coat	0.62	0.29	0.16	0.13	0.02
	Kernel		0.32	0.92	0.99	0.81
	Lint		0.43	0.27	0.04	0.03
MCU 5	Seed coat	0.74	0.42	0.20	0.03	0.03
	Kernel		0.31	0.78	0.84	0.83
	Lint		0.40	0.14	0.04	0.02
MCU 5 mutant	Seed coat	0.51	0.33	0.18	0.10	0.01
	Kernel		0.33	0.71	0.83	0.83

Annexure VII. Time trend changes in potassium content (per cent) of seed coat, kernel and lint of Suvin and MCU 5 and seed coat and kernel of MCU 5 mutant

Genotype	Component	Stages of development				
		S ₁	S ₂	S ₃	S ₄	S ₅
Suvin	Seed coat	1.19	0.73	0.84	0.72	0.66
	Kernel		0.86	1.08	0.78	0.75
	Lint		0.90	0.73	0.41	0.30
MCU 5	Seed coat	1.47	1.00	0.82	0.58	0.58
	Kernel		1.04	0.86	0.69	0.65
	Lint		1.37	0.65	0.44	0.43
MCU 5 mutant	Seed coat	1.04	1.18	0.68	0.61	0.50
	Kernel		1.26	0.78	0.66	0.59

Annexure VIII. Time trend changes in calcium content (per cent) of seed coat, kernel and lint of Suvin and MCU 5 and seed coat and kernel of MCU 5 mutant

Genotype	Component	Stages of development				
		S ₁	S ₂	S ₃	S ₄	S ₅
Suvin	Seed coat	0.14	0.23	0.18	0.14	0.16
	Kernel		0.20	0.26	0.22	0.18
	Lint		0.34	0.12	0.10	0.10
MCU 5	Seed coat	0.16	0.28	0.25	0.24	0.18
	Kernel		0.22	0.27	0.20	0.20
	Lint		0.27	0.18	0.07	0.07
MCU 5 mutant	Seed coat	0.19	0.31	0.28	0.25	0.20
	Kernel		0.25	0.30	0.30	0.27

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Annexure IX. Time trend changes in zinc content (ppm) of seed coat, kernel and lint of Suvin and MCU 5 and seed coat and kernel of MCU 5 mutant

Genotype	Component	Stages of development				
		S ₁	S ₂	S ₃	S ₄	S ₅
Suvin	Seed coat	55.00	183.50	35.00	26.25	63.75
	Kernel		65.00	77.50	66.25	62.50
	Lint		82.50	32.50	22.50	33.75
MCU 5	Seed coat	97.75	177.50	52.50	31.25	47.50
	Kernel		162.50	86.25	81.25	72.50
	Lint		127.50	43.75	25.00	59.25
MCU 5 mutant	Seed coat	53.75	121.25	97.25	59.40	97.50
	Kernel		112.50	102.50	65.00	46.25

Annexure X. Time trend changes in manganese content (ppm)
of seed coat, kernel and lint of Suvin and
MCU 5 and seed coat and kernel of MCU 5 mutant

Genotype	Component	Stages of development				
		S ₁	S ₂	S ₃	S ₄	S ₅
Suvin	Seed coat	32.50	41.70	25.00	33.30	40.00
	Kernel		24.15	17.50	34.15	35.00
	Lint		56.65	25.85	24.15	33.30
MCU 5	Seed coat	40.85	83.30	25.00	23.35	40.85
	Kernel		25.85	25.00	24.15	24.15
	Lint		48.35	25.85	25.00	31.65
MCU 5 mutant	Seed coat	42.50	91.65	40.85	46.85	33.30
	Kernel		91.65	23.35	31.65	26.65

Annexure XI. Time trend changes in total iron content of seed coat, kernel and lint of Suvin and MCU 5 and seed coat and kernel of MCU 5 mutant

Genotype	Component	Stages of development				
		S ₁	S ₂	S ₃	S ₄	S ₅
Suvin	Seed coat	48.35	341.70	130.00	230.00	211.70
	Kernel		106.65	106.65	138.85	85.00
	Lint		103.35	133.35	116.70	63.50
MCU 5	Seed coat	103.65	508.35	160.00	181.65	149.15
			193.20	103.35	233.35	108.35
			106.65	114.85	98.15	33.30
MCU 5 mutant	Seed coat	73.00	693.35	114.85	98.15	93.30
	Kernel		266.65	190.00	105.00	101.65

Annexure XII. Time trend changes in total protein content (per cent) of seed coat, kernel and lint of Suvin and MCU 5 and seed coat and kernel of MCU 5 mutant

Genotype	Component	Stages of development				
		S ₁	S ₂	S ₃	S ₄	S ₅
Suvin	Seed coat	9.81	6.38	5.05	4.03	3.00
	Kernel		8.50	11.13	13.83	18.13
	Lint		4.00	1.10	0.35	0.26
MCU 5	Seed coat	11.04	6.63	5.61	3.08	3.25
	Kernel		9.38	15.00	20.00	21.93
	Lint		6.03	2.55	0.48	0.19
MCU 5 mutant	Seed coat	12.36	8.00	7.50	3.56	3.27
	Kernel		10.14	18.63	22.00	23.50