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Impressive records of world food production during the 'green revolution era' suggest that the greatest single accomplishment of the 20th century is the bumper crop production throughout the world. Not only in India but in other parts of the world also, agricultural production has increased remarkably reaching near self sufficiency inspite of notorious dry spells (Brown 1967, 1968; Wittwer 1970; Kuckuck 1975). The major cause of this exponential increase was the development of early maturing, dwarf, stiff-strawed cultivars with photoperiodic insensitivity. Introduction of a single genetic factor - short stiff straw - makes the plant resistant to lodging, responsive to fertilizers, early in maturity and suitable for easy mechanical harvest. Although dwarf cultivars are now extensively used in the breeding programmes, a thorough understanding of the mechanism of dwarfism is yet to be attained.

Dwarfism as a distinct form of growth was recognised long before the events of modern genetics and biochemistry. Since Mendel's (1866) classical work, its genetical aspects have been investigated in several taxa especially certain groups such as Pharbitis nil, Zea mays, Pisum sativum, Lycopersicum esculentum etc., (See Pelton 1964).
The manifestation of dwarfing genes in comparison with their normal counterparts is expressed clearly at the organ level, giving an indication of the underlying mechanism of growth in higher plants (Felton 1964). In fact, a small change in genetic information is manifested at the organ level resulting from the cellular activities. Hence, if a difference in genetic constitution between dwarf and tall cultivars is located, the resulting differential expression can very well be predicted. This apparently easy prediction, however, due to extreme complexity of genic composition, has become altogether difficult, if not impossible, in higher plants. Reasonably, therefore, the approach has been from 'expression' to 'mechanism' to 'cause' instead of predicting 'results' from genetic diversity, rather an indirect approach.

Comparative studies at organ level, particularly with respect to root, shoot, floral organs etc., are numerous and stress the importance of studies at finer levels i.e., at cellular and genic levels. Organ level experiments have shown that shorter internodes are responsible for dwarfing (See Felton 1964). Progressive shortening of successive internodes in dwarfs as compared to normals was also observed (Harlan and Pope 1922). Similarly Li (1933) found that all internodes in dwarfs were shorter than normals except the one bearing tassel. In short, organ level studies revealed that dwarfism is attributable to shorter organs in general.
Cytological investigations at cellular level in relation to dwarfism revealed that less cell division, reduced rate of cell elongation and a change in differentiation may be operative either singly or collectively and may account for the cellular basis of dwarfism. Blindloss, as early as 1942, reported fewer cell division in dwarf than normal sibs of *Lycopersicon esculentum*. Representative results in different tissues have also been reported (Abbe and Phimney 1940).

The aforementioned morphological observations just served as a source of information and the factors responsible for dwarfism are little understood. Surveying hormonal researches Pelton (1964) pointed out to the general observations that dwarfism is thought to be reflected due to the deficiency of growth hormones responsible for the longitudinal growth of stem. Lower levels of a native hormone - gibberellin, has been attributed to be the causal factor for dwarfism in plants. In many studies lower levels of gibberellic acid (GA) - like substances have been reported (Phimney 1961, Goto and Esashi 1975). Although a suggestion is made that the blockade in GA biosynthesis is the major reason for dwarfism, contradictory reports (Radley 1970) on the endogenous levels and response of dwarf and tall cultivars to applied gibberellins suggest that gibberellin levels alone do not occupy the position of prime importance in the 'modus operandi' of dwarfism in plants.

It is well known that all hormones act through their effects on genes; thus bringing about a change in the metabolism, where also a 'block'
or 'modification' can be logically presumed. The product of genes (enzymes) serves as a powerful means to elucidate the mechanism of growth at the molecular level. Recently attention has been paid to certain metabolic indicators, especially respiration rate, chlorophyll content and enzymes particularly peroxidase. Rahman and Brown (1956) and Israelstam and Fukumoto (1977) detected differences in respiratory activity between dwarf and tall cultivars with respect to oxygen consumption by succinate suggesting the importance of dissipative metabolism in dwarfism.

Higher levels of chlorophyll content were reported in dwarf cultivars (Bouilleme - Warland and Bouilleme 1960). However, recently Moitra (1978) reported contradictory results. Kriedmann et al. (1979) showed that the rate of photosynthesis is not related to the concentration of chlorophyll in the leaves or chloroplasts and chlorophyll plays only a catalytic role. They further suggested that certain ancillary electron donors closely linked to the photoreactions may be responsible for the differences in the photosynthetic efficiency of different cultivars.

Ascorbic acid (AA) - an important redox substance - has been attributed a role in photosynthetic electron transfers (Krasovskii 1960, Mapson 1964). It has repeatedly been shown that addition of ascorbic acid increased photophosphorylation reactions in isolated chloroplasts (Arnon 1956, 1957, 1958, 1961). A close correlation between ascorbic acid
biosynthesis and photosynthesis has been established (Mitsui and Oi 1961).

Extensive studies, carried out in this laboratory, on the role of ascorbic acid during germination, growth and development of plants suggest its inductive effects and active participation in the overall metabolism during these processes (See Chinoy 1977, Chinoy et al. 1970).

Formation of ascorbic acid and its universal occurrence even at organelle level have been reported (Mapson 1958). Active participation of ascorbate in oxidative phosphorylation and nitrate reduction has highlighted its importance in general metabolism (Mapson 1958, Trubchev 1963, Edgar 1970).

Research work in this laboratory and elsewhere has made it exclusively clear that formation as well as enzymic utilization of ascorbate plays a vital role right from the inception of germination and continues to play similar role throughout the complete life cycle of a plant. Khudairi (1968) considered ascorbate as a phytoph ormone. Like other hormones ascorbic acid is known for its inductive effects on enzymes (Saxena et al., 1969) and its interaction with nuclear material (Price 1966).

Even though gibberellins have been implicated with dwarfism in plants, in recent years, a number of reports suggests that IAA plays an important role and that the gibberellin action is mediated though IAA (Mertz 1966, Phillips 1969). Further, studies on endogenous levels of
GA-like substances and the response of different cultivars to applied gibberellins (Radley 1970) indicated that these substances are not the only growth controlling factors solely responsible for the longitudinal growth of stem in plants. Several workers have shown that gibberellin application causes an increase in endogenous levels of auxins in plants (Nitsch and Nitsch 1959, Andersen and Muir 1969). A higher content of auxin-like material has been found in tall than in dwarf cultivars of several species (Van Overbeek 1938, Scott and Briggs 1960, Lantican and Muir 1969).

Conflicting views exist regarding the action of IAA in relation to growth and development. Galston and Davies (1969) proposed a detoxifying role for IAA oxidizing systems and suggested the importance of IAA concentration, while Meudt (1967, 1972) believed that the oxidation product (formed by IAA oxidase and peroxidase systems) of IAA is responsible for growth effects of IAA. Supporting data have been presented by Jacobson and Caplin (1967) who showed young carrot root phloem tissues to respond to IAA more than any other tissue and that the IAA oxidase activity was higher than any other tissue. Ockerse et al. (1970) also reported that apices of tall dark grown pea seedlings contain 35 times higher IAA oxidase activity than dwarf ones.

There are evidences relating manganese (Mn²⁺) as a stimulator or co-factor for IAA oxidase systems (Kenton and Mann 1950, Taylor et al. 1968). This element has been included in hypothetical mechanisms of IAA
oxidase (Kenton 1955, Waygood et al. 1966) and has been related to in vitro destruction of IAA oxidase inhibitors (Furuya et al. 1962). A relation between IAA oxidase and Mn$^{2+}$ nutrition of plants indicates the direct participation of this element in the IAA oxidation. An absolute requirement of manganese in gibberellin biosynthesis has been stated (Ogura et al. 1972).

Nitrate reductase (NR), the first in the series of nitrate reducing enzymes, is considered as the rate limiting step in amino acid synthesis (Schrader et al. 1968, Bevers and Hageman 1969). It has been correlated with growth, metabolic changes, differentiation, plant age, yield characteristics etc. in a number of cases particularly by Hageman's group (Deckard et al. 1973, Eilrich and Hageman 1973, Johnson et al. 1976). The correlation of this enzyme with total dry weight accumulation, grain nitrogen, protein content and grain yield is also attractive (Bowerman and Goodman 1971).

Based on these properties, this group (Hageman et al. 1974) has quite aptly suggested that nitrate reductase can be used as a biochemical criterion for selection of cultivars for breeding programmes.

Recently, wide application of electrophoretic techniques have provided valuable informations from qualitative standpoint as an additional support to quantitative measurements. Further, in systems where quantitative differences were undetectable, qualitative changes could be visualized. Moreover this technique has also helped in the elucidation of mechanism of action of growth regulators and inhibitors e.g. cycloheximide, a known
inhibitor of protein synthesis, has been shown to promote synthesis at lower concentration (Macdonald and Ellis 1969, Ellis and Macdonald 1970). Thus isoenzyme analysis is proved to be one of the most useful techniques in understanding the phenomena of growth and differentiation. In fact isoenzyme polymorphism has been reported in a number of plants with a view to establishing phylogenetic and physiogenetic relationships among different cultivars of various crops (Scandalios 1966, Hamill and Brewbaker 1969, Macdonald and Brewbaker 1975). Shanon (1965) has reviewed the earlier literature on plant isoenzymes.

Considering the significance of these enzymes and methods a concerted attempt was made to understand the physiology of dwarfism in plants. Experiments conducted till today are mostly at later stages of growth whereas in the present investigation juvenile differentiation was taken into consideration. Following experiments were performed at 24 hourly intervals after germination in different organs:

(i) To compare the growth rates of different organs viz. root and shoot of sorghum cultivars with varying degrees of dwarfism.

(ii) To investigate changes in ascorbate turnover in all organs i.e. root, shoot and endosperm, during germination. This includes measurements of free ascorbate levels and the activity of the enzymes participating in the ascorbate oxidizing systems. Since ascorbate is acted upon by a number of enzymes this is collectively termed AA utilization (Chinoy 1962).
(iii) To evaluate the activity of IAA oxidizing enzymes (IAA Oxidase and peroxidase) with a view to understanding physiology of dwarfism,

(iv) To estimate nitrate reductase activity in these cultivars during germination and at later periods in relation to dwarfism,

(v) Electron spin resonance spectroscopy was employed to measure the amount of paramagnetic trace element - manganese which plays a catalytic role in cellular physiology,

(vi) To determine the degree of sensitivity to applied gibberellins of commonly grown wheat cultivars of Gujarat,

(vii) Electrophoretic separation of isoenzymes of amylase, esterase and peroxidase in different organs during germination.