INTRODUCTION

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The rapidly rising global demand for food production, and the need for betterments in agricultural productivity to raise the living standard of those working in agriculture, have been met during this century by an unprecedented spate of technological change, viz. plant breeding, fertilizers, pesticides and mechanisation. The new technologies have radically changed the agriculture in the developed world and are now making a critical impact in developing countries (Lever 1982).

It has been established that normal plant growth and development is controlled by endogenous phytohormones. Ever since the first practical use of plant growth regulators in 1930s plant scientists have been trying to apply chemicals at the crop level. Since 1950 there has been a spectacular development of the technology of chemical regulation of plant growth and development. Simultaneous with almost exponential increase in regulatory systems and regulatory chemicals known to plant physiologists and agriculturists, there has been tremendous economic pressure to offset hand labour in agricultural production, and application of chemicals have been the salient source of change in minimizing hand labour. While herbicides have contributed the most impressive economic aid to agricultural production through the use of chemicals, since about 1965 there has been a burst of development of new chemicals which could be utilized in the regulation of plant growth. These growth regulatory chemicals have found a wide application for a variety of purposes in agriculture. Among these growth regulating substances, one group of synthetic plant growth regulators retard shoot growth in higher plants without causing malformation or damage. These compounds were called plant growth retardants by Cathey (1964) and influence meristematic activity in the subapical zones of the plant that are almost solely responsible for stem-histogenesis (Sachs,1965).

The most common response of plants to growth retardants is reduction of stem elongation which in extreme case can cause almost rosette like growth habit but which, apart from a deeper green colour and greater thickness of leaves, is usually not associated with pronounced anomalies of development or structure (Harada and Lang 1965). Growth retardants are highly specific. There is no obvious correlation between taxonomic classification and plant response to a particular compound. Even different cultivars of the same species vary greatly in the responsiveness to the applied chemical (Cathey 1964). Although growth retardants are quite different in their chemical structure, their effect on the plants is in general quite similar (Harada and Lang 1965).

The most notable growth retardants which are introduced and studied are Ethephon (Kabachnick and Rossiyskaya 1946), Maleic hydrazide (Schoene and Hoffman 1949), AMO 1618 (Wirwille and Mitchell, 1950) CCC (chlormequat chloride or cycocel) (Tolbert 1960) and TIBA (Amchem products inc.1961), Daminozide (Riddell et al.1962). Growth retardants which have been introduced recently include Amcymidol (Tachabold et al. 1970), Mepiquat chloride (Jung et al. 1975), Tetcyclacis (Jung et al. 1980) and Paclobutrazol (Couture 1982).

Chemical Nomenclature of Important Plant Growth Retardants

Maleichydrazide : 1,2-dihydro-3,6-pyridazinedione.

AMO 1618 : 4-hydroxy 5-iso propyl-2-methyl phenyl trimethyl ammonium chloride, 1-piperidine carboxylate.

CCC : (2-chloroethyl) trimethyl ammonium chloride.

Daminozide : N-dimethyl amino succinamic acid.

Ethephon : 2-chloro ethyl phosphonic acid

TIBA : 2,3,5 tri iodo benzoic acid.

Ancymidol : α-cyclo propyl -α- (4 methoxy phenyl)-5-pyrimidine methanol.

Mepiquat chloride : 1,1-dimethyl piperidinium chloride.

Tetcyclacis : 5-(4-chlorophenyl) 3,4,5,9,10-pentaza-tetracyclo- $5,4,1,0^{2,6},0^{8,11}$-dodeca-3,9-diene.

A break through concerning the mode of action of growth retardants was made by the discovery that AMO 1618 and CCC inhibit gibberellin biosynthesis in the fungus *Fusarium moniliforme* (Kende *et al*. 1963; Ninnemann *et al*. 1964). This led to believe that growth retardants also inhibit the biosynthesis of gibberellin in higher plants. These growth regulating chemicals induce dwarfism in plants by influencing cell division and cell enlargement in the subapical meristem of the shoot (Sachs 1965, Nitsche *et al*. 1985) probably by interfering with gibberellin and sterol biosynthesis. The quarternary annonium derivatives, AMO 1618 and CCC inhibit the biosynthesis of gibberellin by blocking the cyclization of geranyl geranyl pyrophosphate to entkaurene (Sembdner *et al*.1980), while the recently developed inhibitors, the pyrimidine ancymidol, the norborneno diazetine tetcyclacis and the triazole paclobutrazol prevent the formation of entkaurenoic acid from ent-kaurene (Coolbaugh and Hamilton 1976, Dalziel and Lawrence 1984, Rademacher *et al*. 1984).

It has been reported that triazoles and norborneno diazetine type of growth retardants reduce the gibberellin contents in intact plants (Izumi *et al*. 1984, Zeevaart 1985). A significant reduction of the gibberellin content in *Fusarium moniliforme* (Ninnemann *et al*. 1964), *Pharbitis* seeds (Zeevaart, 1966), balsam (Ried and Carr. 1967),*Phaseolus vulgaris* (Dale and Felippe 1968) by CCC has also been reported

There are reports that plant growth retardants inhibit sterol biosynthesis too. Tetcyclacis and several triazole compounds interfere with sterol biosynthesis (Grossmann <u>et al</u>. 1985). Barnes and his co-workers (1969) observed that AMO 1618 and CCC did do not affect sterol biosynthesis in either <u>Fusarium moniliforme</u> or barley. However, Douglas and Paleg (1974) found that AMO 1618 and phosphon-d do inhibit sterol biosynthesis in tobacco atleast. It is generally accepted that most common growth retardants inhibit gibberellin biosynthesis as their primary mode of action. It has also been shown that growth inhibition caused by these compounds can generally be relieved by addition of gibberellin (Lang 1970).

Plant growth retardants are reported to modify the reproductive as well as vegetative characters of a wide variety plant types. Several reports indicate that there is a reduction in the longitudinal growth of the stem of the plants treated with growth retarding chemicals in wheat (Humphries <u>et al</u>. 1965; Jackowska 1968; Brown and Earley, 1973; Dahnous <u>et al</u>. 1982; Bengtsson 1987) bean (Chailakhyan and arutyunyan 1968; Wheeler 1969), chrysanthemum (Sachs and Kofranek, 1963 Riess-Bubbenheim and Lewis (1984), <u>Canabis sativa</u> (Dall'ollio 1964a), <u>Samolus parviflorus</u> (Baldev and Lang 1965), sunflower (Sauerbrey <u>et al</u> 1987), soyabean (Chailakhyan and Arutyunyan 1968) rice (Schott <u>et al</u>. 1984; Lürssen and Reiser 1985;

Rucong et al.1987), cotton (Schott and Ritting 1982) grapes (Bourquin and Alleweldt 1970; Shaltout et al 1988) Euphorbia pulcherima (Lange 1976), Primula obconica (Abou-zied and Bakry 1978), oil seed rape (Daniels et al.1982) grasses (Shearing and Batch 1982; Hebblethwaite et al.1982, Field and Whitford, 1982), geranium (Schwarts et al. 1985, Holcomb et al. 1987) and Sage (El-keltawi and Croteau 1987).

Application of growth retardants to plants inhibited root formation or delayed root development (Cathey 1964). Inhibition of root growth in peas (Macchia 1967), Dolichos labab (Tung and Raghavan 1968), rice (Chakraverty 1969, Rucong et al. 1987) and a delay in root development on the cuttings of Chrysanthemum (Cathey 1964) due to the application of growth retardants have been recorded. However, some authors reported that treatment with growth retardants results in the promotion root growth in wheat (Supniewska 1963; Khan and Wasti 1982), Convolvulus (Libbert and Urban 1964), winter cereals (Bragg 1982), Phaseolus vulgaris (Tognoni et al.1987; Davis et al. 1985; Upadhyaya et al. 1986) and in Barley (Naylor et al. 1986).

Plant growth retardants may induce development of darker green leaves and alter the number, area, thickness and chlorophyll content of the leaves in treated plants, for instances, in wheat (Tolbert 1960; Supniewska,1963) tomato (Wittwer and Tolbert 1960), tobacco (Humphries 1963), hemp (Dall'olio 1964a) Datura stramonium (Dall'olio 1964b) cotton

(Bhatt and Ramanujam 1970; El-Fouly and Ashour 1970, Schott and Ritting 1982), Gladiolus (Halevy and Shilo 1970), Euphorbia pulcherima (Lange 1976), Soyabean (Hewitt et al.1982) rye grass (Shearing and Batch 1982), Pelargonium hortorum (Welander 1984) kidney bean (El-Fouly et al.1988) and grapes (Shaltout et al. 1988).

As a result of treatment with growth retardants, the flowering process may remain unaltered, be accelerated, be delayed or be inhibited (Cathey 1964). The promotion of flowering by growth retardants in tomato (Wittwer and Tolbert 1960b), Rhododendron (Stuart 1961; 1962) Impatiens balsamina (Nanda et al. 1968) Hydrangea macrophylla (Milletti and Decapite 1968), Gladiolus (Halevy and Shilo 1970) Vaccinium corymbosum (Robbins and Doughty 1984), geranium (Welander 1984; Schwarts et al. 1985, Holcomb et al. 1987) cherry (Cobianchi et al. 1985), apple (Tukey 1985), Bouvardia humboldtii (Wilkinson and Richards 1987), and pear (Charles et al. 1987; Dheim and Browning 1988) and inhibition of flowering in Bryophyllum diagremontianum (Zeevaart and Lang 1963), Pharbitis nil (Zeevaart 1964), Samolus parviflorus (Baldev and Lang 1965) and winter wheat (Suge and Osada 1966) have been reported. The flowering in Abelmoschus esculentus (Mehrotra et al 1970) and Chrysanthemum morifolium (Reisbubenheim and Lewis 1984) was reported to be delayed by treatment with growth retardants.

There are several cases of yield increase following treatment with growth retardants in crop plants such as potato

(Choudhri et al.1976), barley (Larter 1967, Stokes et al. 1985b) wheat (Schultz 1971, Khan and Wasti 1982), grapes (Shaltout et al.1988), pears (Parson 1967), cherry (Batjar et al. 1969) *Abelmoschus esculentus* (Mehrotra et al.1970) tomato (Sims et al.1973, Bocion et al.1975) soyabean (Hewitt et al.1982).

In the past several years a number of types of research have been developed to improve yield through direct modification of several crop plants, and from such researches it appears that the potentialities of plant growth regulators could be exploited for the development of a new and potentially powerful cultural method for the modification of plant growth and development in a direction leading to improved yields (Archer et al. 1982).

CCC or chlorocholine chloride (2-chloroethyl) trimethyl ammonium chloride , also known as chlormequat chloride and cycocel, is among the most widely used plant growth regulator in the world on crops. This was one of the several compounds reported by Tolbert (1960) to be active on a wide range plant species and used mainly as an antilodging agent in cereals. The practical use of CCC to reduce lodging mainly in North European wheat crops, represents one of the earliest developments of a plant growth regulator by a chemical company, in this instance Cyanamid International (BP 944807) although the initial activity was discovered in a university laboratory.

The early experimental work on the antilodging properties of CCC was carried out in Germany and Austria by Linser *et al*. (1961), Linser and Kühn (1962) and Mayer *et al*.(1962). It was observed that CCC not only caused a reduction in the stem length but could also increase yield. In 1964, in the field trials conducted by Caldicott and Lindley on a wheat variety, Capelle-Desprez, CCC was applied to the crop as foliar spray. The success of CCC in shortening internodes, reducing or even eliminating lodging and increasing yield in these trials ensured its introduction in to commercial practice soon afterwards. Since 1975 CCC has become much more widely used on cereals due partly to an increase in crop area as a result of high prices paid to farmers in the European Economic Community and also to the trend towards high intensity cereal production, with emphasis on wheat (Garrod 1982).

The introduction of CCC in the 1960s was followed by an intense period of research into its mode of action. The primary effect of CCC is to shorten and strengthen the stem of plants thereby reducing the losses caused by lodging (Tolbert 1960, Cathey 1964). CCC blocks gibberellin biosynthesis by inhibiting the cyclization of trans-geranyl geranyl pyrophosphate to entkaurene (Sembdner *et al*. 1980) and severely inhibits subapical meristematic activity of plants (Sachs 1965) leading to reduced stature of plants.

Many species of field, fruit, vegetable, flower and ornamental crops and grasses were treated with CCC and many publications ensured. However, very few uses have been adopted by farmers and growers on a commercial scale. Apart from application to certain varieties of azalea to produce early budded compact, symmetrical plants; to poin settias to reduce plant height; to zonal pelargoniums to reduce their internode growth and hasten flowering and to Asiatic hybrid lilies to control plant height, no major use, apart from that on cereals, has been developed. Although CCC has positive growth effects on potatoes (Humphries 1963), sugar cane, where it has been evaluated as a chemical ripening agent (Nickell, 1977), sunflower (Lovett and Orchard 1974), apples, citrus, grapevines, phaseolus beans, peas, tomatoes and a host of relatively minor vegetable and ornamental plants, it has not been registered for use on any of these crops (Garrod 1982).

The inhibition of culm growth by CCC was abundantly reported in cereals such as wheat (Tolbert 1960; Supniewski et al. 1962; Linser and Kühn 1962; Linser and Kühn 1964, Humphries et al. 1965; Birecka 1967, Primost and Rittmeyer 1968; Page 1973; Gill et al 1974 , Brükner and Höfner 1980; Bengtsson 1987), barley (Linser et al. 1963 ; Humphries 1965; Lacoppe and Gaspar 1968; Koranteng and Matthews 1982; Naylor et al. 1986) and in rice (Chakraverty 1969) and maize (Wittwer and Tolbert 1960a, Kotting et al. 1988). There are several other cases of growth retardation following CCC administration on a wide variety of other plants such as tomato (Wittwer and Tolbert 1960b; Adler and Wilcox 1987), *Phaseolus vulgaris* (Supniewski *et al*. 1962; Felippe 1969; El-Fouly *et al*. 1988) mustard, raddish and tobacco (Humphries 1963) *Datura stramonium* (Dall'olio 1964b). Strawberry (Guttridge 1966), sunflower (Jones and Phillips 1967) pea (Macchia 1967) cotton (Bhatt and Ramajujam 1970), *Abelmoschus esculentus* (Mehrotra *et al*. 1970), *Cyperus alternifolius* (Fisher 1970), (*Aechmea fasciata* (Ziv *et al*. 1986), *Begonia hiemalis* (Roivainen 1987), *Rhododendron obtusum* (Whealy *et al*. 1988), and *Amaranthus caudatus* (Guruprasad and Guruprasad 1988). However, stimulation of growth following CCC application was also reported in some plants such as snapdragons (Halevy and Wittwer 1965, Wünsche 1969), lemons (Monselise *et al*. 1966), peas (Sebanek and Hink 1966, Adedipe *et al*. 1968, Carr and Reid 1968), *Begonia* (Heide 1969), *Gladiolus* (Halvey and Shilo 1970) and *Pimpinella anisum* (Ellabban 1977).

Though CCC is mainly used to prevent yield losses in cereals especially in wheat varieties which are susceptible to lodging, increases in grain yield have been observed even when untreated crops have not lodged (Koranteng and Matthews 1982; Cartwright and Waddington 1982). Apart from wheat (Sturm and Jung 1964b; Caldicottand Lindley 1964; Hungerbuhler and Peclard 1965; Pinthus and Halevy 1965; Humphries *et al*. 1965; Hofner *et al*. 1980; Matthews and Caldicott 1981; Höfner and Kühn 1982; Höfner *et al.* 1984), Barley (Linser *et al.* 1963; Larter 1967; Koranteng and Matthews 1982; Matthews and Thomson 1984; Thomson and Matthews 1984; Stokes *et al.* 1986) and other cereals such as *Sorghum* (Goudreddy *et al.* 1986) and maize (Kotting *et al.* 1988), CCC also was reported to increase yield in other crops viz. grapes (Coombe 1965, 1967; Turkington 1967), mango (Maiti and Sen 1968), potato (Tizio 1969; Hruska and Popper 1970; Shadeque and Pandita 1982; Menzel 1984), carrot (Thomas *et al.* 1982), apple pear and cherry (Agafonov and Kazakova 1984), strawberry (Agafonov and Kazakova 1984; McArthur and Eaton 1988), pumpkin (Verma *et al.* 1987) and kidney bean (El-Fouly *et al.* 1988), Besides, in numerous field trials, CCC in combination with other growth regulators such as Ancymidol, Ethephon, DCiB (2,3, chloro isobutyric acid) etc. reduced culm length and increased grain yield in cereals (Höfner and Kühn 1982).

Mung bean (*Vigna radiata*)is an important legume crop in India and is spread all over the country (2.5 million hectares) with an annual production of 0.8 million tonnes only. Mung bean (Green gram) like other pulses provides the much needed protein to our predominantly cereal based diet. Malnutrition due to protein deficiency amongst millions of Indian infants and young children is a matter of grave concern. Increasing the production of pulses is the least expensive and most immediate practical way of diminishing the intellectual dwarfism caused by malnutrition due to protein deficiency in the under developed nations at present.

Recent studies show that application of gibberellic acid that induces pronounced stem elongation in pea and soyabean plants also produces marked reduction in N_2 fixation. Results of some preliminary studies indicate that the diversion of carbohydrate into the production of increased stem growth occurs at the expense of root growth and, perhaps, at the development of root nodules. These observations suggest that dwarfism in legumes may benefit N_2 fixation. In garden pea dwarfing genes are known to control the biosynthesis of gibberellins. Pea cultivars that possess dwarf genes have retarded stem elongation and are of reduced stature. Dwarf cultivars, in contrast to their counterparts, might then have more carbohydrates available for the production of root nodules necessary for nitrogen fixation.

The present studies have been taken up with a view to examining the effect of CCC on growth yield and N_2 fixing ability of mung bean.