CHAPTER - IV

SUMMARY AND CONCLUSIONS

Summary And Conclusions

Among the economically important CAM plants *Agave* is perhaps the most important from the view point of fibre production. Number of *Agave* species such as *A. sisalana*, *A. cantala*, *A. americana*, *A. veracruz*, *A. fourcroydes*, *A. amaniensis*, *A. angustifolia*, etc., yield a good quality of hard fibre which has got several commercial applications. Besides fibre, some *Agave* species are also potential sources of alcohol. Some *Agave* species also provide food, medicine and wax. Recent phytochemical investigations have indicated presence of number of glycosides and saponins in various *Agave* species. *A. americana*, *A. amaniensis*, *A. angustifolia*, *A. cantala*, *A. fourcroydes*, *A. sisalana*, *A. veracruz*, *A. wightii* have been found in India. Among these species *A. cantala*, *A. sisalana*, *A. veracruz* have been established commercially in the country.

It is very well realised that *Agave* is hardy perennial crop and can grow on a wide variety of soils under varied climatic conditions. It can grow at very low temperatures provided frost doest not occur and on the other hand, it can even grow in temperatures upto 50°C. *Agave* can adapt itself to dry areas having a rainfall as low as 35 cm and it can grow in places with a rainfall of 280 cm provided waterlogging does not occur. Hence this crop has got wider adaptability in India and there is wide scope for its

expansion in the country. A voluminous literature is available regarding various aspects of Agave such as cytology, cultivation, morphology and agronomy (Lock, 1969), but this literature mainly covers work on Agave species in African and Latin American countries and there is hardly any reference to Indian situation. It is very well realised in recent years that understanding of the physiological processes in a crop plant is an essential prerequisite for making further improvement in its quality as well as yield. In case of succulent plants like Agave the physiological process which has attracted the attention of most plant physiologists in last fifty years is Crassulacean Acid Metabolism. There are several attempts to understand the role of endogenous as well as environmental factors in regulation of this metabolism in Agave species namely A. americana, A.sisalana, A. deserti, A. salmiana, A. lechuguilla, A. fourcroydes, A. veracruz, A. angustifolia, A. wightii, etc. Review of literature further indicates that A. cantala the most promising Agave species in India, has not been studied in this respect. Hence we thought it worthwhile to study some physiological aspects in A. cantala. These studies encompass the study of fate of various inorganic constituents as well as important organic constituents during the course of leaf senescence and under the climatic conditions. Prevailing in different seasons of the year. Similarly an attempt is also made to study the influence of various seasons (rainy

season, winter and summer) on the CAM behaviour in A. cantala. Some of the present investigations can be briefly summarised as follows :

A) Mineral nutrition studies :

1. Sodium :

The analysis of sodium contents in different leaf categories (young, mature and senescent) of Agave cantala revealed that the plant contains very low levels of sodium and the sodium contents range from 0.04 to 0.069 g 100 g^{-1} dry tissue. There were very slight seasonal variations in the sodium content. A marked increase in sodium content in senescent leaves was noticed in rainy season and winter. The very low levels of sodium in leaves of A. cantala indicate the low affinity of Agave for sodium which is probably due to the fact that sodium does not play any prominent role in metabolism of this glycophytic species.

2. Potassium :

The analysis of potassium contents in different leaf categories of A. cantala indicated that potassium contents range from 0.2 to 1.04 g 100 g^{-1} dry tissue. The highest potassium accumulation was recorded in winter season and an opposite trend was noticed in rainy season. It was also evident that the young leaves contain the highest level of potassium in all the three seasons. A marked decline of potassium level in senescent leaves was evident in all the

three seasons. The high level of potassium in young leaves clearly indicates its indispensibility for various metabolic processes occurring at high rate in the young rapidly developing tissue. A decline of potassium contents in senescent leaves suggests remobilization of this high essential element during the course of leaf senescence. Thus similar to other higher plants in case of succulents also a considerable retranslocation of potassium from the senescent leaves is evident.

3. Calcium : Calcium was found to be the most prominent cation among the various mineral elements in the leaves of Agave cantala. The calcium content in the three leaf categories of A. cantala varied from 2.56 to 4.78 g 100 g^{-1} dry tissue during different seasons. Not much variation in calcium content was evident during various seasons. There was marked increase in calcium content in the senescent leaves during winter and rainy seasons but in summer season the level of calcium was slightly decreased. The accumulation of high amount of calcium in A. cantala leaves clearly suggests its association with the process of CAM. Our observations recall the findings of Nobel and Berry (1985) where a significant positive correlation between nocturnal acid accumulation and calcium status of chlorenchyma in various Agave species (A. americana, A. deserti, A. fourcroydes, A. lechuguilla, A. salmiana and A. utahensis) was noticed. The increase in calcium in senescent leaves indicates immobile

nature of this essential element.

4. Magnesium

The magnesium contents were found to be rather low in Agave cantala leaves as compared to other divalent cation calcium. The analysis of magnesium contents in the leaves of A. cantala during different seasons revealed that magnesium contents range from 0.547 to 0.712 g 100 g^{-1} dry tissue. Not much variations in level of magnesium were seen in the leaves of A. cantala during various seasons. An increase in magnesium contents was noticed in rainy and winter seasons in senescent leaves. On the other hand, magnesium level was slightly reduced in senescent leaves in summer season. Magnesium is considered as one of the most important essential elements required for architecture of chlorophylls as well as activities of several important enzyme systems. In view of Epstein (1972) optimum level of the magnesium in plant tissue is 0.2% of dry weight. Our observations indicate that A. cantala has got fairly good potential for efficient magnesium uptake in all three seasons of the year. An increase in magnesium content in senescent leaves during rainy season and winter, and decrease of the same in summer season indicates that probably the alterations in magnesium status in senescent leaves are possibly related to differential requirements of this essential element for various metabolic processes in young and mature leaves in the three seasons.

5. Iron

The iron contents in the three leaf categories of Agave cantala during various seasons varied from 0.0122 to 0.0278 g 100 g^{-1} dry tissue. Not much seasonal variations were observed in iron contents in the leaves. A marked increase in iron contents was evident in senescent leaves in each season, Particularly significant in rainy and winter seasons. Although the iron contents recorded for A. cantala leaves are above the optimum value (0.011 g 100 g^{-1} dry tissue) indicated by Epstein (1972), they are below the iron levels determined for other Agave species by Nobel and Berry (1985). The marked accumulation of iron in senescent leaves probably reflects its immobile nature.

B) Organic Constituents

1. Moisture percentage

The leaf moisture percentage in three leaf categories of Agave cantala during different seasons varied from 73.82 to 84.47 %. The maximum moisture percentage was recorded in mature leaves than either young or senescent leaves. Thus Agave is able to maintain a proper water balance in all the three seasons which clearly reveals its highly drought resistance capacity.

2. Titratable acidity

The estimation of Titratable Acid Number (TAN) in

the leaves of Agave cantala during different seasons indicated that TAN values range from 25.61 to 253.60 μeq g^{-1} fresh tissue. The maximum TAN values were recorded in summer season followed by rainy and winter seasons. In all the three seasons the highest TAN values were noticed in mature leaves, intermediate in senescent leaves and lowest TAN values were recorded in young leaves of A. cantala. The TAN values generally give idea about organic acid level in the plant tissue. Hence it is clear that the CAM activity is at its peak during summer season and that too in mature leaves rather than in young developing leaves or old senescing leaves.

3. Carbohydrates

The analysis of various carbohydrate fractions in the different leaf categories of A. cantala has shown that reducing sugars vary from 1.005 to 2.42 g 100 g^{-1} fresh tissue. Not much seasonal variations were recorded in reducing sugars. The non-reducing sugar contents were found to be in the range of 0.098 to 0.665 g 100 g^{-1} fresh tissue. The highest non-reducing sugar content was noticed in the three leaf categories in summer season while in winter season the lowest level of non-reducing sugars was recorded. The leaves of A. cantala were found to be rich in starch contents as compared to other carbohydrate fractions in all the three seasons. The starch contents in the three leaf categories during different seasons varied from 1.93 to

7.208 g 100 g^{-1} fresh tissue. The maximum levels of starch were noticed during summer season in all the three leaf categories. Among various organic constituents the carbohydrates are of great importance because they are products of photosynthesis on one side and the source of respiration on other side. Hence the carbohydrate level indicates a degree of photosynthetic efficiency and an indirect measure of dry matter accumulation. Since A. cantala leaves maintain high carbohydrate status during summer season it is clear that the rate of dry matter production as well as photosynthetic efficiency in this plant are not affected in the summer season which is otherwise harmful for most plant species.

In senescent leaves of A. cantala a marked decline in the level of starch and reducing sugars is evident. This change clearly suggests a decline in photosynthetic efficiency as well as an increase in catabolic activity during the terminal phase of leaf growth.

4. Polyphenols

A great variation in polyphenol contents was noticed in different seasons of the year and the total polyphenol content varied from 0.15 to 1.25 g 100 g^{-1} fresh tissue. The highest total polyphenol contents were recorded during summer season in all the three leaf categories. An increase in polyphenol contents was evident in senescent leaves

during summer and winter seasons. Polyphenols are generally regarded as products of secondary metabolism. The higher level of polyphenols in the summer season indicates probable stimulation of secondary metabolism in this season. The leaf age also appears to have slight influence on this process since the polyphenol level is slightly elevated in the senescent leaves during summer and winter seasons.

5. Proline

The level of free proline in three leaf categories of Agave cantala during three seasons varied from 2.5 to 16 mg 100 g^{-1} dry tissue. The high level of proline was recorded during rainy and winter seasons. There was no definite trend of proline accumulation in the senescent leaves of A. cantala in the three seasons. In last two decades considerable attention has been paid to the fate of free proline accumulation in various crop species and it is now very well established that proline plays an important role in the process of drought resistance in these crops. Since A. cantala leaves contain very low amount of free proline, it is probable that proline may not be playing a prominent role in the drought resistance process in the succulents.

6. Photosynthetic pigments

The level of chlorophyll a , chlorophyll b and carotenoids was determined from young, mature and senescent

leaves of Agave cantala during different seasons. The total chlorophyll contents varied from 5.24 to 57.94 mg 100 g^{-1} fresh tissue. The amount of total chlorophylls was highest during summer season in all leaf categories. The mature leaves contain the highest amount of total chlorophylls. A great variation in chlorophyll a/b ratio was evident and it ranged from 0.645 to 1.63. The chlorophyll a/b ratios were lower during winter season and considerably high during summer season. Thus it is clear that the environmental factors have a definite influence on the synthesis and accumulation of chlorophyll a and b in the leaf tissue which take place at different rates. The high chlorophyll contents during summer season can contribute to higher photosynthetic efficiency of A. cantala during the period of high light intensity. The chlorophyll contents are only slightly reduced in the senescent leaves in all the three seasons which indicates high stability of these pigments during the process of leaf senescence.

The carotenoids are generally regarded as accessory photosynthetic pigments. Their level in A. cantala leaves during different seasons varied from 1.20 to 17.04 mg 100 g^{-1} fresh tissue. The pattern of carotenoid accumulation during different seasons and during the course of leaf senescence was found to be more or less similar to that of chlorophylls. these observations suggest the supporting role of carotenoids in the process of photosynthesis.

C) Stomatal behaviour

The diffusion resistance to water vapour and rate of transpiration were determined from the young, mature and senescent leaves of Agave cantala during different seasons with autoporometer. The abaxial leaf surface showed a higher rate of transpiration than the adaxial leaf surface in case of all the three leaf categories. It was noticed that the diffusion resistance to water vapour was quite high during summer season and there was great reduction in transpiration rate during this season in case of young and mature leaves. Thus it is clear that A. cantala has fairly good stomatal control over the water loss during summer season and this can greatly help in maintaining favourable water balance in the leaf tissue.

D) CAM studies

1. Diurnal fluctuations in carbohydrates :

It was noticed that various carbohydrate fractions show fluctuations in their levels during different hours of the day and this was consistent with the operation of Crassulacean Acid Metabolism in A. cantala. The fluctuations were particularly prominent with respect to starch and reducing sugars in all the seasons. When daily fluctuations in carbohydrate content in different seasons were compared, it was found that the magnitude of fluctuations was quite high during summer season. Thus these observations indicate

that in summer season the operation of CAM is at higher speed.

2. Diurnal fluctuations in titratable acidity :

The leaves of Agave cantala showed distinct diurnal fluctuations in titratable acidity during different seasons which clearly speaks of the 'Full-CAM' nature of this species similar to A. americana (Neales, 1975). The oscillations in titratable acidity were more significant than those observed in case of carbohydrate contents. It was noticed that the magnitude of fluctuations in titratable acidity was quite high during the summer season as compared to rainy season. These observations clearly indicate the efficiency of Agave plants to perform optimum CAM activities and to maintain positive carbon balance during summer months which are otherwise unfavourable for most of the plant species.