CHAPTER II
REVIEW OF LITERATURE

General

Solanum is one of the largest genus of the family Solanaceae, and it has attracted a great deal of scientific attention due to the commercial and medicinal importance of some of its species.

The genus comprises 1700 species (Willis, 1966), all of which have not been investigated so far. Hooker (1885) listed 27 species (not including S. platanifolium), found in the Indian subcontinent. Bailey (1950), Watt and Breyer-Brandwijk (1962) and Kingsbury (1964) described other species found in North America, Canada and South Africa, respectively.

Earlier accounts of the medicinal uses and commercial importance of some species (Watt, 1893; Kirtikar and Basu, 1933; Nadkarni, 1954; Chopra et al., 1956, 1969; and Watt and Breyer-Brandwijk, 1962) have been summarized in Appendix A.

Taxonomical, Histological and Cytological

Ochoa (1964) described S. trinitense from Peru and Marchesi (1965), for the first time, reported S. atropurpureum from Uruguay. Hawkes (1966) reviewed the grouping, distribution and taxonomic characters of Solanum species found in Mexico and some other countries of Latin America.
Saarisalo-Taubert (1967) gave a revised account of the adventive species of Solanum from Finnish Herbaria. Costa (1968) reported that, in addition to such species as S. agrarium, S. mammosum, S. spectabile and S. subscandens, four more species, S. fastigiatum, S. insidiosum, S. paniculatum and S. juripeba also constituted the 'Jurubeba' of the natives of Brazil.

Miller (1969) described the morphology of the fruits of S. mammosum and reported the presence of mammelliate appendages at the base of the fruits.

Sciuchetti and McMurray (1944) investigated the histological characters of fruits, stems and leaves of S. triflorum, and while Verzar-Petri (1964) gave a detailed account of the histology of roots, stems, leaves and the pericarp of the fruits of S. laciniatum, Saber et al. (1965) described the structure of stems, leaves, and flowers of S. atropurpureum.

Sharma (1965) studied the comparative histology of the roots, stems and leaves of S. incanum, S. indicum, S. nigrum, S. pseudocapsicum, S. torvum and S. xanthocarpum. The diagnostic characters of the leaves of S. xanthocarpum were also described by Singh (1967), and of stems and roots by Ansari et al. (1971).

Pharmacognostic studies of the various parts of S. burbankii were carried out by Saber et al. (1968). While Balbaa et al. (1969) described the morphology and anatomy of
S. unguiculatum.

Sizova (1965) reported the differences in the shape and size of epidermal and columnar cells of the leaves of S. tuberosum, grown in S. America and Mexico, and other species such as S. brevimuconatum and S. pseudomedians.

Chandra (1967) also studied the characteristics of the stomatal index of the leaves of S. aviculare, S. aculeatissimum, S. duplosinuatum, S. incanum, S. integrifolium and S. sodomum. Although cruciferous stomata were found in these species yet some abnormal stomatal cells with single guard cells were also observed.

Recently the taxonomic importance of the epidermal trichomes of 17 species of Solanum with special reference to S. chiapasense, S. elaegnifolium, S. sisybrifolium, was discussed by Roe (1971).

Roe (1967) from her studies of chromosome size of different plants, including Solanum, suggested that the present day Solanum species were probably derived from woody ancestors. Other cytological studies, including the effects of chronic gamma-rays and X-rays treatment on the pollen sterility, growth, and inhibition of chromosomal aberrations, in 22 non-tuber bearing species of Solanum, were described by Yamagata et al. (1969).

Chemical

Prelog and Jegar (1953) reviewed the chemistry of
Solanum alkaloids, and Schreiber (1968) described and tabulated the general occurrence of glycoalkaloids in this genus. The glycoalkaloids isolated from species of the genus *Solanum*, belong to one of the five groups such as:

- the *spirosolanes*, i.e., solasodine (I);
- the 16-unsubstituted 22, 26-epiminocholestanes, i.e., tomatillidine (II);
- the *solanidanes*, i.e., solanidine (III); solanocapsine (IV);
- the 3-aminospirostanes, i.e., jurubidine (V).

![Molecular structures of glycoalkaloids](image-url)
Glycoalkaloids to the extent of 4.8 and 3.5 per cent were reported from the fruits of *S. indicum* and *S. xanthocarpum*, respectively (Chopra and Handa, 1963).


Some of the newer glycoalkaloids which were isolated, included dioscorine from *S. introsum* (Bite, 1969), solakhasianine from *S. khasianum* (Maiti and Mookerjea, 1968), paniculonine A and paniculonine B from *S. paniculatum* (Ripperger and Schreiber, 1968), solapalmitine and solapalmitenine from *S. tripartitum* (Kupchan *et al.*, 1967).

Amongst the steroidal alkaloids reported were tomatidine from *S. boerhaavi* (Loken and Sollins, 1970), solacongestidine and solafloridine from *S. congestiflorum* (Sato *et al.*, 1969), solaradixine and solaradinine from *S. laciniatum* (Bite *et al.*, 1972), isojurpidine, isojuribidine and isopaniculidine from *S. paniculatum* (Leekning and Rocco, 1968; Camblaghi *et al.*, 1971). Bite and Shabana (1972) also isolated from *S. laciniatum*, the compounds solashabanine and solaradinine which could be converted to solasonine and solaradixine, respectively, by the
enzyme $\beta$-glycosidase.

Recently Usubillage et al. (1973) reported the presence of salophyllidine and diacetylsalophyllidine in \textit{S. equadorene}.

In addition to the 3-hydroxy steroidal alkamines, aza-steroids in free state, were also found in \textit{S. pseudoquina} by Cevallos and Martinod (1969).

Stereochemistry of Solanum glycoalkaloids was confirmed by extensive work involving a number of newer methods of partial and total synthesis (Schreiber, 1968).

Some newer, modern methods for the quantitative determination of Solanum alkaloids, especially solasodine, were also reported by Ananichev and Loshkarev (1969), Birner (1969), Bite et al. (1970), Pasich et al. (1970), Andreeva and Romanchuk (1970), Tukalo and Tsarik (1971), Hardman and Williams (1971) and Khafagy et al. (1972).

Non-nitrogenous steroidal sapogenins were also found in a number of species of \textit{Solanum} (Schreiber, 1968) and diosgenin was reported in \textit{S. auriculatum} and \textit{S. elaegnifolium} (Mookerjea and Mathew, 1969; Guerreiro et al., 1971), \textit{S. nigrum} (Sen et al., 1970; Varshney and Dube, 1970), \textit{S. pinnatum} (Urzua and Cassels, 1972), \textit{S. vespertilio} (Gonzalez et al., 1971), and \textit{S. xanthocarpum} (Kusano et al., 1973).

Mendez et al. (1970) found in the fruits of \textit{S. toryum}
two steroidal sapogenins, (i) sisalagenone, a dehydro derivative of the known sapogenin, sisalagenin, and (ii) torvogenin, which on chromium trioxide oxidation was converted into sisalagenone. Chlorogenin from *S. oyananthum* (Rizk and Abou Zied, 1970), and a new steroidal sapogenin, bajamarin, from *S. vespertilio* (Gonzalez et al., 1972) were also isolated recently.

Compounds such as n-hentriacontane and hexacosanol were reported in *S. chacoense* (Uzarewicz and Mierzwa, 1971), *S. demissum*, *S. polyadenium* (Ardenne et al., 1965), and *S. tuberosum* (Rodriguez and Ribas, 1972).

Sterols like cholesterol, stigmasterol, campesterol and sitosterol were isolated from *S. tuberosum* (Ardenne et al., 1965), and *S. xanthocarpum* (Kusano et al., 1973). The leaves of *S. dulcamara* were also found to contain the galactosides of cholesterol, brassicas terol, campesterol, stigmasterol, and β-sitosterol, and the palmitic acid esters of these galactosides (Kostens and Willuhn, 1973).

Although β-sitosterol was also reported from a number of species such as *S. bulbocastanum* (Johnson and Sato, 1969), *S. chacoense* (Uzarewicz and Mierzwa, 1971), *S. oyananthum* (Rizk and Abou-Zied, 1970), *S. elaegnifolium* (Appel and Wildgruber, 1969), *S. giganteum* (Govindachari et al., 1969) and *S. indicum* (Varshney and Khan, 1971), the sterol campesterol, and the lactone, solanocarpone, were found only in *S. ferox* (Gupta and Garg, 1968).
Carotenoids such as β-carotene, cryptoxanthin and zeaxanthin were isolated by Nicora et al. (1968) from *S. lanceolatum*, while another minor carotenoid, 3,4-dehydrolycopene-16-al, was found by Baranyai and Szaboles (1972) from *S. dulcamara*.

Vitamins A, B and C were also found in *S. melongena*, whereas both *S. nigrum* and *S. tuberosum* were reported to contain Vitamin C (Watt and Breyer-Brandwijk, 1962).

Angenot (1969) found esculetin, astragalin, isoquercitrin, 3-kaempferol diglucoside and rutin in *S. schimperianum*, and Tupkari et al. (1972) reported the presence of scopolin, scopoletin, esculin and esculetin in *S. xanthocarpum*. Anthocyanins were also found in *S. xanthocarpum* by Nagashima and Taisa (1965), and in *S. nigrum* by Sen et al. (1970).

While chlorogenic acid was isolated from 15 *Solanum* species by Politis (1948), caffeic acid was reported in *S. tuberosum*, and maleic acid in *S. campylacanthum* (Watt and Breyer-Brandwijk, 1962).

Uzarewicz and Mierzwa (1971) found palmitic and stearic acids in the seed oil of *S. chacoense*. Other acids such as linoleic and oleic, in addition to palmitic and stearic, were reported in other species such as *S. ferox* (Garg and Gupta, 1966), *S. indicum* (Puntambekar and Krishna, 1941), *S. nigrum* (Pendse, 1937; Singh and Kumar, 1945) and *S. nudiflorum* (Hilditch and Williams, 1964).
The enzyme polyphenol oxidase was found in \textit{S. quitoense} by Coronel (1970), whereas Gerbrandy and Doorgeest (1972) isolated phosphorylase isoenzyme from \textit{S. tuberosum}.

Tannins were reported from \textit{S. campylacanthum} and \textit{S. tuberosum} (Watt and Breyer-Brandwijk, 1962).

Inorganic substances like mixture of potassium and sodium chlorides, and nitrates were detected in the stems and leaves of \textit{S. villosum} by Guth (1938).

Some of the more important compounds isolated in the last few years have been summarized in Appendix B.

**Physiological**

Saini and Biswas (1967) studied the physiology of \textit{S. khasianum} Clark and commented upon the effects on growth and development, under three different conditions, by varying the sowing dates around the year. They found that the alkaloidal contents as per cent of dry weight were not effected, though the concentration was reduced substantially in individual fruit under warmer weather conditions due to poor seed setting.

Toth (1969) reported that plants of \textit{S. laciniatum} could be acclimatized and cultivated in Hungry and gave a maximum yield of 1.57 per cent of solasodine in September.

Wiese and Vandiver (1970) found that though the growth of \textit{S. rostratum} was reduced in wet conditions, the plant
flourished in dry soils.

Mathe (1970) who studied the variability of alkaloidal concentrations during growth in different strains of *S. dulcamara*, found that the effects of certain ecological factors were quantitative. Yearly, monthly and daily investigations on the glycoalkaloidal contents in different strains of *S. dulcamara* grown in different places in Hungary, showed that climatic factors influenced the formation of these compounds.

Abutalybov and Rakhmanova (1965) observed that phosphorus and potassium effected the sugar transport in the leaves, and in the cortex of the stem of *S. melongena*. Supplementary nutrition with these elements accelerated the transport of sugar but calcium decreased the flow through cortex of the stem.

The effects of boron and manganese on the accumulation of glycosides in *S. laciniatum* were studied by Kvitaishvile (1967), who found that the addition of these trace elements speeded up the vegetative development of the plant by two weeks, and increased the yield of the leaf crop. The glycosidal contents in the plant also increased to a maximum of 5.24 per cent with boron, and to 4.65 per cent with manganese.

White et al., (1970) studied the effects of liming, and the acidity of the fertilizer bands, on the growth and manganese uptake by 'Narland' and 'Sebago' varieties of potatoes.
(S. tuberosum), and found that the uptake of manganese by potato plants was related to soil pH, rather than to the acidity of the fertilizer bands.

Laza and Nichiforescu (1967) reported that the highest yield of solasodine per hectare was obtained by controlled method in which the leaves of S. laciniatum were harvested by mechanical means. The maximum dry matter was produced when the plants were 20-25 cm high above the soil. Muraveva et al. (1969) also observed that in this species the highest concentration of solasodine, determined colorimetrically, was found in leaves during flowering, after which the solasodine contents decreased.

The formation of alkaloids in the leaves of S. laciniatum after harvesting, was studied by Moiseev et al. (1970). It was found that in uniform, upper leaves, wilting for 24 and 72 hours at room temperature, or at 37°C, increased the total glycoalkaloidal contents by 16-19 and 9-20 per cent, respectively. Analysis of intact and powdered leaves showed that in powdered leaves, in the early hours of wilting, the contents of solamargine increased while those of solasodine decreased. After 72 hours of wilting, however, the concentration of solamargine decreased while that of solasodine increased. It was also noted that the concentrations of these two compounds were more in the shade-dried, powdered leaves, as compared to the sun dried leaves, and also higher in leaves collected early in the day than in leaves collected in the evening.
Moiseev and Klyshev (1970) also showed that the leaves of this plant dried at 110-115°C for 10-15 minutes, when stored under Mandelyeev's cement, retained their original concentration of solasonine, solamargine, and total alkaloids even after 4-9 months. This cement was prepared by fusing wax paraffin, colophony and powdered iron oxide.

Aslanov and Mamedova (1971) showed that the accumulation of glycoalkaloids in S. laciniatum was maximum during the middle of the day, and increased from 0.17 to 0.3 per cent. During the same period while the concentrations of the amino acids, cystine, lysine, histidine, valine and isoleucine increased, that of asparagine, glutamic acid and threonine decreased. Aslanov (1971) also found that the growth of S. laciniatum increased during successive generations under 0.4 per cent sulphate-chloride salinization and the concentrations of total glycosides and solasonine, at the flowering time in the first, second and third generations, were 3.2, 3.4 and 3.5 per cent and 1.1, 1.4 and 2.1 per cent, respectively. Earlier, Moiseev and Klyshev (1969) had shown that during budding and flowering the solamargine and solasonine contents in this plant increased but the concentrations of solanine and chaconine were reduced. During the day the concentrations of these compounds were highest at 7.0 a.m., and the lowest at 8.0 p.m. Foldesi et al. (1969) had also found that during vegetative period of growth of S. laciniatum, the localization and accumulation of the active substances,
was highest in the flesh of the berry, and in the leaf lamina, and lowest in the anterior of the stem and the leaf veins. In the beginning of the vegetative growth most of solasodine was localized in the leaves, but towards the end of the vegetative period it was distributed evenly between the berries and the leaves.

Willühn (1967), while investigating the chemical differentiation between two strains of *S. dulcamara*, at various stages of fruit development, found that some changes in the total steroids took place in both the strains during fruit development. The total amount of steroidal alkaloids and steroidal sapogenins increased till the fruits reached their full size. At the time of ripening, however, the steroidal alkaloids disappeared but the concentration of steroidal sapogenins increased. In very young fruits, the two strains of *S. dulcamara* showed either tomatidenol or soladulcidin but in the ripe fruits solasodine was the predominant alkaloid in both cases.

Matsunaga *et al.* (1969) observed that the strain of *S. khasianum*, studied in Japan grew better and produced more fruits, but the percentage of alkaloids in berries varied at different stages of growth. No alkaloids were found in root, stem and leaves. Bakshi and Hamid (1971) also reported that the fully ripe berries of *S. khasianum*, grown in Bombay, gave 2.6 per cent of solasodine, whereas the green unripe berries showed only 0.45-0.1 per cent of the alkaloid. Khanna and
Murty (1972), however, reported that in this plant the concentration of the glycoalkaloid, was only 0.7 per cent in unripe berries and increased, to the maximum of only 1.3 per cent during maturity of the fruits.

Moursi and Ahmad (1973) during their studies on the seasonal changes in the glycoalkaloidal and carbohydrate contents of fruits of *S. laciniatum* showed that solasonine and solamargine were present in the fruits at all stages of growth. The concentrations of total glycoalkaloids, and solasonine, were maximum in 10 days after flower anthesis, but solamargine concentration reached the maximum in only 13 days after anthesis. The concentrations of solasonine, solamargine, and total glycoalkaloids, in the tissues of the fruits, were 4.9, 6.8 and 11.0 per cent, respectively. Solasonine concentration was less than that of solamargine, at various stages of fruit growth. While the concentration of total sugars, such as sucrose and raffinose, was maximum in 13 days after flower anthesis, the amount of mono-, di-, and trisaccharides in fruits increased with maturity.

Korneva *et al.* (1968) studied the physiological and biochemical features of seeds during artificial ripening of the fruits of *S. laciniatum* and showed that artificially ripened seeds had lower accumulation of nutrient components, and showed higher enzymatic activity and acceleration of hydrolytic process by quicker germination, as compared to the naturally ripened seeds. Suzuki (1969) also reported
that viability and longevity of the seeds of *S. melongena* and *S. tuberosum* varied with the species and varieties of plants and was controlled by fruit maturity.

Baylis (1968) investigated the influence of day length on flowering in species belonging to *S. aviculare* group and found that the plants of most species of this group flowered only in long days, although flowering in some species, such as *S. capsiciforme* and *S. simile*, was not affected by day lengths. Generally the members of *S. aviculare* group consisted of those ecotypes in which photoperiodism was adopted to latitude and temperature. Bae and Mercer (1970) also commented on the effects of long and short days on sterol levels in the leaves of *S. andigena*, and showed that, in the plants transferred from long to short day condition, there was an initial sharp decrease in the concentration of β-sitosterol and cycloartenol, but an increase in the cholesterol contents. After 2-3 weeks, however, the levels of these sterols returned to those of the long day leaves.

Kuznetsova (1971), while studying the effects of light quality on the photosynthesis of the glycoalkaloidal contents of *S. laciniatum*, showed that the synthesis of solasodine was more intensive in blue, than in red light, without producing any change in the accumulation of dry substance. It was suggested that the accumulation of alkaloids in blue light was due to increased terpenoid synthesis.
Moiseev (1970), who studied the steroidal alkaloids in *S. laciniacum*, showed that during growth the total concentration of these compounds increased from 1.5 to 3.3 per cent and there was a sharp decrease in solamargine/solasonine ratio from 2.62 to 1.10. The warm dry climate of South Kazakhstan favoured production of high concentration (3.9 per cent) of alkaloids in young plants. Plants in different phases of flowering, but of the same age, revealed no difference in the amount of alkaloids, indicating thereby that age, rather than the advancement of individual development, determined the amount of the alkaloid.

Sinha and Verma (1966) studied the effects of plant hormones on the leaves of tuber-bearing species of *Solanum* and noted that different varieties differed in respect to both survival and rooting response to auxin, the environmental factors, and the concentration of auxin, playing significant role in the extent of the response produced.

Basso (1966) also showed that the application of hormone-like compounds, such as alleghan, aspren, and super tomatoset-2, in 50 and 100 per cent concentrations, to plants of *S. melongena* resulted in increased yield, and advancement in the maturation, of fruits.

Dhesi et al. (1967) in their studies on the effects of transplanting treatment and growth regulators on the growth, flowering, and fruiting of *S. melongena* also found that both
IAA and IBA decreased the spread of roots by 55-70 days after transplanting. Flowering was delayed by IAA but hastened by IBA.

Morris (1967) studied the influence of light, gibberellic acid, and CCC (2-chloroethyl trimethyl ammonium chloride), on the sprouting of *S. tuberosum* and found that warm, white fluorescent light inhibited the elongation of potato sprouts and reduced the rate at which the reserve material in the mother tuber was mobilized. The rate of elongation and increase in dry weight of sprouts were promoted by exogenous gibberellic acid and was independent of the effect of light on these processes, while CCC, showed no effects on sprout length and dry weight.

Gerasimenko (1969) showed that the treatment of seeds of *S. laciniatum* with 0.1 per cent aqueous solution of gibberellic acid for 72 hours before sowing hastened their germination by 6-10 days.

Wakhloo (1970), who studied the role of mineral nutrients and growth regulators in *S. sisymbriifolium*, reported that the lower axillary buds were released from complete inhibition by supplying high dose of potassium to the soil, while complete apical dominance was shown by plants grown in low, but not deficient, amount of potassium. Nitrate and phosphate supplied together or alone were ineffective but when either was supplied along with potassium the effect of the latter on
the growth of axillary buds was enhanced. Buds released from inhibition, elongated further only when supplied with gibberellic acid ($GA_3 10^{-5}$g/ml). Indole acetic acid (10$^{-6}$g/ml) alone had a weaker effect, but it enhanced the stimulatory effect of gibberellic acid. The completely inhibited buds of low-potassium plants could also be released from inhibition by kinetin ($10^{-4}$g/ml). In such buds IAA promoted further extrusion but $GA_3$ did not.

Datta and Neogy (1969) used various concentrations of colchicine to induce polyploidy in S. melongena and Hermesen and DeBoer (1971) treated the seeds of S. acaule and S. bulbocastanum, with 0.3 per cent of colchicine to produce plants of S. acaule with 2n = 96 chromosomes, and of S. bulbocastanum with 2n = 48 chromosomes.

Killian and Henderson (1972) showed that the activity of the enzyme polyphenol oxidase, in the tubers of S. tuberosum, was increased when these tubers were subjected to $\gamma$-radiation, mechanical injury, or controlled storage.

**Tissue Culture and Biogenesis**

Rerabek (1967) working on the tissue culture of the roots of S. laciniatum observed that callus was formed easily by the presence of 2,4-dichlorophenoxy acetic acid and myo-inositol in the nutrient media.

Hebel et al. (1968a,b) isolated solasonine, diosgenin and $\beta$-sitosterol from the tissue culture of S. xanthocarpum.
These porkers also showed (1971) in the tissue culture of this plant, there was hormonal control of steroid synthesis.

Vaguzfalvi et al. (1971) reported that diosgenin was present in the tissue culture of *S. laciniatum* but solasodine was absent. Supniewska et al. (1972) found in low concentrations as many as 21 free amino acids in the tissue culture of this plant, while the leaves from soil grown plants contained only 17 amino acids. Synthesis of asparagine, glutamic acid, aspartic acid, and γ-aminobutyric acid, was also more in tissue culture than in soil grown plants. Except sapogenins, no steroidal alkaloid was found in tissue culture.

Studies on the biogenesis of steroidal alkaloids were reviewed by Heftmann and Mosettig (1960), Willüm (1965), Clayton (1965), and more recently by Schreiber (1968).

Ripperger et al. (1971) by using labelled cycloartenol and lanosterol in *S. chacoense* and *S. pseudocapsicum*, respectively found that these compounds could be converted into Solanum alkaloids such as solanidine, tomatidine, and solanocapsine. In case of tomatidine the radioactivity was localised in the ring.

Mathur (1970), through chromatographic techniques showed that the mode of triglyceride biosynthesis during ripening in *S. indicum* followed essentially the stepwise mechanism involving the formation of mono and diglycerides as intermediate products.
Miscellaneous

The leaf alkaloids produced by tetraploid hybrid of the hexaploid *S. demissum*, and the tetraploid *S. stoloniferum*, were used by Hurborne (1967) to clarify the taxonomic position of some species of the genus *Primula*, especially *P. roseus*.

Desborough and Peloquin (1969) compared 22 species of *Solanum* on the basis of protein patterns, using an acid gel system, and determined the specific protein banding patterns of 16 American and Mexican species. However, no correlation between band patterns and geographical distribution of the species could be established.

Peredes et al. (1970) in their studies of the Flora of Ecuador showed the relation of esteroids, azasteroids, tri-terpenoids, and alkaloids, in 34 species of *Solanum* found in that country.

Bodea et al. (1967) showed that solasodine, chlorosolasodine, and a mixture of glycoalkaloids, solasonine and solaframargine, obtained from *S. aviculare*, caused antimitotic activity, the chlorosolasodine being the most active amongst these compounds. Sharma et al. (1971) also reported the presence of an unknown phytotoxic substance in the pulp of the fruits of *S. surattense* (Syn. *S. xanthsocarpum*) that inhibited the process of germination, and seedling growth, of *Pennisetum typhoides*.
Kahn et al. (1967), during routine quarantine inspection, also found very high incidence (62 per cent) of virus infection on Solanum species.

Recently Haberman (1972) have found that S. tuberosum plants are quite susceptible to nematodes infection by Heterodera rostochiensis Wollenweber.