INTRODUCTION
Plants in semi-arid region differ in shape from plants that live in moist tropical or temperate areas. Semi-arid plants include more or less sparsely distributed semi-shrubs with small, thick, tightly packed leaves often have thick woody stems. The semi-arid flora is characteristic with the co-existence of plants of different morphologies. As a result, taxonomically unrelated associations are formed.

The semi-arid plants are molded by features of the physical environment, thereby possess special morphological characteristics such as a low surface to volume ratio of leaves, reduced intercellular spaces with relatively large root biomass and increased conducting tissue with low leaf tissue moisture. The soil surface receives a high proportion of solar radiation and reaches high temperatures at midday. The amount of organic matter and nitrogen in semi-arid regions tends to be low.

In India, semi-arid areas are the major ones which more or less covered with unproductive woody shrubs, however in some parts of the world the woody perennial shrub plants may be utilized as feed for cows, goats etc., or made into charcoal.

In Andhra Pradesh considerable proportion of land, about 132,870 sq. km is semi-arid and in particular in western part of Andhra Pradesh as much as 16,900 sq. km of land is covered with thorny, sclerophyllous, slow growing and ever green woody
plant species. Inspite of the aridity most of the shrubs do not shed leaves. Presently the marginal land area which is occupied with unproductive plant species, it is essential to improve these areas for maximum productivity in order to achieve the demands of the ever increasing human population.

It is believed that a high degree of similarity exists in the formation of the vegetation of arid, semi-arid zones throughout the world. Nye and Mackell (1970) stated that the vegetation in a desert region is composed of plant species that escape or endure high rates of transpiration, low humidity, high and low temperatures, severe drought, and low soil fertility.

The distribution of shrubs, their habit, growth and survival under arid conditions encountered by the limited water availability. The shrubs survive in arid region consists of a combination of physiological and morphological adaptations (Turner, 1956, 1968; Fahn, 1964). In some instances arid conditions are largely avoided by maintaining growth during wet cool periods or by growing in regions where water is available, such as water courses and washes (Fahn, 1964). Some plants may reduce surface area by shedding leaves and photosynthesising largely with green stem tissue (Adams et al., 1967). Another group of winter-deciduous plants is phreatophytic and possess a root system deep enough to reach the ground water.
Hellmuth (1971) examined the patterns of CO₂ and water vapour exchange of several arid and semi-arid shrub species, and stated that the physiology of some arid zone species did not differ qualitatively from that of plants of temperate climates, but their metabolic processes are active under a wide range of environmental conditions.

Maximov (1929) claimed that some xerophytes transpired at a greater rate per unit leaf area than the mesophytes. However, Holmgren et al., (1965) Cowan and Milthorpe (1968) cited a number of instances where the transpiration in xerophytes is less than mesophytic species and supported the idea that xerophyllous plants with heavy cuticles are suited for water conservation unlike the mesophytes. The ability of the xerophytic shrubs to survive under extreme arid conditions is well illustrated by the studies of Slayter (1960, 1961) which is partly due to their resistance to extreme desiccation over long periods. The leaves of xerophytic shrubs are often small to bring about a reduction in the transpiration (Fahn, 1964).

The importance of leaf surface in terms of regulatory role for the entry of chemical herbicides and transpiration has been described by several workers. Martin and Juniper (1970) provided a general review on the role of plant leaf surfaces. The epicuticular wax is normally deposited on the outer surface of the cuticle in a specific and characteristic pattern. The environmental factors like light, temperature and humidity affect the development of cuticle as well as
epicuticular waxes (Skors, 1955; Juniper, 1960; Hallam, 1970; Whitecross and Armstrong, 1972; Baker, 1974; Ball et al., 1975). The stomatal antichambers and epistomatal chambers are also occluded with the greatest density of waxes (Thair and Lister, 1975; Reicosky and Hanover, 1976).

The different patterns of epicuticular wax depositions are dependent on their chemical composition (Von-Wettstein-Knowles, 1974; Chambers et al., 1976). In recent years, many workers have elucidated the chemical composition of leaf epicuticular waxes of many plants. Chibnall and Piper (1954); Purdy and Truter (1965); Polattubody (1965); Netting and Macey (1971); Baker (1974) in *Brassica oleracea*, Chibnall and Piper (1954); Juniper (1959 a, b); Macey and Barber (1970) and Holloway et al., (1977 b) in *Pisum sativum*, Horn et al., (1964) in *Eucalyptus*, Hamilton and Power (1969) in *Lolium perenne*, Tulloch (1974) in *Portulaca oleracea*, Bianchi and Salamini (1975); Bianchi et al., (1975); Hunt et al., (1976) in *Clarkeia elegans*, Bianchi et al., (1977 a) in *Sorghum vulgare*, Bianchi et al., (1977 b) in different varieties of *raze* and Holloway et al., (1977 a) in *Brassica napus* have determined the chemical composition of the epicuticular waxes. Generally the plant epicuticular waxes are complex mixtures of long chain alkanes, esters, ketones, aldehydes, alcohols and fatty acids.

The waxy components of the cuticle provide the prime barrier to water loss from plants. It has long been
established that disruption of waxy surfaces of leaves and fruits results in greater cuticular transpiration as evidenced from the rapid wilting of leaves and drying of fruits. Several workers reported a direct correlation between water relations and the conditions of the epicuticular wax layers (Kurts, 1950; Hall and Jones, 1961; Chambers and Possingham, 1963; Vaadia and Weisbl, 1963; Horrocks, 1964; Radler, 1965; Rain and McQueen, 1967; Possingham et al., 1967; Leyton and Armitage, 1968; Denna, 1970; Tanton and Crowdy, 1972).

Marked resistance of vines to desiccation during drought is attributed to the effective reduction in loss of water by cuticular transpiration through the thick waxy covering over the cuticle of the needles (Oppenheimer, 1960). The study of glaucous and green leaved *Poa colensoi* indicated the possibility of the dense leaf wax coatings which may function directly in reducing the rate of transpiration (Daly, 1964). The increase in transpiration rate under high wind current is attributed to decreased stomatal and cuticular resistance as a result of leaf buffeting (Grace, 1974). It is demonstrated that few of the components of the surface waxes like long chain hydrocarbons, alcohols, aldehydes and esters are effective in controlling the transpiration (Ornarevic et al., 1968).

A number of investigators have discussed the role of cuticle and epicuticular waxes in foliar penetration of the herbicides. (Crafts and Foy, 1962; Robertson and Kirkwood,
1969; Hull, 1970; Martin and Juniper, 1970; Baker and
Kirkwood et al., (1966, 1968) attributed the resistance of
Vicia fava to MCPB in part to a failure of the compound to
pass through the cuticle as readily as MCPA. The protec-
tion of barley from picloram (Sharma and Vandenborn, 1973)
has been attributed to the slow rate of the absorption of
the herbicide. Recently Schrenk and Rukovac (1978) have
reported that foliar penetration of succinic acid-2,2-Di-
methylhydrazide takes place by diffusion controlled by the
cuticular membrane.

The removal of the epicuticular wax resulted in greater
permeability of phenoxy acetic and benzoic acids through
enzymatically isolated cuticles of Lycopersicon fruits by
Rukovac et al., (1971) and the sorption of HAA through iso-
lated pear leaf cuticle by Rukovac et al., (1972) have been
reported. Partial removal of the surface wax with chloroform
resulted in one to four fold increase in penetration of 2,4-D
and picloram (Sharma and Vandenborn, 1970) and doubling of
nitrate ion uptake with apricot leaf discs (Leece and Kenworthy
1972). The entry of dinquat into the leaf is directly related
to the amount of cuticular wax on the leaves of various spe-
cies (Thrower et al., 1965).

Dewey et al., (1956) reported the damage of wax deposits
on leaves and stems leading to an increase in the susceptibili-
ity of crop plants to herbicides. Periera et al., (1971)
reported the intraspecific selectivity of cabbage to nitrogen and related to the quantity of wax present on the leaves at the time of herbicidal application.

Several workers reported the inhibitory effect of wax production by thioscarbamates which reduces the cuticle thickness of leaves by reducing the wax content (Getner, 1966; Wilkinson and Hardcastle, 1969, 1970; Wilkinson, 1974). Getner (1966) noticed the increased transpiration rate associated with reduced surface wax. Still et al., (1970) studied the influence of several carbamate herbicides on the deposition of epicuticular waxes in *Pisum sativum*. The observations showed that diallate can inhibit wax synthesis quantitatively but not qualitatively except for primary alcohols. Kollattukudy (1974) suggested that thioscarbamates reduce the cuticular lipid formation by a concentration dependent inhibition of the various chain-elongating enzyme systems. Recently Leavitt et al., (1978) observed the inhibition of epicuticular wax deposition on cabbage with ethofumesate and EPTC causing the increase in the cuticular transpiration.

Shrub sprouting has been shown mostly to the effects of burning, chemicals and moving or cutting. As carbohydrates are the primary source of reserve energy essential for the survival of either binomial or perennial plants (Smith, 1969), several investigators have reported a positive correlation between carbohydrate reserve levels in roots of woody plants and the degree of sprouting (Baker, 1918; Aldous, 1975; Jones
and Lande, 1960; Tew, 1970). Accelerated conversion of starch to sugars in plants under water stress has been discussed by Vandel et al., (1961). Gates (1964) also reported an increase in respiratory rate during moisture stress, which is accompanied by a drop in starch level and a simultaneous rise in reducing and total sugars. The regrowth of grasses after clipping occurred at the expense of the previously accumulated carbohydrate reserves and the amount of growth produced was related to the amount of these reserves (Graber et al., 1927; Weinmann, 1962; Ward and Elaser, 1961; Alberda, 1966).

Several reviews on the mode of action of bipyrhidylum herbicides have been given by Calderbank (1964, 1968, 1972), Dodge (1971, 1975), Ashton and Crafts (1973) and Corbett (1974). Parker (1966) noted that the paraquat is capable of killing Oxalis latifolia but, the timing of application has been considered as critical for the best results. The destruction of foliage stimulates the ripening of the new bulbs since the food reserves in the tuber being transferred apparently as a consequence of defoliation (Evans, 1967; Fryer and Wakepeace, 1970), and many species disappeared after repeated applications of paraquat (Austin, 1968).

Light and temperature greatly influence the activity of bipyrhidylum herbicides. High humidities and high temperatures enhance the toxicity of both dicot and paraquat. The necessity of light and oxygen are there for the rapid action of the herbicides (Nees, 1960; Musik, 1976). Brain (1966)
feels that a period of darkness following the herbicidal treatment enhanced the weed-killing activity. In contrast to the above finding, Akhavein and Linescott (1970) reported that darkness following the application did not affect the number of plants killed, although the growth is affected. Baldwin (1963) and Brain (1967) noticed the immobility of diquat and paraquat in the leaves during dark period following the application. The acoplastic movement (Baldwin, 1963), the rapid production of free radicals from the bipyridylium herbicides (Brain, 1964) and change in the membrane permeability (Merkle et al., 1965) in the presence of light have been reported.

It has been shown that the uptake of paraquat by leaves is not affected by soil moisture, but movement and activity are greater at high relative humidity than at low relative humidity (Thrower et al., 1965; Brain, 1966; Brain and Ward, 1967). High temperature and high light intensity accelerated the rate and magnitude of chlorosis (Akhavein and Linescott, 1968).

The paraquat treatment results in the inhibition of radical elongation of dark-grown honey mesquite seedlings (Merkle et al., 1965), Callus tissue of tobacco (Jordan et al., 1966), per cent germination of several species of grasses (Appleby and Frenchley, 1968) and the injury of white leaves of Hibiscus rosa-sinensis (O'neal and Miller, 1968) and this inhibition by paraquat has been explained due to the free
radical formation via the respiratory electron transport system. Further, α-amylose enzyme activity in barley seeds (Jones and Way, 1971) has shown to be inhibited by 72 percent with paraquat treatment.

The bipyridylum herbicides, diquat and paraquat causes initial wilting followed by necrosis which brings about rapid desiccation and ultimate death of the foliage to the plants applied. At the cellular level, it is considered that the products like N₂O₂ formed by the effect of the herbicide on photosynthetic electron transport system would attack the lipids of the cell membranes particularly tonoplast where it is located in close proximity to the chloroplasts (Harris and Dodge, 1972) and thereby causing more permeability.

Herbicides of chlorohenoxy family affects almost every biological activity of a plant (Crafts, 1961). However, the biochemical mechanisms by which the chlorohenoxy compounds affect the plants has proven to be very elusive. Linum usitatissimum L. variety "new bud" is susceptible to MCPA (Nalewaja and Rothum, 1969). Low volatile esters of 2,4-D and 2,4,5-T are fairly effective as foliar sprays to control Leprosa divaricata depending on the season and concentration of the herbicides (Pull et al., 1971). The foliar absorption and translocation of 2,4-D and 2,4,5-T has been recently reviewed by Richardson (1977).
Herbicides that affect synthetic processes in plants influence carbohydrate composition and utilization. A survey of the effects of numerous chlorinated phenoxycetic acids on specific carbohydrate fractions of bean has been reported by Sell et al., (1957). Alabisi and Shillins (1959) observed increase in total carbohydrate content after 2,4-D treatment in dwarf bean.

It is considered that the possible mechanism contributing to the herbicidal action of 2,4-D is the increased respiration that depletes the food reserves (Tukey et al., 1945) which later discounted by Smith et al., (1947). Depletion of reducing and non-reducing sugars, starch, crude fibre and acid hydrolysable polysaccharides in stems and depletion only in non-reducing sugars of roots and leaves has been noticed by Sell et al., (1940), Keller et al., (1950). Wort (1951) also recorded a decline in the total sugar content and starch dextrin fraction.

The depletion of starch and sugar in tomato plants with MCPA treatment is due to a 50% decline in the rate of synthesis rather than a depletion of the reserves (Rhodes, 1952). Accumulation of intermediary metabolites which causes a decrease in the production of metabolic end products has been shown as due to the effect of various herbicides on glucose metabolism (Rourke et al., 1962). 2,4-D at 10⁻⁵ M caused a greater reduction than 3,5-D in carbohydrate content of storage tissue whereas in artichoke tissue 3,5-D reduces
carbohydrate content greater than 2,4-D (Vain, 1964). The increase in hydrolase and invertase activities and an extensive hydrolysis of oligosaccharides has been noted (Rutherford et al., 1969; Flood et al., 1970). Strong inhibition of \( \alpha \)-Amylase formation with 2,4,5-T (Moreland et al., 1969), stimulatory and inhibitory effects of low and high concentrations of 2,4-D on glycolysis in pea tissues (Bourke and Pate, 1962) has been observed.

The variety of specific effects on intermediary metabolism in plant tissues by the action of 2,4-D has been investigated by several groups of workers. 2,4-D stimulated the respiration rate of etiolated pea seedlings and increased the metabolism of \( \text{Glucose-}^1\text{C} \) via the pentose phosphate pathway (Humphreys and Reger, 1957 a and b) and also this increase in respiration via pentose phosphate pathway is due to the blockage of the synthetic metabolic pathways (Humphreys and Reger, 1958).

2,4-D and DNP promoted the oxidation of exogenously supplied substrate by blocking the synthetic pathways (Humphreys and Reger, 1959). Similar treatment of etiolated corn seedlings with 2,4-D produced a general increase in glucose catabolism through an increase in the activity of enzymes associated with the pentose phosphate pathway (Key, 1962; Black and Humphreys, 1962).

The studies with \( ^{14}\text{C}-\text{acetate} \) indicate that phenoxy acids reduced the incorporation into cell wall constituents
(Humphreys and Dugger, 1950; Stevens et al., 1962). The carboxylation of pyruvic acid and entry into Kreb's cycle of acetate derived from pyruvate is inhibited by 2,4-D (Kim and Bidwell, 1967). The time course experiments on the in vitro effect of 2,4-D (10^{-4} M) on the metabolism and incorporation of specific 14C labelled glucose into pea and corn found that 2,4-D affected the preferential release of C-1 as CO₂ and enhanced C-6 oxidation in pea roots and corn stems via the glucoronic acid pathway and a reversible effect on DPP (Heston and Tang, 1971).

The activities of glycolaldehyde-3-phosphate dehydrogenase and isocitric dehydrogenase are stimulated at low concentration and inhibited at high concentration (Freed et al., 1961). The greater inhibitory effect is observed with 2,4-D on malate and isocitric dehydrogenases (Wedding and Black, 1962). At higher concentrations all phenozy herbicides strongly inhibited respiration possibly due to the inhibition of malate and succinate dehydrogenases (Wedding and Black, 1962; Pottrill and Hanson, 1969) to the inhibition of an energy dependent substrate translocation (Dan, 1967).

As the experimental plants are growing under arid environment which is reckoned as an area periodically exposed to water stress, during these conditions protein synthesis decreased and proteolysis may occur promoting an increase in soluble nitrogen compounds such as amino acids, amides and
soluble proteins (Stecker, 1960). Further, water stress causes deamination of the amine acids and other intragenous degradation products, thus allowing toxic amounts of ammonia to accumulate which ultimately result in the death of the plant. Tolerant plants retain their synthetic capacities longer under stress than non-resistant plants and the plants capacity to control pH build-up appears to be a major adaptation to drought (Kenkel, 1964). With a view to examine any such accumulation would help these scrub species to adopt to arid condition, the study of protein synthesis has been carried out.

The effect of 2,4-D treatments on various nitrogenous constituents of plants have been reported by numerous investigators (Adua, 1976). 2,4-D accelerated growth and RNase activity up to 50 ppm but at higher concentration both are inhibited, and the protein content decreased in excised maize mesocotyl (Shannon et al., 1964). In general any treatment that causes injury to plants will increase the percentage nitrogen, but not total nitrogen per plant (Steenbjerg et al., 1972).

The chlorophenox herbicides effect the nitrogenous content of several tissues quite markedly by inducing metabolic sinks (Ashton and Bayer, 1976). Treatment with 2,4-D in field bind weed decreased the total nitrogen in the leaves and increased in the stems and roots and underground rhizomes (Smith et al., 1947), and also substantial increase in total N, protein, RNA and DNA in the apex, stem and tap root with
corresponding increase in other parts has been observed in zanthium species (Cardenas et al., 1968). Selective phytotoxicity of auxin-like herbicides is based on differential alteration of RNA and interference with protein synthesis (Chen et al., 1973).

The increase in protein content, nucleic acids and soluble nucleotides and protein synthesis has been observed by the treatment with 2,4-D or 2,4,5-T (Key, 1959; West et al., 1960; Shannon et al., 1964; Chen et al., 1972) Contrary most of the herbicides tested are inhibitory in ATP, RNA and protein synthesis in vivo maize mesocotyls (Moreland et al., 1969). Reduced ATP levels and RNA and protein synthesis are reported in soybean hypocotyls with 2,4,5-T, propachlor, pyridichlor and fenac (Cravenhagen and Moreland, 1971). The study of the effect of 2,4-D on Amaranthus albidus roots recorded starch reduction, protein increase, emulsion of nucleotides (Coble and Clife, 1971) and also a marked change in the cellulose content of the cell walls of Vicia faba root tips (Grant and Fuller, 1971).

Phenoxy acid herbicides are known to affect lipid synthesis. Mann and Pa (1969) found that 2,4,5-T and 2,4-D stimulated lipogenesis, however the stimulation declined over the concentration range tested. Similarly Sumida and Veda (1973) reported that 2,4-D stimulated lipid biosynthesis in chlorella.
Klepper (1974) reviewed the inhibition caused by phenoxys of the normal process of nitrite reduction. The herbicides 2,4,5-T, Pebulate and promham inhibited nitrite reduction from 57 to 79% in soybean leaf tissue.

The aim of the present investigation is to examine the influence of two different classes of chemical herbicides, a bipyrildilium compound (paraquat) and a chlorophenoxy compound (2,4,5-T) on five selected dominant semi-arid scrub species. As these plants are biologically least productive with a view to get an insight of the response of these chemicals on these plants, and further to bring their growth under herbicidal control, the rate of cuticular, and total transpiration rate, their relationship with the deposition of epicuticular waxes, and cuticle has been taken up. The effect of chemical herbicides on carbohydrate and nitrogen metabolism would help in deeper understanding about the mode of action, as carbohydrates are the primary sources of energy essential for the successful growth of the semi-arid plants under stress conditions besides the cumulative effect of accumulated nitrogenous compounds. Hence the influence of paraquat and 2,4,5-T on the qualitative and quantitative changes in epicuticular waxes, levels of cuticle, carbohydrate and nitrogen metabolism has been taken up which may contribute towards thorough understanding of the mode of action of these herbicides.