II - Review of Literature

Glyphosate is a broad-sprectrum, non-selective, post emergence herbicide used in the form foliar sprays. It is absorbed quickly through the leaves and translocated to the different parts of the plant. Glyphosate has been reported to affect the germination, growth and various metabolic processes in the plant. The effects of glyphosate with respect to various morphological, anatomical, physiological and biochemical changes in the plant have been discussed in this review.

A. Effect on germination and growth

Glyphosate affected germination and growth of legumes *Medicago* and *Trifolium* when applied directly to their seeds. It also reduced germination in few grass species and seedling growth in most of the grasses. This work was carried out by Salazar and Appleby (1982). Similarly glyphosate has been reported to reduce germination and shoot dry weight of common rye (Young *et al.* 1984). While studying response of three perennials to glyphosate, Comes *et al.* (1981) observed a variation in their tolerance to glyphosate. Seedlings of red tap (*Agrostis alba*) were found intermediate where as those of canary grass (*Phalaris arundinae*). were sensitive to glyphosate treatment. In case of maize, glyphosate, applied before the grain maturity, reduced seed weight and also induced subsequent, abnormalities in the seedlings.

Treatment of glyphosate efficiently reduced the regrowth of perennials such as Johnson grass (Skender _et al._ 1983). _Teucrium canadense_ (Swanton 1985), _Ampelomus olbidus_ (Moshier 1980), _Circium arvense_ (Mikulka and Zemanek 1981) etc. as compared to the other herbicides. On the contrary Blowes _et al_. (1985) observed no significant adverse effect on establishment, growth and nodulation of 14 pasture legume cultivars at the high rates of glyphosate treatment to the soil. The effect of glyphosate on frond regeneration, bud development and survival & rhizome-starch content was studied by Al-Jaff _et_. _al_. (1982) in _Pteridium aquilinum_. They observed a considerable inhibition of the rhizome system at high levels of glyphosate. Dimitrova and Benko (1987) have also reported control of _P_. _aquilinum_ with the glyphosate treatment.

Growth of bacterium (_E_. _coli_), alga (_Chlamydomonas_), plant cell cultures (Carrot and Soybean) and roots of whole plant (_Arabinopsis thaliana_) was found inhibited by glyphosate in a study carried out by Gresshoff (1979). According to Brecke and Duke (1980) glyphosate is quickly obsorbed by the whole plant as compared to the individual cells, causing a reduction in leaf dry matter, leaf expansion, etc. without affecting the water status of the plant. However Crowley and Prendeyille (1980) have reported increased leaf cell permiability in _Phaseolus_ due to glyphosate which was associated with the wilting of the plant.

Song et al. (1983) have reported a reduction in linear growth, dry weight of mycelium, sporogenesis and spore germination of *Fusarium oxysporium* by glyphosate. Discharge of total ascospores of *Venturia inaqualis* was significantly reduced by glyphosate applied to apple leaf discs (Yoder and Klos 1982).

B. **Effect on Secondary Metabolism**

Secondary products of plants have no direct role in primary metabolism. Secondary products of many chemical classes exist in plants. These compounds are thought to function during a pathogenic attack or any type of stress (DiCosmo and Towers 1984) and Harborne 1986). The effects of glyphosate on the synthesis of phenolic secondary compounds are summarised in detail by many workers (Lydon and Duke 1989, Duke 1985). Glyphosate blocks synthesis of aromatic amino acids and all phenolic compounds derived from them by inhibiting EPSPS of shikimic acid pathway (Hollander and Amrhein 1980, Saltveit 1988, and Canal et al. 1987). According to Duke et al. (1979) glyphosate generally causes an increase in PAL activity with a decreased synthesis of phenolic compounds. Deregulation of the shikimate pathway results in increased levels of certain benzoic acids (Canal et al. 1987, Lydon and Duke 1988, and Becerril et al.1989) Content of tannins derived from benzoic acid may also be increased by glyphosate (Kakhniashvili et al. 1989). However it is observed that glyphosate-induced reduction in phenolic compounds derived from aromatic amino acid is less, what is than expected. This might be due to aromatic amino acids formed by protein degradation, pools of amino acids present in vacuoles and freshly syntheised amino acids available for synthesis of phenolic compounds (Margna et al. 1989). This results in differences in the effects of glyphosate on biosynthesis of these compounds from the two pools. In a few cases glyphosate has been reported to increase levels of phenolc compounds in plants (Morandi 1989). According to Becerril (1989) at sublethal levels there are pronounced effects on metabolic sinks such as fruits of flowers.

C. Effect on Photosynthetic Carbon Fixation

Glyphosate being pholem mobile in plants, its translocation may be limited by an indirect effect on carbon matabolism. Geiger and co-workers have shown that glyphosate affects carbon fixation through an effect on RuBP levels and starch production (Geiger et al. 1986, Servaites et al. 1987, Geiger and Bestman 1990). This effect occures as a secondary effect of deregulation of shikimate pathway by glyphosate. Initially starch maintains the supply of assimilate for translocation through its degradation but soon becomes depleted.

D. Glyphosate and Resistance of Plant Tissues.

Many workers have reported that herbicides increase or decrease the susceptibility of crop or plant tissues to pathogens. (Altman and Campbell 1977, Katan and Eshel 1973), depending on the synthesis of phytoalexins. As glyphosate blocks synthesis of phenolic phytoalexins, it is expected to enhance susceptibility to pathogens. Johal and Rahe (1984) have reported that bean plants treated with glyphosate died when grown in non-sterile soil due to root infesting pathogens but survived in sterile soil. Crops such as wheat, beans, corn, flags and several weed species become susceptible to fungal attack when treated with glyphosate. (Rahe et al. 1990, Brown and Sharma 1984, Levesque et al. 1987 and Sharon et al. 1993). In some studies reduced phytoalexin synthesis due to glyphosate has been correlated with increased susceptibility of several species to fungal pathogens as observed in Phaseolus vulgaris by Johal and Rahe (1988). In case of leucern and soybean also glyphosate has been reported to reduce the resistance of these crops to fungal infection. (Latunde-Dada and Lucan 1985, Ward 1984, Holliday and Keen 1982).

Glyphosate, being toxicologically and environmentally safe (Duke 1988) is considered as an ideal herbicide for development of herbicide resistant crops. Herbicide resistant weeds are unlikely to arise rapidly in such crops. The primary target of glyphosate is EPSPS, an enzyme in the shikimic acid pathway that synthesises aromatic amino acids. Glyphosate resistant EPSPS has been found in Salmonella typhimurium (Stalker et al. 1985). Arobactor, aerogenes (Sost et al. 1984) and E. coli (Kishore et al. 1986). Glyphosate resistance has been engineered into tabacco and tamato by transferreing the mutant aro A gene for resistant EPSPS from S. typhimurium (Comai et al. 1985).

E. **Effects on Harmone Levels.**

At sublethal doses glyphosate has been reported to disrupt apical dominance (Parkar 1975. Lee 1984). Such effects occure due to direct disruption of apical meristem or indirect effects on endogenous harmone level or herbicide-induced changes in sensitivity to endogenous harmones. Synthesis of tryptophan, an aromatic amino acid and precurssor of auxin is directly inhibited by glyphosate (Cole 1985). In a few studies IAA content in glyphosate treated plant tissue was found increased and this increase was associated with the increase in benzoic acids (Canal et al. 1987). They observed a five-fold increase in the content of gentisic acid, an inhibitor of IAA oxidase. In other studies glyphosate reduced free endogenous IAA. (Lee 1984). According to Lee (1982, 1985) changes in IAA oxidase levels due to altered phenolic content may increase the metabolism of IAA in glyphosate treated tissues. Further IAA oxidase activity may be stimulated or inhibited by different phenolic compounds, (Lee et al. 1982, and Grambow and Langenbeck-Schwich 1989). Due to this, conflicting results, with different species regarding phenolic content and IAA oxidase activity, are obtained.

F. Residual Effects of Glyphosate

Persistance of glyphosate in sandy loam was studied by Eberbach and Douglas (1983). They found that glyphosate is not inactivated during 120 days after its application. Emergence, growth and survival of seedlings has been found supressed in the soils containing residues of glyphosate (Faulkner 1981). A greater dose of herbicide results in the greater amount of residue in the soil (Raatkainen et al. 1976). Residues of weeds which have been treated with glyphosate also cause a poor establishment and growth of seedling crop as observed by Lynch and Penn (1980).

G. Scope of Present Investigation

Glyphosate is a non-selective, broad-spectrum, herbicide, widely used for controlling weed infestation in field crops, orchards, plantation crops, vegetables and ornamental crops. Being non-selective it may cause serious damage during spot treatment, if proper care is not taken. It is usually applied as a foliar herbicide in the form of directed sprays to avoid the contact of above ground parts of crops with the herbicide. In the absence of special protective appliances during the application of the herbicide, the spray drift onto the crops may result in serious damage and low yield of crop.

In the present investigation two weed and two crop species have been selected for analysing the effect of foliar spray of glyphosate. As glyphosate is a non-selective herbicide, used to control weeds in a wide variety of crops, it was thought worth-while to select both the monocot and the dicot species for analysis. The crop species undertaken for the study are wheat (Triticum aestivum L.) and soybean (Glycine max L.) and the weed species are Cyperus rotundus L and Celosia argentea L. Folliar sprays of glyphosate were applied to these plants, raised in pots and the effect was studied with respect to various biochemical parameters, such as organic and inorganic constituents and the activities of certain enzymes.

Much of the work carried out with glyphosate is devoted for studying its effects on growth of crops, weeds and other plants. Some workers are dealing with its mode of action and hence working only on the secondary metabolic processes. There are several other biochemical reactions in plants which may be affected by glyphosate treatment. Reports available regarding such analysis are very scanty. In the present investigation an attempt has been made to study the effect of glyphosate on various biochemical parameters of plants. The work may add to the existing knowledge regarding the interaction of plants and herbicides.