Chapter – 1

INTRODUCTION
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*Cicer arietinum* (chickpea) is an edible legume of the family Fabaceae. The plant is erect or spreading, much branched, and an annual herb that attains a height of about 30-50 cm. The plant body is covered all over with glandular hair which is rich in both oxalic acid and malic acid. The leaves are pinnately compound with 9-17, opposite or alternate, stipulate and strongly veined leaflets. The flowers are papilionaceous, varying in shades from white to pink or blue. The pods bear one or two round or semi-round, wrinkled or semi-wrinkled exalbuminous seeds. Chickpea is widely distributed in North Africa, Ethiopia and in the East Mediterranean region to central Asia. In India, Chickpea is commonly known as gram and is extensively cultivated as a winter (October-March) crop throughout the country, especially in northern states. However, severe cold and frost are injurious to it, so it is not successfully cultivated in the Himalayan regions above 500m. It is primarily a crop of low rainfall areas but provides good yields under irrigated conditions as well. Chickpea is grown on a wide range of soil types ranging from sandy loam to clayey loam. The crop is sensitive to alkaline pH and salinity which adversely affects its germination, growth and yield.

There are two main groups (types) of chickpea cultivated in India. One is the “Desi” type, which has small dark and wrinkled seeds which constitutes about 85% of total production and the other type is the “Kabuli” type which has larger sized, lighter coloured seeds with a smoother coat and constitutes the rest of the total production.

Chickpeas are of great food value. The unripe seeds are often removed from the pods and eaten as a raw snack. Mature seeds of chickpea have great nutritional
value and a variety of dishes are prepared out of it and eaten worldwide. The dried
and mature seeds of chickpea are ground into flour called gram flour out of which
many popular dishes are prepared.

Chickpea is a good source of minerals, protein and folate. After soybean it ranks
second in seed protein content. The seeds are rich in dietary fiber and hence a healthy
source of carbohydrate for persons with insulin sensitivity or diabetes. Chickpea is
low in fats most of which are polyunsaturated. According to International Crops
Research Institute for the semi arid tropics, Hyderabad, India, besides having high
protein content chickpea seeds possess about 64% total carbohydrate, 5% fat and 6%
fiber. The seeds are also rich in minerals like phosphorus (340 mg), calcium (190
mg), magnesium (140 mg), iron (7 mg) and zinc (3 mg) estimated per 100 g.

The impact and long-term ecological ramifications of heavy metal pollution on
the biosphere have resulted in an increased interest in evaluating the interaction
between heavy metals and flora. “Heavy metals” are defined as the metals having
density higher than 5 g cm\(^{-3}\). Of the major heavy metals, cadmium (Cd) is a major
industrial pollutant, particularly in areas associated with smelting of zinc and heavy
road traffic (Somasekaraiah et al., 1992; Das et al., 1997). Cadmium, an element of
group IIIB in the Periodic Table, is a white lustrous element with melting and boiling
points of 321 and 767 °C, respectively, and a density of 8.64 g cm\(^{-3}\). Its atomic number
is 48 and atomic mass is 112.64. The heat of vaporization of Cd is 26.8 k cal mol\(^{-1}\)
(Cotton and Wilkinson, 1966) and this property of Cd makes it susceptible to enter the
atmosphere (Laws, 1993). Based on its solubility, Cd is one of the most toxic and
mobile heavy metals in contaminated crop environment. It is easily taken up by plants
and accumulated to high levels in the aerial organs (Kabata-Pendias and Pendias,
2001) thereby causing potential damage. Cadmium preferentially accumulates in the
chloroplasts and disrupts chloroplast function by damaging its membrane, inhibiting the activities of the biosynthesis of chlorophyll and CO₂ fixation (Boddi et al., 1995; Siedlecka et al., 1997) or the aggregation of pigment protein complexes of the photosystems (Horvath et al., 1996) Various physiological processes may be altered, including growth retardation (Cataldo et al., 1983; Dewdy and Ham, 1997; Drazic et al., 2006; Krantev et al., 2008; Ekmekci et al., 2008; Hasan et al., 2008) and plant-water relations (Barcelo and Poschenrieder, 1990; Das et al., 1997). Cd-induced generation of superoxide (O₂⁻) anions, hydroxyl (OH) radicals and H₂O₂ cause a considerable membrane damage. It induces the peroxidation of polyunsaturated fatty acids (De Vos and Schat, 1981) and also alters the activity of antioxidative enzymes (Mishra et al., 2006; Hasan et al., 2007; Hasan et al., 2008). Cd directly or indirectly interferes with the nutrient uptake in plants. This is due to the fact that the mechanism for Cd uptake by the plant root generally involves competition for absorption sites between the heavy metals and several mineral nutrients like Ca⁺⁺ and Mg²⁺ which sharing similar chemical properties (Jarvis et al., 1976).

When exposed to stressful conditions, plants accumulate an array of metabolites, particularly amino acids. Amino acids have traditionally been considered as precursors as well as constituents of proteins, and play an important role in plant metabolism and development. Proline, an amino acid, plays a highly beneficial role in plants exposed to various stress conditions. Besides acting as an excellent osmolyte, proline plays three major roles during stress, i.e., as a metal chelator, an antioxidative defense molecule and a signaling molecule. Stressful environment results in an overproduction of proline in plants which in turn imparts stress tolerance by maintaining cell turgor or osmotic balance; stabilizing membranes thereby preventing electrolyte leakage; and bringing concentrations of reactive oxygen species (ROS)
within normal ranges, thus preventing oxidative burst in plants. Proline, when supplied exogenously at lower concentrations to plants exposed to various biotic and abiotic stresses, results in stress mitigation thereby enhancing growth and other physiological characteristics of plants. Exogenous proline maintains the turgidity of the cells and also enhances photosynthesis during times of stress. Lower concentrations of proline are known to provide tolerance against the damaging effects of salinity, drought, irradiance or heavy metal stress (Ashraf and Foolad, 2007). Exogenous proline also affects the activity of antioxidative enzymes viz. CAT, POX, SOD, etc. and also the enzymes of nitrogen metabolism (Hoque et al., 2007).

Metabolism provides the power and building blocks for plant life, whereas, the hormone regulates the speed of growth of individual parts and integrate these parts to produce the form that we recognize as a plant (Davies, 1987). Salicylic acid is ubiquitously distributed in the entire plant kingdom. It was recognized as an endogenous plant growth regulator after finding that it generates a wide range of metabolic and physiological responses in plants thereby affecting their growth and development (Hayat et al., 2010). A common consequence of most biotic and abiotic stresses is an increased production of ROS such as O$_2^-$, OH$^-$ and H$_2$O$_2$ which creates a state of oxidative stress in plants (Elstner, 1982; Panda et al., 2003 a,b). However, exogenous application of SA at suitable concentration has been found to enhance the activity of the antioxidative defense system thereby providing tolerance to the plants against oxidative burst. The application of SA has been found to be effective in enhancing the growth of plants exposed to various stressful environments such as high salinity, heavy metals, temperature extremes, water stress and irradiance (Hayat and Ahmad, 2007; Hayat et al., 2010). Exogenous application of SA has been found to
increase the photosynthetic parameters and plant water relations (Hayat et al., 2005; Yusuf et al., 2008).

Keeping in view the diverse physiological roles of proline and SA in plants, it was decided to study the individual as well as cumulative effect of proline and SA on Cd-induced changes in chickpea (*Cicer arietinum* L.) cv. Avarodhi with the following objectives:

- To study the effect of varying concentrations of Cd applied to soil.
- To select the most effective concentration of proline applied as foliar spray.
- To select the most effective concentration of SA applied as foliar spray.
- To study the effect of the selected concentrations of proline on Cd-induced changes in chickpea.
- To study the effect of the selected concentration of SA on the Cd-induced changes in chickpea.
- To study the interactive effect of proline and SA on Cd-induced changes in chickpea.