VI. SUMMARY

*Allium cepa* var. *Aggregatum*, a biennial herb with a characteristic smell, is one of the most important vegetable crops in India used mainly for seasoning of curries. The southern regions of India distinguish *Allium cepa* var. *Aggregatum* (shallot) from onions in recipes more often, especially the much loved tiny varieties (about the width of a finger); these are widely used in curries and different types of *Sambar*, a lentil-based dish. Shallots pickled in red vinegar are common in many Indian restaurants, served along with sauces and *Papad* on the condiments tray. In Nepal, shallots are used as one of the ingredients for making *Momo*. In Kashmir, shallots are widely used in preparation of Wazwan Kashmiri cuisine, as they add distinct flavor and prevents curry from getting black which is a common problem with the onions.

Drought, the most critical threat to world food security, is one of the most important environmental factors that affect plant growth and development and thus limits plant production. Plants in response to drought stress adapt themselves by altering their cellular metabolism and invoking different defense mechanisms. These defense mechanisms may also be induced or enhanced by exogenous application of plant growth regulators. Salicylic acid (SA) and Jasmonic acid (JA) are naturally occurring plant growth regulators which can affect many physiological and biochemical processes and can protect plants stress injuries. These two growth regulators are
also involved in a complex signal-transduction network that coordinates growth and development with plant responses to drought stress.

With respect to drought stress, relevant work is limited especially in case of *Allium cepa* var. *Aggregatum*, which is an important crop plant with a number of agro-industrial uses. This is of great interest since increasing the amount of irrigated land is difficult; water is scarce and only the most efficient agricultural systems are likely to receive inputs of irrigation water. There is no information about the morphological, physiological and biochemical responses of the *Allium cepa* var. *Aggregatum* to SA and JA under water stress, which is supposed to influence many physiological processes in drought stressed plants. Hence, keeping the above facts in view, initiative has been taken to study the ameliorative effects of SA and JA in *Allium cepa* var. *Aggregatum* under drought stress. The aim of the present investigation was to evaluate the ameliorative effects of SA and JA on growth parameters like root length, shoot length, number of leaves per plant, whole plant fresh weight and dry weight, yield parameter like number of cloves per plant and total bulb weight per plant, relative water content, mineral ions like calcium and potassium, photosynthetic pigments such as chlorophyll ‘a’ and ‘b’ and carotenoid content, biochemical constituents like protein, amino acid, proline and glycine betaine, total soluble sugar, sucrose and starch content, proline metabolizing enzymes like proline oxidase and
γ-glutamyl kinase antioxidants like ascorbic acid, α-tocopherol and reduced glutathione and antioxidant enzymes like, superoxide dismutase, catalase, peroxidase and ascorbate peroxidase activity, hydrogen peroxide and lipid peroxidation in *Allium cepa Var. Aggregatum* under drought stress.

A pot culture experiment was conducted to assess the ameliorative effects of jasmonic acid and salicylic acid on drought stressed *Allium cepa* var. *Aggregatum*. Plastic pots, 32 cm diameter and 20 cm height, were filled with 8 Kg of sand, farm yard manure and garden soil (ratio 2:2:1) and pots were arranged in complete randomized block design (CRBD). Seeds of *Allium cepa* var. *Aggregatum* were surface sterilized with 0.2% mercury chloride solution, thoroughly washed with distilled water and then were planted 1-2 cm deep in all pots. Pots were regularly irrigated up to 5 weeks to maintain the required moisture for normal growth. In meantime, the seedlings were thinned to five plants per pot on 3rd week after sowing. Pots were divided into eight groups, each group with 25 replicates viz., control with normal irrigation (C), five days interval drought (D), drought with 0.5 mM SA (DS1), drought with 1.0 mM SA (DS2), drought with 1.5 mM SA (DS3), drought with 25 μM JA (DJ1), drought with 50 μM JA (DJ2) and drought with 100 μM JA (DJ3) . Drought stress treatment (D) in the form of five days interval drought (5 DID), was imposed on 35th to 95th day after sowing (DAS), whereas, SA (0.5, 1.0, 1.5 mM) and JA (25, 50, 100 μM) treatments
were exogenously applied through foliar spray, 15 days before each sampling i.e., on 35th, 50th, 65th and 80th DAS. The *Allium cepa* var. *Aggregatum* crop matures between 90 to 110 days that is why sampling days were fixed up to 95 DAS. The plants were harvested for analysis on 50th, 65th, 80th and 95th DAS, were selected randomly from each group, uprooted and washed carefully and then separated into root and shoot for estimating morphological, physiological and biochemical parameters.

Drought stress alone significantly affected root length, shoot length, number of leaves, whole plant fresh weight and whole plant dry weight, number of cloves per plant and total bulb weight of *Allium cepa* on all growth stages as compared to control. However, foliar application of SA and JA in presence of drought stress enhanced these growth and yield parameters but does not exceed the control. There were found less difference in number of leaves and number of cloves per plant among the groups.

Relative water content and mineral ion concentrations (Ca$^{2+}$, K$^+$) were found decreased under drought stress in *Allium cepa* as compared to control on all growth stages. When SA and JA treatments were applied to these drought stressed *Allium cepa* plants, RWC and mineral ion concentrations significantly increased as compared to drought stress alone. Drought stress decreased the photosynthetic pigments such as chlorophyll-a, chlorophyll-b and carotenoid contents in leaves of *Allium cepa* on all growth stages. However,
exogenous foliar application of SA and JA enhanced the above said photosynthetic pigment contents in leaves of *A. cepa* under drought stress.

Drought stress decreased protein and starch contents both in root and shoot of *A. cepa* as compared to control. On the other hand, exogenous treatments with SA and JA in presence of drought stress enhanced protein and starch contents as compared to drought stress alone. The compatible solutes like, free amino acid, total soluble sugar, sucrose, proline and glycine betaine contents in root and shoot of *A. cepa* increased under drought stress as compared to control. The foliar application of SA and JA in presence of drought stress further enhanced the accumulation of these compatible solutes when compared with untreated drought stressed and control plants.

The activity if proline oxidase was inhibited due to drought stress in root and shoot of *A. cepa* plants on all growth stages. However, foliar spray of SA and JA, in presence of drought, increased proline oxidase activity as compared to drought stress alone, but was does not exceed the control. Under drought stress, γ-glutamyl kinase activity was increased as compared to control. Foliar treatments with SA and JA further increased rate of γ-glutamyl kinase activity in drought stressed *A. cepa* on all growth stages.

Drought stress increased lipid peroxidation by increasing MDA content and hydrogen peroxide concentration in *A. cepa* when compared with control. However, this effect was lowered by foliar
application of SA and JA. Drought stress significantly increased antioxidant contents such as, α-tocopherol, ascorbic acid and reduced glutathione contents in root and shoot of A. cepa as compared to control. These antioxidant contents were further increased in SA and JA treated drought stressed plants as compared to plants which did not receive any treatment except drought stress. Drought stress markedly increased activity antioxidant enzymes such as, Superoxide dismutase, peroxidase, catalase, and ascorbate peroxidase in root and shoot of A. cepa plants on all growth stages. However, exogenous foliar application of SA and JA further enhanced the activity of these antioxidant enzymes in presence of drought stress.

From the above it may be concluded that drought stress affected growth and yield of A. cepa by affecting morphological as well as physiological processes. However, exogenously applied SA and JA through foliar spray ameliorated the adverse effects of drought stress in A. cepa by inducing morphological growth such as root length, shoot length, leaf number, total biomass, clove number and bulb weight and improved RWC, mineral contents, photosynthetic pigments, biochemical components and compatible solutes and antioxidant system and inhibited lipid peroxidation and H$_2$O$_2$ production.