Coleus forskohlii Syn Plectranthus barbatus is gaining more of attention day by day because of its multitherapeutic properties as discussed elsewhere. Coleus forskohlii is a great source of many medicinally important biochemcials and antioxidants such as flavonoids, alkaloids, polyphenols, antioxidants, essential oil and many, however this plant roots are rich and exclusive source of vital diterpene forskolin and coleonol. So increasing demand of this plant is putting burden on its naturally available resources. Because of this, there is severe depletion of this plant from wild sources. In view of this attempts has to be made to increase the cultivation of this crop along with its productivity. Developing more promising cultivation practices is one of the measure to improve plant growth, quality and yield of economically and medicinally important medicinal crops. In case of Coleus forskohlii several attempts have been made to increase the yield of coleus plant w. r. t improve its medicinal value by taking measures to enhance secondary metabolism and economic production of this plant both in field trials and In Vitro. Various strategies have been applied by many workers to achieve this goal by applying varied cultivation practices, use of fertilizers, inoculation with AM-fungi and plant growth regulators application. Application of PGRs for crop improvement is one of the most promising road to reach success in terms of both qualitative and quantitative advancement in medicinal crop development. Review of literature emphasized the competence of growth promoters like triacontanol and brassinosteroids and growth retardants like CCC and ethephon in manipulating crop growth and development as discussed in ‘Review of literature’ part of this thesis. Hence an attempt has been made in the present investigation to understand the influence of these plant growth regulators application on growth, metabolism and medicinal value of C. forskohlii.

Some of the significant findings of the present work can be summarized as follows.

Effect of PGRs on various growth parameters and overall yield growth

A. Growth Studies

1. Effect of Pre-treatment of PGRs or dipping method

The growth analysis of C. forskohlii plants subjected to dipping or pre-treatment of stem cuttings in respective PGRs solution was carried out at three distinct growth stages of the plant such as at 45 DAP, 90 DAP and 135 DAP or at maturity of plant. The constant increment in all values of all the growth parameters along with
increase in growth or age of plant from zero growth stage to maturity of plant (135 DAP) was noticed due to both concentrations of triacontanol, brassinosteroids, CCC and ethephon.

At 45 DAP stage there was no or very slight variation in levels of all the growth parameters studied due to all the PGRs pre-treatment and control except that PGRs treated plants showed early tuberization and more rooting. Triacontanol, brassinosteroids and ethephon were found more effective in tuberization and root length stimulation as compared to control.

At 90 DAP growth stage analysis, both doses of triacontanol effectively increased all the growth characters however low dose of triacontanol was more promising. Both doses of BRs positively influenced most of important growth attributes and high concentration of BR was found more dominant than low concentration. CCC at both doses caused increase in most of root growth characters however caused decrease or no change in most of leaf and stem growth characters. CCC exerted similar level of effect irrespective of its concentration. Ethephon at 90 DAP also contributed in overall enhancement of most of growth attributes but most characteristically caused enhanced root circumference and stem base circumference as compared to all the other treatments. However lower dose of ethephon was more prominent in causing positive effect on growth as compared to control and high dose of ethephon.

At 135 DAP or at maturity stage of *C. forskohlii*, significant increase was noticed in levels of all the growth parameters studied due to all PGRs pre-treatments as compared to control. However, among all PGRs pre-treatments, plants subjected to triacontanol, BRs and ethephon (low dose) pre-treatment showed maximum enhancement in growth of both above and underground plant parts. Stem base circumference was highest in case of ethephon pre-treatment. Maximum shoot height was noticed due to high dosage of BRs.

Among all PGRs treatments tried, both concentrations of CCC proved to be less effective but certainly gave better results than control. Both concentrations of triacontanol, BRs and ethephon at low concentration found to be more promising as a pre-treatment causing significant increment in overall growth of coleus.

Dry matter partitioning and source-sink relationship under the influence of PGRs was determined by considering the root/total dry weight ratio at the harvest or
SUMMARY AND CONCLUSIONS

maturity stage. It was noticed that both concentrations of all the PGRs like triacontanol, BRs, CCC and ethephon caused increment in the root/ total dry weight ratio as compared to control. All the PGRs caused increase in dry matter accumulation in root part than leaf and stem part of plant as compared to control pre-treatment and thus increase in economic yield. Triacontanol and ethephon showed maximum positive effect on root dry matter partitioning.

It can be summarised that among all the PGRs applied as a pre-treatment triacontanol, BRs and lower dosage of ethephon along with CCC positively influenced overall growth and yield of *C. forskohlii*. Thus, the application of growth regulators in present study will be beneficial for significantly enhanced growth and productivity of this plant however triacontanol and BRs and low doses of ethephon will be more beneficial as a pre-treatment.

2. Influence of foliar spray of PGRs on growth

The Influence of foliar spray of triacontanol, brassinosteroids, CCC and ethephon on all the growth parameters of *Coleus forskohlii* was assessed at the 2.5 month-old age (75DAP) and at the harvesting stage or at 165 DAP of plant. All the growth parameters of coleus plants were noticed to be positively influenced at both growth stages of analysis because of foliar application of all PGRs triad except for high concentration of ethephon. Only low concentration of ethephon was found to be effective in increasing all the growth parameters as compared to control while high concentration of ethephon exhibited negative effect on all growth characters of both aboveground and underground plant parts of coleus. The triacontanol caused significant increment in all the growth attributes of both aboveground and underground plant parts of Coleus however high dose of triacontanol was more promotive.

The brassinosteroids positively influenced all growth characters of coleus studied as compared to control. Low concentration of BRs more effectively stimulated shoot and leaf growth parameters as compared to root where as high concentration of BRs positively influenced both above ground and underground growth characters. Thus, both doses of BRs improved source-sink transportation and increased root yield as compared to control.

The CCC effectively increased all the growth parameters at the harvesting stage of Coleus as compared to 2.5 month old stage of growth. CCC improved all the
growth attributes of both above ground and underground parts except for shoot length as compared to control thus emphasizing dwarfism inducing ability of CCC. High dose of CCC caused more dwarfism and increased stem and root base circumference.

Ethephon, at high concentration negatively influenced all growth parameters but increased shoot base circumference more significantly than all the foliar treatments. Low dosage of ethephon foliar spray positively affected all growth parameters against control but decreased plant height, total leaf area and root base circumference.

The influence of various concentrations of PGRs on dry matter partitioning and source – sink translocation measured in terms of ratio of root dry weight to total dry weight in *C. forskohlii* proved efficiency of PGRs in increasing the yield by modifying source-sink relationship or pattern of dry matter accumulation. Both concentrations of triacontanol, low concentration of ethephon and CCC showed higher ratio of root to total dry weight among all the treatments. Thus, it can be summarised that the accumulation of dry matter in root was higher than other plant parts due to these PGRs. Though BRs exhibited comparatively low root to total dry weight ratio, it increases the overall dry matter accumulation whereas ethephon high dose showed decreased dry matter accumulation and partitioning as compared to all the other treatments.

Thus, both pre-treatment and foliar treatment with PGRs in *Coleus forskohlii* might improve overall growth and yield of the plant. However, between these two methods of PGR application, both methods were found effective and more promising for triacontanol, BRs and low doses of ethephon while in case of CCC more positive results noticed by foliar treatment only. It can be concluded that triacontanol and BRs influences the Coleus plant growth and yield irrespective of concentration and method of application however only low doses of CCC and ethephon are effective in improving growth and yield by both methods of application.

**B. Photosynthetic pigments**

1. **Chlorophylls**

The chlorophyll contents like chlorophyll a, chlorophyll b and total chlorophylls were significantly increased due to both, low and high concentrations of triacontanol and ethephon as compared to control where as in case of both concentrations of brassinosteroids and CCC, all the values of chlorophyll a,
chlorophyll b and total chlorophyll were noticed to be at par with the control or slightly increased due to low doses only against control. However, there was no significant variation found regarding the ratio of Chl a/ Chl b because the level of Chl a and Chl b was not found changed due to any PGR application. Thus, an increase in chlorophyll content due to foliar application of growth regulators would undoubtedly help the plant to improve the photosynthetic efficiency of the plant leading to maximum productivity. The applications of growth regulators may prove beneficial for improvement of growth and productivity of medicinally important *C. forskohlii* plant.

2. Carotenoids

The carotenoid content in leaves of Coleus was increased because of both concentrations of triacontanol (Vipul), ethephon and BRs except for high dosage of BRs it was at par with control treatment whereas slightly decreased due to both doses of CCC as compared to control and all other PGR treatments. Thus, increased level of carotenoids due to triacontanol, brassinosteroids, ethephon and to some extent by CCC might be beneficial to increase chlorophyll stability, photosynthetic efficiency, enhanced carbon metabolism leading to improved growth and better protection of plant cells from photooxidation and maintaining chlorophyll stability, better growth and productivity.

C. Carbohydrate metabolism

1. Carbohydrates

The overall enhancement in reducing sugars and starch content in both stem and root part of Coleus was noticed due to all PGRs with exception of BRs high dose, while, in leaf tissue the reducing sugars was increased by triacontanol and BRs only but starch content was increased due to all PGRs while soluble sugar level was decreased due to all PGRs. Thus, it can be concluded that among all PGRs both doses of triacontanol, Brassinosteroids and lower doses of CCC and ethephon were found to be beneficial for the coleus plant as far as carbon metabolism and accumulation of carbohydrate fraction in root, stem and leaf along with quality of coleus root is considered. So, the application of growth regulators will be beneficial for induction of synthesis of primary metabolic products followed by synthesis of secondary metabolites in *C. forskohlii*. 
2. Enzyme α -amylase activity

It was noticed that in root tissue α -amylase enzyme activity was increased due to both concentrations of triacontanol and CCC, whereas, it was decreased due to both doses of BRs and ethephon. It can be concluded that activity of alpha amylase was influenced by PGRs differentially. As amylases play a significant role in carbohydrate metabolism and also in regulation of source - sink translocation, change in its activity under the influence of PGRs will certainly influence growth and quality of roots in coleus plant.

3. Enzyme Invertase activity

The activity of enzyme invertase in root tissue of *C. forskohlii* was decreased due to all doses of all PGRs as compared to control. Among all PGRs lowest activity of invertase was due to both doses of ethephon foliar spray. The invertase activity is also influenced by substrate and product concentration in cell sap (Nikam, 2007) which might be the factor behind reduced invertase activity in root of coleus by PGRs. It can be concluded that activity of enzyme invertase in root tissue was reduced due to all PGRs as compared to control may result in increased accumulation of sucrose or sugars in root tissue which will be beneficial to quality and yield of coleus root.

D. Organic acids (TAN)

The amount of organic acids in Coleus leaf tissue (as indicated by TAN value) was slightly increased due to triacontanol, high concentration of BRs and due to low concentration of CCC and ethephon as compared to control. Organic acids are perhaps the most common metabolites present in all aerobic organisms. However, there was no significant increase or decrease was observed in organic acids by other PGRs doses as compared to control. Thus, it can be said that organic acid level was not much influenced by these PGRs significantly. The level of organic acid found in leaf tissue due to PGRs application was at par with the control so this does not indicate any major shift in the organic acid metabolism of coleus under the influence of PGRs.
E. Antioxidant status

1. Enzymatic antioxidants
   a. Enzyme Catalase activity

   The enzyme catalase is one of the most important enzyme of plant’s complex antioxidative defense system. The activity of enzyme catalase was stimulated due to both concentrations of all the PGRs in leaf tissue where as in root tissue it was positively influenced due to triacontanol and ethephon and decreased due to BRs and CCC. The overall catalase enzyme activity in root tissue was higher than leaf tissue except CCC. The increased leaf catalase due to PGRs might be an indicator of increased rate of photosynthesis, growth and strong antioxidant system of plant induced by PGR. The increased catalase activity due to PGRs will boost its antioxidant system and protect plant from ROS.

   b. Enzyme Peroxidase activity

   The activity of enzyme peroxidase was found to be decreased in leaf and slightly increased or at par with control in root tissue due to both doses of triacontanol. Whereas in case of BRs only high concentration stimulated peroxidase activity in leaf while in root both doses of BRs decreased the activity of peroxidase. In CCC treated plants, only high dose of CCC stimulated leaf and root peroxidase while opposite trend was noticed due to low concentration of CCC. Ethephon showed significant enhancement in leaf peroxidase activity while in root tissue only high dose of ethephon caused stimulation of peroxidase activity. Thus, it can be concluded that activity of peroxidase was differentially influenced based on concentration and part of plant. However overall enhancement in peroxidase activity due to triacontanol, CCC and ethephon in leaf and more prominently in root exhibit positive influence of PGRs on antioxidant defence system of Coleus.

2. Non enzymatic antioxidants
   a. Ascorbic Acid content

   Ascorbic acid or Vitamin C is multifunctional molecule essentially required by plants as well as by human beings. Vitamin C (L-ascorbic acid) is an antioxidant that performs a chiefly protective role in both plants and animals. In leaf tissue the ascorbic acid content was reduced due to both concentrations of all the PGRs while lower concentration of CCC, significantly increases ascorbic acid in leaf tissue as compared to control. Whereas, in case of root tissue ascorbic acid level increased by
all PGRs applications except for, BRs high and CCC low dosage it was at par with the control treatment. Thus, increased accumulation of ascorbic acid is beneficial for healthy root growth and also improve the antioxidant potential of this medicinally important plants.

F. Secondary metabolism

Influence of foliar spray of PGRs on secondary metabolites and enzymes of secondary metabolism

1. Total polyphenol content

Phenolics are considered as powerful antioxidants and have proved to be more potent antioxidants The various PGRs affected the contents of polyphenols differently at different concentration in leaf and root tissue. It may be an indicator of increased or altered rate of secondary metabolism in plants which might be induced due to respective PGR application. Total polyphenol content was increased due to both concentrations of ethephon, low concentration of CCC and high concentration of BRs in both leaf and root. High dose of triacontanol reduced total polyphenol content in both tissue while low dose showed total polyphenols at par with the control.

The increased level of phenolic compounds in a leaf and root tissue due to PGRs is an indicator of plants capacity of free radical scavenging. It can be also a measure of its enhanced therapeutic efficiency as a multifunctional medicinal plant used for various ailments.

2. Total flavonoids content

The content of flavonoids was found to be decreased due to both concentrations of all PGRs in root tissue where as in leaf tissue it was increased only by low concentrations of BRs and ethephon while triacontanol and CCC treatments exerted negative effect on flavonoids content in leaf as compared to control. The flavonoids content was decreased in root and less affected in leaf tissue due to PGRs as compared to control which can be most presumably due to altered path of secondary metabolism. Increased level of flavonoids in leaf tissue than root is beneficial for increasing medicinal efficiency of its leaves as Coleus leaves are also medicinally important and contains essential oil glands.

3. Total alkaloid content

Alkaloids are the nitrogen containing secondary metabolites which are the pharmacologically active ‘basic principles’. In coleus leaf tissue total alkaloid content
was slightly decreased due to all PGRs. There was less impact of all the PGRs on leaf alkaloid content. Whereas in root tissue it was increased only due to high dosage of ethephon and low dose of CCC while there were no variations found due to other treatments as compared to control. This proves usefulness of ethephon and CCC in alkaloids formation and their role in alkaloids synthesis and overall secondary metabolites.

4. Forskolin

The forskolin content was not noticed due to both doses of triacontanol and ethephon in leaf tissue where as it was found in very low concentration in leaves due to both doses of BRs and CCC treatment. In stem part, the forskolin was detected due to all PGRs application however forskolin level was detected high due to both doses of CCC and high dose of ethephon as compared to BRs and ethephon. Lowest forskolin contents was reported due to high dose of ethephon. In root tissue increased level of forskolin was found as compared to leaf and stem parts. The forskolin content was increased slightly due to all PGRs except for high dose of ethephon. Thus, PGRs play role in accumulation and biosynthesis of forskolin in coleus plants.

5. Enzyme Polyphenol oxidase activity

The activity of enzyme polyphenol oxidase was increased in leaf and root tissues due to both concentrations of triacontanol, BRs and ethephon except for high dose of ethephon. Whereas CCC treated plants exhibited low activity of polyphenol oxidase in root tissue and slightly increased or at par with control activity in leaf tissue. The overall polyphenol oxidase was higher in roots of Coleus as compared to leaf. PGRs induced enhanced activity of PPO is an indicator of plants increased ability to survive through adverse condition via oxidation or synthesis of polyphenols which confirms growth promoting ability of PGRs to boost resistance in plant. It will also helpful to plant to increase rate of secondary metabolism and thus improve bioactive potential of coleus root.

6. Enzyme Phenylalanine ammonia Lyase activity

The most plentiful classes of secondary metabolites in plants are resulting from phenylalanine through the action of enzyme phenylalanine ammonia lyase (PAL) which is the first critical rate limiting enzyme in secondary metabolism. It was observed that the activity of enzyme phenylalanine ammonia lyase was enhanced in both leaf and root tissue due to both doses of triacontanol and BRs and low dosage of
SUMMARY AND CONCLUSIONS

CCC where as in case of ethephon PAL activity was increased only in leaf tissue but not in root as compared to control. The increased activity of PAL indicates enhanced level of secondary metabolism. Specifically, being tuberous root as medicinally most important plant part in coleus high activity of PAL in root might be beneficial to improve bioactive potential of roots.

G. Nitrogen Metabolism

Influence of foliar spray of PGRs on nitrogen metabolism

1. Nitrogen content

Nitrogen is the important structural constituent of proteins and nucleic acid as well as many metabolic compounds. It also acts as an important component of many vitamins and some of growth regulators as indicated by several researchers. The increased level of the total nitrogen content in all plant parts of \textit{C. forskohlii} in response to high concentration of triacontanol and low dose of ethephon appear to be beneficial for the improvement of plant metabolism.

2. Nitrate content

In root tissue of \textit{C. forskohlii} the amount of nitrate content was reduced due to both concentrations of triacontanol, BRs, CCC and ethephon whereas in case of leaf tissue it was increased due to both concentrations of all PGRs except in high concentration of ethephon leaf nitrate content was decreased as compared to control. Highest nitrate content in leaf was found due to CCC low treatment and lowest in root was due to BRs low dosage. Decreased nitrate content in roots and increased nitrate content in leaves of \textit{C. forskohlii} due to triacontanol, BRs, CCC and ethephon is an indicative of its good quality and suitability for consumption.

3. Enzyme Nitrate reductase activity

Enzyme nitrate reductase activity was found to be enhanced in both leaf and root tissue of \textit{C. forskohlii} due to both concentrations of triacontanol, CCC, BRs except that in leaf tissue treated with low concentration of BRs. The ethephon treatment reduces NR activity significantly in both leaf and root tissue. Among all the treatments, highest NR activity was detected in leaves due to BRs, in root tissue due to triacontanol low dosage. The activity of enzyme nitrate reductase was found more dominantly in leaf tissue than root tissue in all the treatments along with control. Thus increased activity of enzyme nitrate reductase due to all PGRs foliar application will be beneficial for increased rate of photosynthesis, increased protein and amino acid
SUMMARY AND CONCLUSIONS

synthesis in leaf and overall nitrogen metabolism. This will be beneficial for root tissue also as increased activity of NR will consume more nitrate from root tissue and stimulate protein and amino acids which will be used in secondary metabolism by reducing harmful level of nitrate from root tissue. It can be concluded that PGRs helps in improvement of N and C metabolism by stimulated action of enzyme NR.

4. Soluble protein content

Proteins are made up of amino acids and these are of crucial significance among all the important biomolecules as these molecules carry out all the cell processes and important for every biological system. Soluble protein content was found to be enhanced in root tissue of *C. forskohlii* due to both concentrations of PGRs than control whereas in leaf tissue soluble protein content was decreased due to PGRs indicating root as a site of elevated metabolism than leaf in coleus. The cell responds to internal and external changes by regulating the level and activity of proteins. Thus, increased protein content in root tissue as compared to leaf indicates positive effect of PGRs like triacontanol, BRs, CCC and ethephon will surely boost all metabolic activities leading to maximum productivity.

5. Free amino acid content

Amino acid is the most preferable form of organic nitrogen for transportation in many plants and plays a central role in many metabolic processes. The free amino acid content was enhanced in both leaf and root tissue of in *C. forskohlii* due to both doses of triacontanol, BRs, CCC whereas in case of ethephon treated plants it was increased in leaf tissue and decreased in root tissue. Thus increased level of free amino acids indicate increased level of nitrogen metabolism and other related biochemical activities.

H. Phosphorus Metabolism

1. Phosphorus content

The phosphorus content of all plant parts namely leaf, stem and root of *C. forskohlii* was increased by both concentrations of triacontanol, BRs and ethephon whereas CCC caused decrease in P content in all plant parts. After nitrogen, phosphorus is the second most important mineral element for plant life. Phosphorus is involved in regulation of various metabolic pathways, as phosphorylation and dephosphorylation of enzyme proteins play a key role in regulation of various life processes in plant cell. So increased level of P content in all plant parts found to be
effective in overall enhancement of plant growth and productivity. Increased level of P content is also an indicator of increased membrane permeability and other positive chemical and compositional changes induced due to PGRs like triacontanol and BRs and to some extent by CCC and ethephon. Thus, all the PGRs was found beneficial in increment of P content resulted in qualitative and quantitative growth of coleus.

2. Enzyme ATPase activity

The activity of enzyme ATPase was remarkably increased in both leaf and root tissue of *Coleus forskohlii* Willd. in response to both concentrations of all the plant growth regulators Triacontanol, BRs, CCC and ethephon as compared to control. Enzyme ATPase is called as ‘master enzyme’ of plant cells and also as ‘eco enzyme’ because of its varied adjustability under varied environmental conditions (Rockel *et al*., 1998, Xia *et al*., 2000 and Yu *et al*., 2001). This enzyme is present in almost all plant cells. So increased activity of this important enzyme in response to PGRs is surely advantageous over control leading to increased rate of metabolic processes and finally growth and productivity. Increased activity of enzyme ATPase also indicates increased demand of energy which is fulfilled by breaking down of ATP.

3. Enzyme Acid phosphatase activity

The alterations in the enzyme acid phosphatase from leaf and root tissue of *C. forskohlii* was influenced by various concentrations of PGRs. As triacontanol was found effective only at low concentration and only in root tissue of Coleus in increasing ACPase whereas both concentration of BRs was found ineffective in increasing the activity of enzyme ACPase in both leaf and root tissue. Low concentration of CCC and ethephon caused increase in activity of enzyme acid phosphatase in both leaf and root tissue. Also the activity of enzyme acid phosphatase was found more in root tissue than leaf tissue of *C. forskohlii* in all treatments. According to Tabaldi *et al*., (2007) and Mishra and Dubey, (2008) this enzyme play important role in supply and metabolism of inorganic phosphates for the maintenance of cellular metabolism. So, this enzyme activity determines plant’s efficiency in relation to P acquisition and utilization. So, it can be concluded that triacontanol, CCC and ethephon will prove beneficial in plant and its more activity in root indicates increased plant efficiency in P acquisition and utilization.
4. Enzyme Alkaline phosphatase activity
   Alkaline phosphatases in plants also play an important role in the supply and metabolism of inorganic phosphate to maintain cellular metabolism. The activity of enzyme alkaline phosphatase in *C. forskohlii* was found to be increased in leaf and root tissue due to high dose of triacontanol, low dose of BRs and ethephon and both doses of CCC. So these PGRs at respective concentrations will prove beneficial in enhancing the P metabolism.

5. Enzyme Inorganic pyrophosphatase activity
   The activity of enzyme inorganic pyrophosphatase was remarkably decreased in both leaf and root tissue subjected to both concentrations of PGRs as compared to control. Leaf tissue showed maximum activity of IPPase enzyme than root tissue in all treatments including control. Thus, it can be concluded that all the PGRs negatively affected the activity of enzyme IPPase indicating altered mode of P metabolism. This might be due to change in internal and external pH induced by PGRs or by changing membrane permeability and alteration in biochemical and compositional activities triggered by PGRs.

H. Mineral nutrition

Influence of foliar spray of PGRs on inorganic constituents
   The potassium content was found to be increased in all plant parts due to both concentrations of triacontanol and treatment as compared to control however low dose of triacontanol was found more effective in 'K' content accumulation. High dose of BRs showed no significant variations in potassium content whereas low concentration of BRs showed higher potassium content in all plant parts against control. Higher potassium accumulation in all plant parts was noticed due to high dose CCC whereas low dose showed potassium content at par with control. Higher potassium content was found in all plant parts due to both concentrations ethephon treatment. Overall increased level of potassium in all plant parts in response to all PGRs will be beneficial to plant in efficient nutrient uptake, increased photosynthesis and other several metabolic activities leading to increased growth of the plant and all the other yield attributes.

   The foliar application of triacontanol and ethephon, the calcium Ca\(^{2+}\) content increased in leaf, root and stem due to both concentrations as compared to control. High concentration of BRs caused increase in Ca\(^{2+}\) content in all plant parts while at
SUMMARY AND CONCLUSIONS

low concentration of BRs showed values at par with the control. Calcium content was increased in leaf and stem but slightly decreased in root by the both concentrations of CCC. The overall accumulation of calcium is found in the order as leaf>stem>root part in all treatments including control. Calcium is important for membrane permeability and integrity. Enhanced calcium content will certainly play a key role in activating various enzymes of several metabolic process and will boost the overall growth and health of the Coleus plant.

Magnesium content was increased in leaf due to high concentration while decreased due to low dosage of triacontanol whereas in both root and stem part, \( \text{Mg}^{2+} \) was at par with the control due to both doses of triacontanol. Both concentrations of BRs, decreased the content of \( \text{Mg}^{2+} \) in all plant parts as compared to control. Similar reduction in \( \text{Mg}^{2+} \) was also visible in all plant parts due to both concentrations of CCC. In case of ethephon treated plants, \( \text{Mg}^{2+} \) was decreased in all plant parts by low dosage while increased in root and stem part due to high concentration of ethephon. The increased Mg content in leaf due to triacontanol and in root and stem due to all other PGRs as compared to all treatment will surely support plant in photosynthesis and other metabolic events.

Iron is very crucial micronutrients involved in various metabolic processes in cell. Significant increase in root Fe content was noticed due to low doses of triacontanol, CCC and high dosage of BRs while in case of stem part no significant decrease or increase in Fe content was seen. In case of leaf, Fe content was either at par with control or decreased due to all PGRs except for high dose of ethephon it was distinctly enhanced as compared to all treatments. The accumulation of Fe which might be attributed to increased nitrogen metabolism and antioxidant system as Fe is an important co factor for many antioxidant enzymes.

Mn content was increased in all plant parts due to low dose of triacontanol and high doses of BRs and ethephon as compared to all other PGRs concentrations.

In leaf dry tissue Cu content was at par with control due to all PGRs except for CCC low dose Cu content was lowest in leaf while for ethephon high dose it was highest. In root dry tissue, Cu content was at par with control or decreased due to all PGRs except for low dose of triacontanol and high dose of BRs. High dose of ethephon caused highest Cu content in all plant parts. Overall accumulation of Cu in
root and stem than leaf in coleus indicates healthy root growth with improved antioxidant mechanism.

In leaf, root and stem dry tissue, Zn content was found decreased due to all PGRs except for BRs low and ethephon high dosage it was at par with control in leaf and increased in stem due to high dose of ethephon as compared to control. Maximum Zn content in all plant parts was found due to ethephon high dosage among all PGR treatments. Thus, it can be concluded that in present study application of PGRs induced increased content of K, Ca, Mg, Cu, Fe and Mn which might be advantageous for plant growth and yield.

Coleus forskohlii (Willd.) syn Plectranthus barbatus (Andr.) is a precious, multitherapeutic, economically and medicinally important plant. The application of PGRs advanced the various attributes of the plant studied. Thus, it is evident from the present investigation that the studied physiological aspects of Coleus forskohlii are considerably altered by foliar applications of triacontanol, brassinosteroids, CCC and ethephon. Coleus forskohlii exhibited positive response to both pre-treatment and foliar application of PGRs. Triacontanol and Brassinosteroids proved best in improving overall growth and development of Coleus plant along with enhanced root yield irrespective of method of application. Both growth promoters influenced source-sink relationship and dry matter partitioning in C. forskohlii. CCC at high and ethephon at low concentration might be beneficial when used as foliar spray while high dose of ethephon was found harmful for overall growth and metabolism as a pre-treatment as well as foliar spray. Pre-treatment/dipping of stem cuttings of coleus with PGRs during nursery stock development before transplanting will help to growers and nursery developers in production of nursery plantlets which will be useful for improvement of plantation value of this medicinal plant.

All PGRs except high dose of ethephon positively influenced all the biochemical changes i.e. various enzymatic alterations, nitrogen fractions, phosphorus fractions, primary and secondary metabolites, antioxidant status and inorganic constituents which indicates that the overall metabolism and growth of C. forskohlii was influenced by PGRs. Hence, due to application of plant growth regulators the overall yield quality of medicinally and economically important roots of Plectranthus is improved. This will be helpful to farmers to improve the overall productivity of roots. The forskolin content of Coleus is considerably increased in response to all
SUMMARY AND CONCLUSIONS

centrations of BRs and triacontanol. Thus, these growth regulators improved the bioactive potential of Coleus roots which will be found beneficial for farmers and pharmaceutical industries to access biomass on large scale for extraction and synthesis of various bioactive molecules for the development of drugs against many diseases such as asthma, glaucoma, heart and lung diseases, intestinal disorders, insomnia, kidney disorders, skin diseases, obesity, thyroidal malfunctioning etc.