SUMMARY AND CONCLUSIONS
SUMMARY AND CONCLUSIONS

Metabolism provides the power and building blocks for plants while it is the hormones that regulate the speed of the individual parts and integrate these parts to produce the form that we recognize as plants. There are commonly five recognized group of plant hormones—auxins, gibberellins, cytokinins, abscisic acid and ethylene. Of the five plant hormones, auxins and cytokinins are shoot and root hormones respectively, and gibberellins, ethylene and abscisic acid are involved in both long term, seasonal and environmental responses of the plants. Auxins were the first plant hormone to be discovered. The principle auxin in plants is Indole-3-acetic Acid (IAA). Auxin influences cell enlargement, root intention bud formation etc. GA was first discovered by Japanese researches. GA plays an important role in seed germination, enzymic activity during seed germination, internode elongation, flowering etc. cytokinin also known as KIN was first isolated from in matured kernels from Zea mays. KIN influenced cell division, shoot formation, delay in senescence etc. IAA, GA and KIN promoted the growth while ETH and ABA inhibited growth. The growth hormones are also known as plants growth regulators. Plant growth regulators (PGRs) are chemical tools and exogenously used to promote the growth and productivity of plants. Generally PGRs are applied as foliar spray or as presoaking of the seeds.

AA universally present in plants plays an important role in various physiological and biochemical processes of plants. The foliar spray of AA and pretreatment with AA is also known for increasing growth and yield of agricultural crops. Chicory is a herb plants the root is tap root. Growth characteristics of chicory are very similar to carrot. The dry root of chicory as used is a coffee substitute or supplement. The root is diuretic and tonic also. The leaves are applied as poultice for
inflammation. There was no caffeine in chicory and it gives roasted flavor as compared to coffee. The boiled leaf is used in mouth cancer treatment while the boiled root is used to cure breast and face cancer. Looking to the importance of chicory it was selected for the study. IAA, GA and KIN were selected as PGRs. The effect of foliar spray of PGRs (IAA, GA, KIN and their mixtures), AA, AA+PGRs as well as presoaking treatment with PGRs and AA+PGRs on chicory performance is so far not reported. The response of chicory to PGRs was studied as follows:

Expt.-I: EFFECT OF DIRECT APPLICATION OF PGRs ON PERFORMANCE OF CHICORY

IA. --: STUDY ON GROWTH AND METABOLISM OF CHICORY SEEDLINGS GROWN WITH PGRs

The seeds of chicory were germinated in sterilized petriplates lined with sterilized Whatman filter paper no. 1. The seeds were germinated in DW (control), IAA, GA, KIN, IAA+GA, IAA+KIN, GA+KIN and IAA+GA+KIN. The PGRs concentration was $10^{-5}$ M. Experiment was conducted at $28\pm2^\circ$C under laboratory conditions up to 120h. The response of seedlings to PGRs was studied as follows:

(i) Study on seedling growth:
10 seedlings from each treatment were studied for growth after 72h, 96h and 120h of germination. Root length, shoot length, fresh weight and dry weight were the growth parameters.

(ii) Study on metabolism:
72h, 96h, and 120h old DW and PGRs grown seedlings (in replicate) were analyzed for the following enzymatic activities and metabolites.

Carbohydrate metabolism

1) $\alpha$-amylase and $\beta$-amylase Activities:
2) Invertase Activity:
3) **Reducing sugar and Non-reducing Sugar:**

**Protein metabolism**

4) **Protease Activity:**

5) **Protein:**

6) **Total Amino acid:**

**Oxidizing enzymes and Phenolic compound**

7) **Peroxidase Activity:**

8) **Total Phenol:**

**IB. STUDY ON GROWTH, PHOTOSYNTHETIC PIGMENTS AND LEAF METABOLISM OF CHICORY PLANTS GROWN WITH FOLIAR SPRAY OF PGRs**

The plants of chicory were raised in plots (1 M X 1 M) under field conditions. On completion of 40 and 80 days of sowing, the plants were sprayed with DW, IAA, GA, KIN, IAA+GA, IAA+KIN, GA+KIN and IAA+GA+KIN (10⁻⁵ M each). DW spray was control of spray treatment. The plants without any spray were control. 5 plots were kept for each treatment, each plot had 10 plants. Hand spray was used and spray was given till both the sides of leaf became wet, three such sprays were given within a week. Response of Chicory plants to PGRs was studied as follows:

**(i) Study on growth:**

10 plants from each treatment on completion of 60, 90, 120 and 150 days of growth were studied for the growth. The root length, shoot length, leaf number, fresh weight and dry weight of root and shoot were recorded.

**(ii) Study on photosynthetic pigments:**

The leaf (in replicate) of 60, 90,120 and 150 days old control, DW and PGRs sprayed plants were analyzed for photosynthetic pigments i.e. chlorophyll-'a', chlorophyll-'b', total chlorophyll and carotenoids.
(iii) Study on metabolism:
The enzymes and metabolites mentioned in Expt.-IA (ii), were estimated from the leaf (in replicate) of 60, 90, 120, and 150 days old control, DW and PGRs sprayed plants.

IC.-I: EFFECT OF PGRs FOLIAR SPRAY ON GROWTH OF LATE SOWN CHICORY PLANTS

The seeds of Chicory were sown on 16th Nov. and 16th Dec. (2007) in plots (1 M x 1 M). On completion of 40 days of sowing, late sown plants were sprayed with IAA, GA, KIN, IAA+GA, IAA+KIN, GA+KIN and IAA+GA+KIN (10^{-5} M). DW was also sprayed as control of spray treatment. Three sprays were given within a week. The plants without any spray were the control. At regular intervals control and treated plants were selected for the growth. The effects of PGRs foliar spray on growth of late sown chicory were studied as follows.

(i) Study on growth:
10 plants of normal sown, late sown control, DW and PGRs sprayed plants were studied for root length, shoot length, fresh weight and dry weight of root and shoot. The observations were recorded on 60, 90, 120 and 150 days of growth. The growth of late sown control, DW and PGRs sprayed plants were compared with growth of normal sown plants.

Expt.-II: EFFECT OF PRESOASKING SEED TREATMENT WITH PGRs ON PERFORMANCE OF CHICORY

IIA.-I: EFFECT OF PRESOASKING SEED TREATMENT WITH PGRs ON GROWTH AND METABOLISM OF CHICORY SEEDLINGS

The uniform graded seeds of chicory were soaked in IAA, GA, KIN, IAA + GA, IAA + KIN and IAA + GA+ KIN (10^{-5} M). for four hours and then dried under laboratory conditions at room temperature. Seeds were also
soaked in DW for four hours then dried. The unsoaked seeds were control. The unsoaked, DW and PGRs soaked i.e. pretreated seeds were kept on sterilized petriplates lined with sterilized Whatman filter paper no.1. Seeds were germinated in DW and experiment was conducted at 28±2°C under laboratory conditions up to 120h. The response of chicory seedlings to PGRs presoaking treatments were studied as follows:

(i) **Study on growth:**
10 seedlings grown from control, DW and PGRs pretreated seeds were studied for root length, shoot length, fresh weight and dry weight. The data were recorded on completion of 72h, 96h and 120h of germination.

(ii) **Study on metabolism:**
72h, 96h and 120h old seedlings grown from untreated (control), DW and PGRs pretreated seedlings in replicate were analyzed for enzymes and metabolites. The biochemical parameters and methods were the same as mentioned in Expt.-IA (ii)

IIB.-: **EFFECT OF PRESOAKING SEED TREATMENT WITH PGRs ON GROWTH, PHOTOSYNTHETIC PIGMENTS AND LEAF METABOLISM OF CHICORY PLANTS**

The untreated i.e. control, DW and PGRs pretreated seeds (Expt.-IIA) were sown in the plots of 1 M x 1 M size. Total nine treatments and five plots (10 plants/plot) were kept for each treatment. Necessary irrigation was given. Plants were grown using normal agriculture practices. The response of chicory plants to PGRs presoaking treatments was studied as follows.

(i) **Study on growth:**
10 plants from each treatment were regularly studied for different parameters of growth. The parameters and methods were the same as mentioned in Expt. IB (i). 30, 60, 90 and 120 days old plants were used
for study purpose.

(ii) Study on photosynthetic pigments:
The photosynthetic pigments from leaf (in replicate) of 30, 60, 90, and 120 days old control, DW and PGRs pretreated plants were estimated as per the method mentioned in Expt. IB (ii).

(iii) Study on metabolism:
The enzymes and metabolites listed in Expt. IA (ii) were estimated in replicate from the leaf of control, DW and PGRs pretreated plants. The biochemical estimations were carried out from 30, 60, 90 and 120 days old plants.

Expt. – III: INTERACTIVE EFFECT OF ASCORBIC ACID AND PGRs ON GROWTH PERFORMANCE OF CHICORY

IIIA. - INTERACTIVE EFFECT OF ASCORBIC ACID AND PGRs ON GROWTH PERFORMANCE OF CHICORY SEEDLINGS
The uniform graded seeds of chicory were germinated in sterilized petriplates lined with sterilized Whatman filter paper no.1. The media for germination were DW, AA, PGRs (IAA, GA, KIN and mixtures of PGRs) and AA+PGRs. 10^{-5} M concentration of AA and PGRs was used. The experiment was conducted under laboratory conditions up to 120h. Interactive effect of AA with PGRs on performance of chicory seedlings was studied as follows:

(i) Study on growth:
72h, 96h and 120h old control, AA, PGRs and AA+PGRs grown seedlings were selected for growth, 10 seedlings from each treatment were used for growth study. The parameters and methods were the same as mentioned in Expt.-IA (i).

IIIB. - INTERACTIVE EFFECT OF ASCORBIC ACID AND PGRs ON GROWTH PERFORMANCE OF CHICORY PLANTS
The seeds of chicory were sown in the plots (1 M x 1 M). The necessary
irrigation was given and on completion of 45 days of growth, plants were sprayed with DW, AA, PGRs and mixtures of AA with PGRs. Three such sprays were given in the week and five plots (10 plants per plot) were kept for each treatment. The growth performance of chicory plants sprayed with DW, AA, PGRs and mixtures of AA with PGRs was studied as follows:

(i) Study on growth:
10 plants from each treatment at regular intervals were used for growth study. The parameters were the same as mentioned in Expt. -IB (i).

Expt. -IV: INTERACTIVE EFFECT OF SEED TREATMENT WITH ASCORBIC ACID AND PGRs ON GROWTH PERFORMANCE OF CHICORY

IVA.-: INTERACTIVE EFFECT OF SEED TREATMENT WITH ASCORBIC ACID AND PGRs ON GROWTH PERFORMANCE OF CHICORY SEEDLINGS
The seeds of chicory were soaked in DW, AA, PGRs and AA+PGRs ($10^{-5}$ M each) for four hours, then dried at room temperature under laboratory conditions. The control i. e. untreated, DW, AA, PGRs and AA+PGRs pretreated seeds were germinated in petriplates lined with Whatman filter paper no.1. DW was used for germination. The experiment was conducted up to 120h. The response of chicory seedlings to interactive effects of seed treatment with AA and PGRs was studied as follows:

(i) Study on growth:
10 seedlings from each treatment at regulator intervals were studied for various growth parameters (Expt. IA (i)).

IVB.-: INTERACTIVE EFFECT OF SEED TREATMENT WITH ASCORBIC AND PGRs ON GROWTH PERFORMANCE OF CHICORY PLANTS
The untreated, DW, AA, PGRs and AA+PGRs pretreated seeds (EXPT.-
IVA) were sown in plots (5 for each treatment, 10 plants/plot) and standard agricultural practices were used for cultivation of chicory plants. The response of chicory plants to interactive effects of seed treatment with AA and PGRs was studied as follows:

(i) **Study on growth**

10 plants at regular intervals from each treatment were selected for the study. The growth parameters were the same as mentioned in Expt-IB (i).

**Statistical analysis**

The growth data, data on photosynthetic pigments, enzymes and metabolites (Expt. -I, II, III and IV) were analyzed statistically using ANOVA.

The following conclusions were drawn from the above experiments.

1) GA, IAA+GA enhanced the growth of chicory seedlings; response to PGRs was noted after short period of PGRs application. Direct application of PGRs to the growing seedlings enhanced α-amylase, β-amylase, invertase, protease and peroxidase activities in the young seedlings, the amount of reducing sugar, protein and total amino acids were also higher in PGRs grown seedlings. Determination of these activities in young seedlings may be selected as biochemical parameter for knowing the response of chicory seedlings to direct application of PGRs. PGRs foliar spray at 40 DAS and 80 DAS influenced the growth of chicory. The foliar spray of GA,IAA+GA,IAA+KIN and IAA+GA+KIN may be used for promoting the growth, spray at 80 DAS was more beneficial than spray at 40 DAS, maximum dry matter of root was available in the plants sprayed with IAA+GA at 40 DAS. The foliar spray of PGRs at 40 DAS, 80 DAS increased the level of chlorophyll-'a', chlorophyll-'b', total chlorophyll and carotenoids after few days of spray treatments. PGRs
foliar spray also altered the enzymic activities and metabolites in the leaf of treated plants. The response was noted after a few days of PGRs foliar spray application. The metabolic response was complex and it was different with different PGRs, age of plants and time of PGRs application. The beneficial effect of the PGRs on growth may be correlated with higher amount of reducing sugar, protein and total amino acid in the leaf. The estimation of reducing sugar from the leaf of young plants may be selected as a marker for evaluating response of chicory to foliar spray of PGRs. Late sowing increased the shoot elongation but significantly lowered leaf number, fresh and dry weight of root and shoot of chicory, foliar spray of PGRs alleviated the adverse effect of late sowing on growth, IAA+GA and IAA+GA+KIN may be used to ameliorate the adverse effect of late sowing on growth of chicory.

II) PGRs pretreatment to the seeds promoted seedling growth. IAA, GA and IAA+GA remarkably increased root length but KIN and mixtures of PGRs lowered it. Shoot length and fresh biomass were more in PGRs pretreated seedlings than that in control seedlings. The higher amount of protein in seedlings grown from pretreated seeds was correlated with better growth of pretreated seedlings. The seed pretreatment with IAA GA and IAA+GA significantly enhanced the chicory growth i.e. root length, shoot length, leaf number, fresh weight and dry weight of root and shoot of chicory were more than control. The chlorophyll-‘a’, chlorophyll-‘b’ total chlorophyll and carotenoids amount were higher in the leaf of younger plants grown from PGRs pretreated seeds. PGRs pretreatment enhanced the α-amylase, β-amylase, invertase and peroxidase activities, the amount of reducing sugar and protein in the leaf of young plants grown from PGRs pretreated seeds. The determination of peroxidase activity may be the marker of growth response of chicory to PGRs applied as priming agent.
There is no image or content provided in the image for conversion.
Metabolic response was also predicted by studying the metabolic changes in the seedlings/leaf after short period of PGRs treatments. The metabolic profile study of control and PGRs treated seedlings/leaf indicate that beneficial effect of PGRs on chicory growth was correlated with protein biosynthesis. Adverse effect of late sowing on growth of chicory was alleviated by foliar spray of PGRs. AA directly applied to the germinating seeds/leaf or as presoaking treatment altered the growth of seedlings and plants. Interactive effect of AA with PGRs was synergistic/antagonistic/non significant and effects varied with type of PGR, kind of parameter and age of plants. The economic yield i.e. root dry matter can be increased by foliar spray of IAA+GA to young chicory plants. Foliar spray of AA+IAA+KIN and pretreatment of seeds with AA+GA+KIN can be recommended for better root growth. The procedures of foliar spray, presoaking are simple, easy and cost effective.