EXPERIMENTAL RESULTS

4.1 Experiment 1

Experiment 1 was performed in the field according to a simple randomized block design. The experiment was conducted to study the effect of foliar application of six concentrations of irradiated sodium alginate (ISA), viz. 20, 40, 60, 80 and 100 mg L\(^{-1}\) respectively on growth, physiological and biochemical attributes, yield, content and active constituents of essential oil of fennel (*Foeniculum vulgare* Mill.). Spray of DDW (double distilled water) was treated as control. Growth, physiological and biochemical parameters were analyzed at vegetative (80 DAS) and flowering (120 DAS) stages. However yield and quality attributes were recorded at the time of harvest (150 DAS). The effect of irradiated sodium alginate (ISA) at a definite concentrations range of 20-100 mg L\(^{-1}\), was found significant for most of the parameters studied. The concentration, 80 mg L\(^{-1}\) proved optimum for most of the attributes studied. The details of results are briefly described below and summarized in Tables 4-10.

4.1.1 Growth parameters

The growth parameters, namely shoot and root lengths as well as plant fresh and dry weights recorded at vegetative (80 DAS) and flowering (120 DAS) stages, were found to be affected significantly by the application of ISA. The remarkable features of the results (Tables 4-5) are described below.

4.1.1.1 Shoot length per plant

The effect of foliar application of ISA was found significant on shoot length per plant at two sampling stages. Treatment ISA\(_{80}\) significantly enhanced shoot length per plant by 24.1 and 29.3 % at vegetative and flowering stages respectively, over the respective controls (Table 4).

4.1.1.2 Root length per plant

Foliar application of ISA\(_{80}\) gave significantly maximum values for root length per plant at two sampling stages. ISA\(_{80}\) gave 24.5 and 27.3 % higher values for root length per plant at vegetative and flowering stages respectively, over the respective controls (Table 4).
4.1.1.3 Plant fresh weight

The foliar application of ISA on plant fresh weight was found to be significantly augmented at the studied stages. ISA\textsubscript{80} significantly increased plant fresh weight by 24.4 and 26.9 \% at vegetative and flowering stages, respectively over their respective controls (Table 5).

4.1.1.4 Plant dry weight

Treatment ISA\textsubscript{80} proved superior to the other treatments of ISA and gave maximum values for plant dry weight. Controls gave the poorest response at both the growth stages. The percent increase in dry weight by ISA\textsubscript{80} over the respective controls was 25.0 and 27.8 \% at vegetative and flowering stages, respectively (Table 5).

4.1.2 Physiological and biochemical parameters

Physiological and biochemical parameters such as total chlorophyll content, total carotenoids content, nitrate reductase and carbonic anhydrase activities, nitrogen, phosphorus and potassium content in leaves studied at vegetative and flowering stages, were affected significantly by ISA treatments. Following are some important features of the data (Tables 6-8).

4.1.2.1 Total chlorophyll content

A progressive increase in total chlorophyll content was noted from ISA\textsubscript{20} to ISA\textsubscript{100} over the controls at the two stages of sampling. ISA\textsubscript{80} proved optimum and enhanced total chlorophyll content by 18.1 and 20.2\% over the water sprayed controls at vegetative and flowering stages, respectively (Table 6).

4.1.2.2 Total carotenoids content

Among five levels of ISA treatments, ISA\textsubscript{80} proved best and gave significantly maximum value for total carotenoids content at vegetative and flowering stages. An increase of 9.6 and 10.4 \% was observed in ISA\textsubscript{80} over the controls at vegetative and flowering stages, respectively (Table 6).

4.1.2.3 Carbonic anhydrase activity

Application of ISA on carbonic anhydrase activity was found effective over the control at the two stages of sampling. ISA\textsubscript{80} proved optimum and gave maximum
value for this parameter and significantly increased carbonic anhydrase activity by 21.7 and 24.7 % over the respective controls at vegetative and flowering stages, respectively (Table 7).

4.1.2.4 Nitrate reductase activity

Nitrate reductase activity was affected by different ISA treatments significantly at vegetative and flowering stages. ISA$_{80}$ showed maximum effect and significantly increased nitrate reductase activity by 19.1 and 21.5 % at vegetative and flowering stages, respectively over their respective controls (Table 7).

4.1.2.5 Leaf-nitrogen content

The application of ISA gave higher value for leaf-nitrogen content than control at the two growth stages of sampling. Among five levels of ISA treatments, ISA$_{80}$ proved superior and gave significantly maximum value at vegetative and flowering stages. The percent increase in leaf-nitrogen content by application of ISA$_{80}$ was 14.7 and 16.0 % over the water sprayed control at vegetative and flowering stages, respectively (Table 8).

4.1.2.6 Leaf-phosphorus content

A progressive increase in leaf-phosphorus content was noted from ISA$_{20}$ to ISA$_{100}$ at both the growth stages of sampling. ISA$_{80}$ proved best and enhanced leaf-phosphorus content by 12.6 and 13.4 % over the control at vegetative and flowering stages, respectively (Table 8).

4.1.2.7 Leaf-potassium content

Application of different concentrations of aqueous solution of ISA did not affect leaf-potassium content at both the growth stages of sampling (Table 8).

4.1.3 Yield and quality attributes

All yield and quality attributes, viz. number of umbels per plant, seed yield, essential oil content, essential oil yield, trans-anethole content, trans-anethole yield, fenchone yield except 1000-seed weight and fenchone content were found to be affected significantly by ISA treatments at the time of harvest (150 DAS). The data (Tables 9-10) are summarized below.
4.1.3.1 Number of umbels per plant

A progressive increase in number of umbels per plant was noted by the application of ISA at harvest. ISA$_{80}$ proved optimum and enhanced number of umbels per plant by 39.0 % over the control at harvest respectively (Table 9).

4.1.3.2 1000-seed weight

All the treatments of ISA were found insignificant for 1000-seed weight at harvest (Table 9).

4.1.3.3 Seed yield

All treatments of ISA showed positive response and increased the seed yield over the control at harvest. Application of ISA$_{80}$ proved optimum and significantly enhanced seed yield by 37.2 % at harvest respectively over the control (Table 9).

4.1.3.4 Essential oil content

A progressive increase in essential oil content was noted by the application of ISA at harvest. ISA$_{80}$ proved optimum and enhanced essential oil content by 21.4% over the control at harvest, respectively (Table 10).

4.1.3.5 Essential oil yield

All treatments of ISA showed positive response and increased the essential oil yield over the control at harvest. Application of ISA$_{80}$ proved optimum and significantly enhanced essential oil yield by 67.1% at harvest, respectively over the control (Table 10).

4.1.3.6 Trans-anethole content

All treatments of ISA showed positive response and increased the trans-anethole content compared to control estimated at harvest. Application of ISA$_{80}$ proved optimum and increased trans-anethole content by 5.1 % at harvest over the control (Table 10 and Figures 8-9).

4.1.3.7 Trans-anethole yield

Application of ISA was found very effective in increasing trans-anethole yield over the control. ISA$_{80}$ increased trans-anethole yield by 75.9 % compared to control at harvest, respectively over the control (Table 10).
4.1.3.8 Fenchone content

All the treatments of ISA were found insignificant for fenchone content at harvest (Table 10 and Figures 8-9).

4.1.3.9 Fenchone yield

Application of ISA on fenchone yield was found effective over the control. ISA\textsubscript{80} proved optimum and significantly increased fenchone yield by 53.7\% over the control at harvest (Table 10).

4.2 Experiment 2

The experiment 2 was performed in the field according to a simple randomized block design. The experiment was conducted to study the effect of foliar application of ISA\textsubscript{80} combined with different doses of soil-applied nitrogen, \textit{viz}. 30, 45, 60, 75 and 90 kg ha\textsuperscript{-1} (ISA\textsubscript{80}+N\textsubscript{30}, ISA\textsubscript{80}+N\textsubscript{45}, ISA\textsubscript{80}+N\textsubscript{60}, ISA\textsubscript{80}+N\textsubscript{75} and ISA\textsubscript{80}+N\textsubscript{90}) respectively on growth, physiological and biochemical attributes, yield, content and active constituents of essential oil of fennel (\textit{Foeniculum vulgare} Mill.). Spray of DDW (double distilled water) was treated as control. Growth, physiological and biochemical parameters were analyzed at vegetative (80 DAS) and flowering (120 DAS) stages. However, yield parameters were taken into consideration at harvest (150 DAS). The effect of ISA\textsubscript{80} combined with different doses of nitrogen was found significant for most of the studied parameters. The treatment ISA\textsubscript{80}+N\textsubscript{90} proved optimum for most of the attributes studied. The details of results are briefly described below and summarized in Tables 11-17.

4.2.1 Growth parameters

The foliar application of ISA\textsubscript{80} combined with different doses of soil-applied nitrogen, significantly enhanced the growth characteristics, namely shoot and root lengths as well as plant fresh and dry weights, recorded at vegetative (80 DAS) and flowering (120 DAS) stages. The remarkable features of the data (Tables 11-12) are given below.

4.2.1.1 Shoot length per plant

The effect of foliar application of ISA\textsubscript{80} combined with different doses of nitrogen was found significant on the shoot length per plant. Treatment ISA\textsubscript{80}+N\textsubscript{90} significantly ameliorated shoot length per plant by 31.6 and 35.1\% as compared with
that of their respective controls at vegetative and flowering stages, respectively (Table 11).

### 4.2.1.2 Root length per plant

The foliar application of ISA\textsubscript{80} together with different doses of nitrogen gave significantly maximum values for root length per plant at both the growth stages of sampling. Treatment ISA\textsubscript{80}+N\textsubscript{90} recorded 28.5 and 33.7 \% higher values for root length per plant at vegetative and flowering stages, respectively, over their respective controls (Table 11).

### 4.2.1.3 Plant fresh weight

Plant fresh weight was found significantly affected by combined application of ISA\textsubscript{80} and nitrogen at both the growth stages studied. The maximum plant fresh weight was recorded in ISA\textsubscript{80}+N\textsubscript{90} treatment, which was 29.5 and 31.7 \% more as compared to control at vegetative and flowering stages, respectively (Table 12).

### 4.2.1.4 Plant dry weight

The effect of foliar application of ISA\textsubscript{80} combined with different doses of nitrogen was found significant on plant dry weight. Treatment ISA\textsubscript{80}+N\textsubscript{90} gave significantly maximum values 30.7 and 34.2 \% as compared with that of their respective controls at vegetative and flowering stages, respectively. The lowest value was recorded for controls at both stages (Table 12).

### 4.2.2 Physiological and biochemical parameters

Physiological and biochemical parameters such as total chlorophyll content, total carotenoids content, nitrate reductase and carbonic anhydrase activities, nitrogen, phosphorus and potassium content in leaves studied at vegetative and flowering stages, were affected significantly by combined application of ISA and nitrogen. The results are summarized below (Tables 13-15).

#### 4.2.2.1 Total chlorophyll content

The effect of foliar application of ISA\textsubscript{80} combined with different doses of nitrogen was found significant on total chlorophyll content per plant at both the growth stages of sampling. The percent increase in chlorophyll content resulted from the application of ISA\textsubscript{80}+N\textsubscript{90} was 23.3 and 29.4 \% over their respective controls at vegetative and flowering stages, respectively (Table 13).
4.2.2.2 Total carotenoids content

Foliar application of ISA$_{80}$ together with different doses of nitrogen gave significantly maximum values for total carotenoids content in the leaves at both the growth stages of sampling. Treatment ISA$_{80}$+N$_{90}$ recorded 12.8 and 14.4 % higher values over their respective controls for total carotenoids content at both the growth stages of sampling, respectively (Table 13).

4.2.2.3 Carbonic anhydrase activity

Application of ISA$_{80}$ and different doses of nitrogen gave significantly higher values for carbonic anhydrase activity at both the sampling stages. ISA$_{80}$+N$_{90}$ recorded 24.1 and 27.4 % higher values over their respective controls for carbonic anhydrase activity at vegetative and flowering stages, respectively (Table 14).

4.2.2.4 Nitrate reductase activity

The combined application of ISA$_{80}$ and nitrogen was found significant on nitrate reductase activity. Treatment ISA$_{80}$+N$_{90}$ showed maximum effect and significantly increased nitrate reductase activity by 25.7 and 28.4 % at vegetative and flowering stages, respectively over the control (Table 14).

4.2.2.5 Leaf-nitrogen content

A progressive increase in leaf-nitrogen content was noted by the combined application of ISA$_{80}$ with soil-applied nitrogen, at both the growth stages of sampling. Treatment ISA$_{80}$+N$_{90}$ proved optimum and enhanced leaf-nitrogen content by 20.3 and 25.1 % higher values over their respective controls at vegetative and flowering stages, respectively (Table 15).

4.2.2.6 Leaf-phosphorus content

Foliar application of ISA$_{80}$ combined with different levels of soil-applied nitrogen gave significantly maximum values for leaf-phosphorus content at both growth stages of sampling. Treatment ISA$_{80}$+N$_{90}$ recorded 19.0 and 23.9 % higher values over their respective controls for leaf-phosphorus content per plant at vegetative and flowering stages (Table 15).

4.2.2.7 Leaf-potassium content

The effect of combined application of ISA and nitrogen was insignificant on this parameter at the both stages (Table 15).
4.2.3 Yield and quality attributes

The effect of ISA\textsubscript{80} together with different levels of nitrogen was found significant on the number of umbels per plant, seed yield, essential oil content, essential oil yield, trans-anethole content, trans-anethole yield, fenchone yield were found significant except 1000-seed weight and fenchone content and the data are described below (Tables 16-17).

4.2.3.1 Number of umbels per plant

Application of ISA\textsubscript{80} along with different levels of nitrogen was found effective over the control in increasing number of umbels per plant. Treatment ISA\textsubscript{80}+N\textsubscript{90} enhanced number of umbels per plant by 41.1\% over the control at the time of harvest (Table 16).

4.2.3.2 1000-seed weight

The effect of various treatments of combined application of ISA\textsubscript{80} and nitrogen was insignificant on this parameter (Table 16).

4.2.3.3 Seed yield

Foliar application of ISA\textsubscript{80} combined with different doses of nitrogen was found significant on seed yield. Treatment ISA\textsubscript{80}+N\textsubscript{90} increased seed yield by 46.9\% as compared with that of the control (Table 16).

4.2.3.4 Essential oil content

A progressive increase in essential oil content was noted by foliar application of ISA\textsubscript{80} combined with different doses of nitrogen at harvest. Treatment ISA\textsubscript{80}+N\textsubscript{90} increased essential oil content by 25.0\% as compared with that of the control at harvest (Table 17).

4.2.3.5 Essential oil yield

Foliar application of ISA\textsubscript{80} combined with different doses of nitrogen was found significant on essential oil yield. Treatment ISA\textsubscript{80}+N\textsubscript{90} increased essential oil yield by 83.7\% as compared with control at harvest (Table 17).

4.2.3.6 Trans-anethole content

A progressive increase in trans-anethole content was recorded by the foliar application of ISA\textsubscript{80} combined with different doses of nitrogen. ISA\textsubscript{80}+N\textsubscript{90} proved
optimum and enhanced trans-anethole content by 13.3 % over the control (Table 17 and Figures 10-11).

### 4.2.3.7 Trans-anethole yield

Foliar application of ISA$_{80}$ along with different levels of nitrogen was found effective over the control in increasing trans-anethole yield. Treatment ISA$_{80}$+N$_{90}$ enhanced trans-anethole yield by 109.4 % over the control (Table 17).

### 4.2.3.8 Fenchone content

The effect of ISA together with different levels of soil-applied nitrogen was insignificant on fenchone content at harvest (Table 17 and Figures 10-11).

### 4.2.3.9 Fenchone yield

Foliar application of ISA$_{80}$ combined with different doses of nitrogen was found significant on fenchone yield. Treatment ISA$_{80}$+N$_{90}$ increased fenchone yield by 80.5 % as compared with control at harvest (Table 17).

### 4.3 Experiment 3

Experiment 3 was performed in the field according to a simple randomized block design. The experiment was conducted to study the effect of foliar application of ISA$_{80}$ combined with different doses of soil-applied phosphorus, viz. 10, 20, 30, 40 and 50 kg ha$^{-1}$ (ISA$_{80}$+P$_{10}$, ISA$_{80}$+P$_{20}$, ISA$_{80}$+P$_{30}$, ISA$_{80}$+P$_{40}$ and ISA$_{80}$+P$_{50}$) respectively on growth, physiological and biochemical attributes, yield, content and active constituents of essential oil of fennel (*Foeniculum vulgare* Mill.). Spray of DDW (double distilled water) was treated as control. Growth, physiological and biochemical parameters were analyzed at vegetative (80 DAS) and flowering (120 DAS) stages. However, yield parameters were taken into consideration at the time of harvest (150 DAS). The effect of ISA$_{80}$ combined with different doses of phosphorus was found significant for most of the parameters studied. Also, this treatment proved optimum for most of the attributes studied. The details of results are briefly described below and summarized in Tables 18-24.

#### 4.3.1 Growth parameters

The growth parameters, namely shoot length, root length, plant fresh and dry weights were recorded at vegetative and flowering stages and found to be significantly affected by the foliar application of ISA$_{80}$ combined with different doses
of soil-applied phosphorus. The salient features of data (Table 18-19) are given below.

4.3.1.1 Shoot length per plant

The effect of ISA$_{80}$ application combined with different levels of soil-applied phosphorus was found significant on the shoot length per plant. Treatment ISA$_{80}$+$P_{40}$ enhanced shoot length per plant by 29.1 and 33.8 % as compared with that of their respective controls at vegetative and flowering stages, respectively (Table 18).

4.3.1.2 Root length per plant

An increase in root length per plant was noted when ISA$_{80}$ was applied with different doses of phosphorus. Treatment ISA$_{80}$+$P_{40}$ improved root length per plant by 27.4 and 31.2 % over their respective controls at vegetative and flowering stages, respectively (Table 18).

4.3.1.3 Plant fresh weight

The effect of ISA$_{80}$ application combined with different levels of soil-applied phosphorus was found significant on the plant fresh weight. Treatment of ISA$_{80}$+$P_{40}$ significantly enhanced plant fresh weight by 25.7 and 28.5 % over their respective controls at vegetative and flowering stages, respectively (Table 19).

4.3.1.4 Plant dry weight

Regarding the combined effect of foliar application of ISA$_{80}$ and soil-applied phosphorus, it was noted that ISA$_{80}$+$P_{40}$ increased plant dry weight over the control. Application of ISA$_{80}$+$P_{40}$ proved optimum at both the growth stages of sampling. ISA$_{80}$+$P_{40}$ showed an increase in plant dry weight by 30.0 and 32.0 % over their respective controls at vegetative and flowering stages, respectively (Table 19).

4.3.2 Physiological and biochemical parameters

Physiological and biochemical parameters viz. total chlorophyll content, total carotenoids content, nitrate reductase and carbonic anhydrase activities, nitrogen, phosphorus and potassium content in leaves studied at vegetative and flowering stages, were affected significantly by combined application of ISA$_{80}$ and various levels of soil-applied phosphorus. Following are some important features of the data (Tables 20-22).
4.3.2.1 Total chlorophyll content

An increase in total chlorophyll content was noted when ISA\(_{80}\) was applied with different doses of phosphorus. ISA\(_{80}+P_{40}\) increased total chlorophyll content by 20.9 and 24.4 % over their respective controls at vegetative and flowering stages, respectively (Table 20).

4.3.2.2 Total carotenoids content

Foliar application of ISA\(_{80}\) together with different doses of phosphorus on total carotenoids content was found significant and gave maximum values for total carotenoids content in the leaves at both the growth stages of sampling. Treatment ISA\(_{80}+P_{40}\) recorded 10.9 and 11.9 % higher values over their respective controls for total carotenoids content at both the growth stages of sampling (Table 20).

4.3.2.3 Carbonic anhydrase activity

The effect of foliar application ISA\(_{80}\) combined with different levels of soil-applied phosphorus was found significant on carbonic anhydrase activity. Treatment ISA\(_{80}+P_{40}\) enhanced carbonic anhydrase activity by 22.4 and 25.1 % as compared with that of control at vegetative and flowering stages, respectively (Table 21).

4.3.2.4 Nitrate reductase activity

Foliar application of ISA\(_{80}\) together with different doses of phosphorus on nitrate reductase activity was found significant and gave maximum values for total carotenoids content in the leaves at both the growth stages of sampling. Treatment ISA\(_{80}+P_{40}\) gave 21.2 and 24.6 % higher values over their respective controls for nitrate reductase activity at the both growth stages of sampling (Table 21).

4.3.2.5 Leaf-nitrogen content

A progressive increase in leaf-nitrogen content was noted by the combined application of ISA\(_{80}\) with soil-applied phosphorus, at both the growth stages of sampling. Treatment ISA\(_{80}+P_{40}\) proved optimum and enhanced leaf-nitrogen content by 17.6 and 19.1% over their respective controls at vegetative and flowering stages (Table 22).
4.3.2.6 Leaf-phosphorus content

The effect of foliar application ISA$_{80}$ combined with different levels of soil-applied phosphorus gave significantly maximum value for leaf-phosphorus content at both growth stages of sampling. Treatment ISA$_{80}$+P$_{40}$ recorded 14.1 and 16.8 % higher values for leaf-phosphorus content per plant at vegetative and flowering stages, respectively, over their respective controls (Table 22).

4.3.2.7 Leaf-potassium content

Foliar application of ISA$_{80}$ combined with different doses of phosphorus was found insignificant leaf-potassium content at both vegetative and flowering stages (Table 22).

4.3.3 Yield and quality parameters

Combined application of ISA$_{80}$ and various doses of soil-applied phosphorus was found effective in increasing yield and quality parameters, viz. number of umbels per plant, seed yield, essential oil content, essential oil yield, trans-anethole content, trans-anethole yield, fenchone yield were found significant except 1000-seed weight and fenchone content and the data are described below (Tables 23-24).

4.3.3.1 Number of umbels per plant

Number of umbels per plant was found significantly affected by combined application of ISA$_{80}$ and phosphorus at harvest. The maximum number of umbels per plant was recorded in ISA$_{80}$+P$_{40}$ treatment, which was 40.0 % higher as compared to the control (Table 23).

4.3.3.2 1000-seed weight

The effect of combined application of ISA$_{80}$ and phosphorus was insignificant on this parameter (Table 23).

4.3.3.3 Seed yield

Application of ISA$_{80}$ along with different levels of phosphorus was found effective over the control in increasing seed yield. Treatment ISA$_{80}$+P$_{40}$ enhanced seed yield by 43.2 % over the control at harvest (Table 23).
4.3.3.4 Essential oil content

Foliar application of ISA$_{80}$ combined with different doses of phosphorus was found significant on essential oil content. Treatment ISA$_{80}$+P$_{40}$ significantly enhanced essential oil content by 22.8 % as compared with that of the control (Table 24).

4.3.3.5 Essential oil yield

A progressive increase in essential oil yield was noted by foliar application of ISA$_{80}$ combined with different doses of phosphorus. Treatment ISA$_{80}$+P$_{40}$ increased essential oil yield by 76.2 % as compared with that of the control (Table 24).

4.3.3.6 Trans-anethole content

A progressive increase in trans-anethole content was noticed by foliar application of ISA$_{80}$ combined with different doses of phosphorus. ISA$_{80}$+P$_{40}$ proved optimum and enhanced trans-anethole content by 10.2 % over the control (Table 24 and Figures 12-13).

4.3.3.7 Trans-anethole yield

Application of ISA$_{80}$ along with different levels of phosphorus was found effective over the control in increasing trans-anethole yield. Treatment ISA$_{80}$+P$_{40}$ enhanced trans-anethole yield by 94.5 % over the control (Table 24).

4.3.3.8 Fenchone content

The effect of ISA$_{80}$ together with different levels of soil-applied phosphorus was found insignificant on fenchone content at harvest (Table 24 and Figures 12-13).

4.3.3.9 Fenchone yield

Foliar application of ISA$_{80}$ combined with different doses of phosphorus was found significant on fenchone yield. Treatment ISA$_{80}$+P$_{40}$ increased fenchone yield by 69.9 % as compared with that of the control at harvest (Table 24).

4.4 Experiment 4

The experiment 4 was performed in the field according to a simple randomized block design. The experiment was conducted to study the effect of foliar application of ISA$_{80}$ combined with split doses of nitrogen and phosphorus (N$_{90}$+P$_{40}$, N$_{45}$+P$_{40}$, N$_{90}$+P$_{20}$+20 and N$_{45}$+P$_{20}$+20) respectively on growth, physiological and biochemical attributes, yield, content and active constituents of essential oil of fennel.
(Foeniculum vulgare Mill.). Spray of DDW (double distilled water) was treated as control. Growth, physiological and biochemical parameters were analyzed at vegetative (80 DAS) and flowering (120 DAS) stages. However, yield and quality attributes were recorded at the time of harvest (150 DAS). The effect of ISA$_{80}$ combined with nitrogen and phosphorus given in two splits was found significant for most of the studied parameters except a few. The treatment ISA$_{80}$+ N$_{45+45}$+P$_{20+20}$ proved optimum for most of the attributes studied. The details of results are briefly described below and summarized in Tables 25-31.

### 4.4.1 Growth parameters

The growth parameters, namely shoot length, root length, plant fresh and dry weights were recorded at vegetative and flowering stages and found to be significantly affected by the combined application of ISA$_{80}$ and split doses of soil-applied nitrogen and phosphorus. The remarkable features of the results (Table 25-26) are described below.

#### 4.4.1.1 Shoot length per plant

The effect of ISA$_{80}$ application together with split doses of nitrogen and phosphorus was found significant on the shoot length per plant. Treatment ISA$_{80}$+ N$_{45+45}$+P$_{20+20}$ gave 46.0 and 51.6 % higher values for shoot length per plant as compared with that of their respective controls at vegetative and flowering stages (Table 25).

#### 4.4.1.2 Root length per plant

Foliar application of ISA$_{80}$ combined with split doses of nitrogen and phosphorus gave significantly maximum values for root length per plant at both the stages of sampling. The maximum root length was recorded in treatment ISA$_{80}$+ N$_{45+45}$+P$_{20+20}$ which was 43.5 and 48.5% higher as compared to their respective controls at vegetative and flowering stages (Table 25).

#### 4.4.1.3 Plant fresh weight

The effect of foliar application of ISA$_{80}$ combined with split doses of nitrogen and phosphorus on plant fresh weight was found to be significantly augmented at the stages studied. ISA$_{80}$+ N$_{45+45}$+P$_{20+20}$ significantly increased plant fresh weight by 32.2 and 37.0 % at vegetative and flowering stages, over their respective controls. The
values recorded for control (water sprayed) was lowest at the two growth stages (Table 26).

4.4.1.4 Plant dry weight

Plant dry weight was influenced significantly by foliar application of ISA\textsubscript{80} and soil-applied nitrogen and phosphorus considered at both growth stages. ISA\textsubscript{80}+ N\textsubscript{45+45}+P\textsubscript{20+20} showed maximum effect and significantly increased plant dry weight by 37.0 and 39.9 % over their respective controls at vegetative and flowering stages. Both the controls gave the lowest value for this parameter also (Table 26).

4.4.2 Physiological and biochemical parameters

Total chlorophyll content, total carotenoids content, nitrate reductase and carbonic anhydrase activities, nitrogen, phosphorus and potassium content in leaves were studied at vegetative and flowering stages. All physiological and biochemical parameters were affected significantly by the combined foliar application of ISA\textsubscript{80} with split doses of soil-applied nitrogen and phosphorus. Following are some important features of data (Tables 27-29).

4.4.2.1 Total chlorophyll content

A progressive increase in total chlorophyll content by foliar application of ISA\textsubscript{80} combined with soil-applied nitrogen and phosphorus was noted at both the growth stages of sampling. ISA\textsubscript{80}+ N\textsubscript{45+45}+P\textsubscript{20+20} treatment proved best and gave significantly maximum values at vegetative and flowering stages of sampling. The percent increase in chlorophyll content resulted from application of ISA\textsubscript{80}+ N\textsubscript{45+45}+P\textsubscript{20+20} was 27.4 and 34.0 % over their respective controls at vegetative and flowering stages (Table 27).

4.4.2.2 Total carotenoids content

Total carotenoids content in the leaves was influenced significantly by foliar application of ISA\textsubscript{80} combined with soil-applied nitrogen and phosphorus considered at both growth stages. Application ISA\textsubscript{80}+ N\textsubscript{45+45}+P\textsubscript{20+20} showed maximum effect and significantly increased total carotenoids content by 14.6 and 17.4 % over their respective controls at vegetative and flowering stages (Table 27).
4.4.2.3 Carbonic anhydrase activity

The foliar application of ISA$_{80}$ combined with soil-applied nitrogen and phosphorus gave significantly higher values for carbonic anhydrase activity at both the sampling stages. ISA$_{80}$+ N$_{45+45}$+P$_{20+20}$ recorded 29.2 and 34.1 % higher values over the control for carbonic anhydrase activity at vegetative and flowering stages, respectively (Table 28).

4.4.2.4 Nitrate reductase activity

Among various combined treatments of ISA$_{80}$ along with nitrogen and phosphorus, ISA$_{80}$+ N$_{45+45}$+P$_{20+20}$ proved best and gave significantly maximum values for nitrate reductase activity at both the growth stages of sampling. An increase of 22.1 and 32.7 % was observed in ISA$_{80}$+ N$_{45+45}$+P$_{20+20}$ treated plants as compared to control at vegetative and flowering stages, respectively (Table 28).

4.4.2.5 Leaf-nitrogen content

The effect of foliar application of ISA$_{80}$ combined with different levels of soil-applied nitrogen and phosphorus was found significant on leaf-nitrogen content. Treatment ISA$_{80}$+ N$_{45+45}$+P$_{20+20}$ enhanced leaf-nitrogen content by 28.6 and 35.0 % as compared with their respective controls at vegetative and flowering stages (Table 29).

4.4.2.6 Leaf-phosphorus content

The foliar application of ISA$_{80}$ combined with different levels of soil-applied nitrogen and phosphorus gave significantly maximum values for leaf-phosphorus content at both growth stages of sampling. Treatment ISA$_{80}$+ N$_{45+45}$+P$_{20+20}$ recorded 27.0 and 31.5 % higher value for leaf-phosphorus content per plant at vegetative and flowering stages respectively, over the control (Table 29).

4.4.2.7 Leaf-potassium content

Application of ISA$_{80}$ with soil-applied nitrogen and phosphorus did not affect leaf-potassium content measured at both, vegetative and flowering stages (Table 29).

4.4.3 Yield and quality attributes

The effect of foliar application of ISA$_{80}$ combined with different levels of soil-applied nitrogen and phosphorus was found to be significant on number of umbels per plant, seed yield, essential oil content, essential oil yield, trans-anethole content, trans-
anethole yield, fenchone yield were found significant except 1000-seed weight and fenchone content and the data are described below (Tables 30-31).

4.4.3.1 Number of umbels per plant

The effect of foliar application of ISA\textsubscript{80} combined with different levels of soil-applied nitrogen and phosphorus was found to be significant on number of umbels per plant. Treatment ISA\textsubscript{80}+\textsubscript{N}45+\textsubscript{P}20+20 proved best and gave significantly value for number of umbels per plant by 47.3 over the control at harvest (Table 30).

4.4.3.2 1000-seed weight

The effect of foliar application of ISA\textsubscript{80} combined with soil-applied nitrogen and phosphorus was found insignificant on 1000-seed weight (Table 30).

4.4.3.3 Seed yield

Among various combined treatments of ISA\textsubscript{80} along with nitrogen and phosphorus, ISA\textsubscript{80}+\textsubscript{N}45+\textsubscript{P}20+20 proved to be optimum and significantly increased seed yield per plant by 51.3 \% over the control (Table 30).

4.4.3.4 Essential oil content

An increase in essential oil content was observed when the plants were supplied with foliar application of ISA\textsubscript{80} combined with soil-applied nitrogen and phosphorus. Application of ISA\textsubscript{80}+\textsubscript{N}45+\textsubscript{P}20+20 increased the essential oil content by 29.1 \% over the control (Table 31).

4.4.3.5 Essential oil yield

The effect of foliar application of ISA\textsubscript{80} combined with soil-applied nitrogen and phosphorus was found significant on essential yield also. Treatment ISA\textsubscript{80}+\textsubscript{N}45+\textsubscript{P}20+20 enhanced essential oil yield by 94.4 \% as compared with that of the control (Table 31).

4.4.3.6 Trans-anethole content

An increase in trans-anethole content was observed when the plants were supplied with foliar application of ISA\textsubscript{80} combined with soil-applied nitrogen and phosphorus. Application of ISA\textsubscript{80}+\textsubscript{N}45+\textsubscript{P}20+20 increased the trans-anethole content by 20.5 \% over the control (Table 31 and Figures 14-15).
4.4.3.7 Trans-anethole yield

The effect of foliar application of ISA$_{80}$ combined with soil-applied nitrogen and phosphorus was found significant on trans-anethole yield also. Treatment ISA$_{80}$+N$_{45+45}$+P$_{20+20}$ enhanced trans-anethole yield by 134.4 % as compared with that of the control (Table 31).

4.4.3.8 Fenchone content

Foliar application of ISA$_{80}$ with soil-applied nitrogen and phosphorus did not affect fenchone content at harvest (Table 31 and Figures 14-15).

4.4.3.9 Fenchone yield

The effect of ISA$_{80}$ application combined with soil-applied nitrogen and phosphorus was found significant on fenchone yield also. Treatment ISA$_{80}$+N$_{45+45}$+P$_{20+20}$ proved to be optimum and significantly increased fenchone yield per plant by 88.8 % over the control (Table 31).