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# Effect of Plant Growth Regulators on the Morphology, Flowering, Maturity, Yield Attributes, and Yield of Lentil (*Lens culinaris* L. Medik.)

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***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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## ABSTRACT

Comprehensively, nutrient deficiencies in humans and animals are a quiet epidemic in many underdeveloped nations. Nutrient deficiencies in humans and animals are a global problem in most developing countries. Lentil is one of the most important and nutritious *Rabi* pulse in India. It's a

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leguminous crop that improves the soil fertility through biological nitrogen fixation. In this contest an experiment was conducted to study the enhancement of plant growth, chlorophyll content, flowering, yield and seed protein content by plant growth regulators in DPL-62 lentil (*Lens culinaris* L. Medik) variety during two *Rabi* seasons of 2019-20 and 2020-21. The field experiment was laid out in randomized block design (RBD). Five growth regulators *viz*. triiodobenzoic acid (TIBA), gibberellic acid ($GA_3$), cytokinin, indole acetic acid (IAA), and naphthaleneacetic acid (NAA) were used in Eleven treatments were tested T1: Control, T2: 25 ppm TIBA, T3: 50 ppm TIBA, T4: 25 ppm GA3, T5: 50 ppm GA3, T6: 5 ppm Cytokinin, T7: 10 ppm Cytokinin, T8: 25 ppm IAA, T9: 50 ppm IAA, T10: 25 ppm NAA, T11: 50 ppm NAA. The results revealed that the maximum plant height (38.12 & 38.15 cm at harvest) was obtained by the 50 ppm GA3 followed by 50 ppm IAA (37.00 & 38.10 cm at harvest) spray at all stages. However, the 50 ppm TIBA showed better results (per plant) *viz*., number of branches (15.00, 15.33 at 110DAS), leaf area (86.50, 86.32 at 110DAS), number of pods (160.20, 160.37), pod setting (65.45, 65.50%), seed weight (2.02, 2.10g), test weight (27.32, 27.39g) and seed yield (1500.00, 1510.00 kg $ha^{-1}$) of lentil as compared to all other treatments. The maximum days of flowering (67.50, 67.85) and days of maturity. On the basis of the observed results the growing of DPL-60 lentil variety with foliar applications of 50 ppm TIBA is recommended for the farmers of the test area for greater production and profitability.

*Keywords: Lentil; PGR; $GA_3$; TIBA; IAA; NAA; yield; morphology; flowering; Maturity.*

## 1. INTRODUCTION

One of the most important and healthiest Rabi pulses is lentil. It could make up for the risk of farming in the rain. It can also be used as a cover crop to stop soil erosion in places where it is a problem. The crop residues serve as green manure by being tilled back into the ground [1]. Most people consume it as "dal", the grain is split into two orange-red or orange-yellow cotyledons, which are used to make Dal. Some of the dishes also use the whole grain. Since it is a leguminous crop, it makes the soil more fertile by fixing nitrogen in a natural way. The starch in lentil seeds is also used to make textiles and ink. Feed for animals are made from lentil waste. Soups can be thickened with lentil flour. It is added to wheat flour to make bread and cakes. Lentil is usually grown as a rain-fed crop after rice, maize, and pearl millet during the Rabi season [2]. Lentils have always been a part of the human diet, and after soybeans and hemp, they have the third-highest amount of protein. Methionine and cysteine are two essential amino acids that lentil doesn't have enough of lentils also have minerals, fibre, and vitamin B1 in them. Lentils are a good source of iron, one cup of lentils has more than half of a person's daily iron needs [3]. Lentils can handle drought pretty well and are grown all over the world. It's one of the 30 most economically important plant groups that many people use as their main source of nutrition and it has a lot of carbs, protein, and amino acids [4]. Per 100 grams of lentil have 24–26% protein, 57–60% carbohydrates, 1.3% fat, 3.2% fibre, 300mg phosphorus, 7 mg iron, 10-15 mg vitamin C, 69 mg calcium, 343 Kcal, and 450 IU of vitamin A.

"India ranked first in the area and second in the production with 43% and 37% of world area and production respectively. The highest productivity is recorded in New Zealand (2667 kg/ha) followed by China (2239kg/ha). The Canada ranks first in production (38%) due to very high level of productivity 1971 kg/ha as compared to India 600 kg/ha" [5]. During 2019-20 the country's area under Lentil was 13.90 lakh hectares with a production of 12.30 lakh tonnes. In India Madhya Pradesh ranks I$^{st}$ in acreage i.e., 35.54% (4.94 lakh ha) followed by UP 32.30% (4.49 lakh ha) and Bihar 10.43% (1.45 lakh ha). While in terms of production Madhya Pradesh ranks I$^{st}$ at 34.79% (4.28 lakh tonnes) followed by UP 33.25% (4.09 lakh tonnes) and Bihar 10.89% (1.34 lakh tonnes). The highest productivity was recorded by the state of Meghalaya (1107 kg/ha) followed by Rajasthan (1007 kg/ha) and Manipur (929 kg/ha). The National yield average was (855 kg/ha).

Plant Growth Regulators (PGRs) are non-nutrient organic molecules. NAA, TIBA, IAA, GA3, Cytokinin, and other synthetic PGR-like substances are sold commercially [6]. Plant Growth regulators have been used for a wide range of purposes, including overcoming dormancy problems in seeds, accelerating seedling growth, hastening and increasing rooting of cuttings in several vegetative propagated plants, and altering plant growth in areas where genetic or other manipulation is not possible. PGRS affects germination, vigour, soil nutrient uptake, photosynthesis, respiration, assimilate partitioning, growth inhibition, defoliation, and postharvest ripening [7]. Plant growth regulators (PGRs) increase agricultural yields by improving plants' physiological efficiency and photosynthetic capabilities [8]. PGRs improve source-sink relationships and photo-assimilates translocation, boosting productivity. PGRs have significant promise, but their application, accrual assessment, and ideal concentration, stage, species specificity, and seasons must be carefully managed. Even a small increase of 10-15% in their effectiveness on every element of plant growth could enhance gross annual productivity by 10-15 m tonnes. These PGRs promote floral production when administered during flowering. Spraying foliage with growth regulators reduces flower and pod drop. PGR and urea foliar spray dramatically boosted seed output per plant [9].

TIBA (2, 3, 5-triiodobenzoic acid), an auxin polar transport inhibitor, embryogenesis from embryogenic cells. Cell division is unaffected. TIBA suppresses stage-specific axial and bilateral polarity in globular embryos. TIBA-induced malformed embryos decrease shoot and root apical meristem and vascular differentiation [10]. Thus, triodobenzoic acid inhibition causes aberrant embryo development and plantlets without branches and roots. Growth enhancers like gibberellins. In crop improvement projects, retardants stimulate cell division, growth, wall flexibility, and amylase gene transcription. These cause Brioche plants to grow slower, root faster, and resist environmental stress. Growth regulators promote crop physiological efficiency, photosynthetic ability, and assimilate partitioning from source to sink in field crops [11]. Foliar use of growth regulators and chemicals during blooming can boost crop output and physiological efficiency. GA3 foliar spray boosted black gramme plant height by increasing internodes and vegetative and reproductive growth. GA3 boosted groundnut plant height by lengthening the main axis [12].

“Cytokinins boosted soybean cell growth and stem thickness while kinetine reduced shoot length but improved fresh weight by increasing stem diameter in morning glory and okra” [13]. “Cytokinins regulate bud initiation, flowering, abscission, and yield. IAA exerts influence on plant growth by enlarging leaves and increasing photosynthetic activities in plants. It also activates the translocation of carbohydrates during their synthesis Indole-3 acetic Acid (IAA) is a well-known natural auxin generated in the apical meristem of the shoot” [14]. “IAA is produced by the developing seed and stimulates the formation of a succulent fruit. The removal of seeds from a strawberry, for example, inhibits the fruit from expanding. After removing the seeds, IAA is applied to the fruit, which causes it to grow naturally. IAA is involved in elongation and is produced in actively growing shoot tips and developing fruit. Before a cell can elongate, its cell wall must become less rigid in order to grow. IAA causes an increase in the cell wall's plasticity, or ability to withstand stress” [15]. “NAA is a synthetic plant hormone in the auxin family and is an ingredient in many commercial plant rooting horticultural products. It is a rooting agent and used for the vegetative propagation of plants from stem and leaf cuttings” [16]. It is also used for culture. The hormone NAA does not occur naturally, and, like all auxins, is toxic to plants at high concentrations. The objectives of these experiments were to evaluate the effect of some growth regulators on yield attributes of DPL-62 lentil variety and to identify the best of these GRs for enhancing its yield and quality.

## 2. MATERIALS AND METHODS

### 2.1 Experimental Site

The field experiment was conducted on Student’s Instructional Farm (SIF) at Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India. This is situated in the alluvial tract of Indo - Gangetic plains in central part of Uttar Pradesh between 25º 26’ to 26º 58’ North latitude to 79º 31’ to 80º 34’ East longitude at an elevation of 125.9 m above mean sea level. This region falls under agro-climatic zone V (Central Plain Zone) of Uttar Pradesh. The location of the experimental field was the same for both the years of investigation.

### 2.2 Climate and Weather Conditions

This zone has semi-arid climatic conditions, having alluvial fertile soil. The normal rainfall of the area is about 890 mm per annum. Most of the rains are received from mid-July to end of September. The winter months are cooler with occasional rains as well as frost during last week of December to mid-January. The temperature in the month of May and June goes up to 44-47$^{o}$C or beyond and during winter it goes down up to a certain degree. Mean relative humidity (7:00 A.M.) remains nearly constant at about 80-90% from July to end of March and after March slowly declines to about 40-50% by the end of April and remains constant at 80% up to May.

### 2.3 Soil Characteristics

The soil as a medium of plant growth is bound to affect profoundly the rate of growth of plants and ultimately the final yield through its properties. The general character of the field were soil texture is sandy loam soil with pH (7.83, 7.87), Electrical conductivity (0.26, 0.27 dSm$^{-1}$ at 25ºC), Bulk density (1.39, 1.40 g cm$^{-3}$), Particle density (2.64, 2.63 g cm$^{-3}$), Organic Carbon (0.33, 0.35 %), Available nitrogen (156.22, 161.32 kg ha$^{-1}$), Available $P_2O_5$ (17.24, 18.15 kg ha$^{-1}$), Available $K_2O$ (175.35, 181.49 kg ha$^{-1}$), Available Zn (0.56, 0.58 mg kg$^{-1}$), Available Fe (8.02, 8.07 mg kg$^{-1}$) and Available B (0.28, 0.38 mg kg$^{-1}$), Moisture content in air dried soil (5.3, 5.5), Water holding capacity (42.1, 40.8 %), Permanent wilting point (4.4, 4.6), Field capacity (19.5, 20.0 %) in both year 2018-19 and 2019-20, respectively.

### 2.4 Experimental Details

The experimental design was Randomized Block Design (RBD) with three replications. The experiment consisting of eleven treatments with lentil variety DPL-62 i.e., T1: Control, T2: TIBA@25 ppm, T3: TIBA@50ppm, T4: GA3@25ppm, T5: GA3@50ppm, T6: Cytokinin @ 5ppm, T7: Cytokinin@10ppm, T8: IAA@25ppm, T9: IAA@50ppm, T10: NAA@25 ppm, T11: NAA@50 ppm. The size of each plot was (13.5 m$^2$), 4.5m long and 3.0 m width.

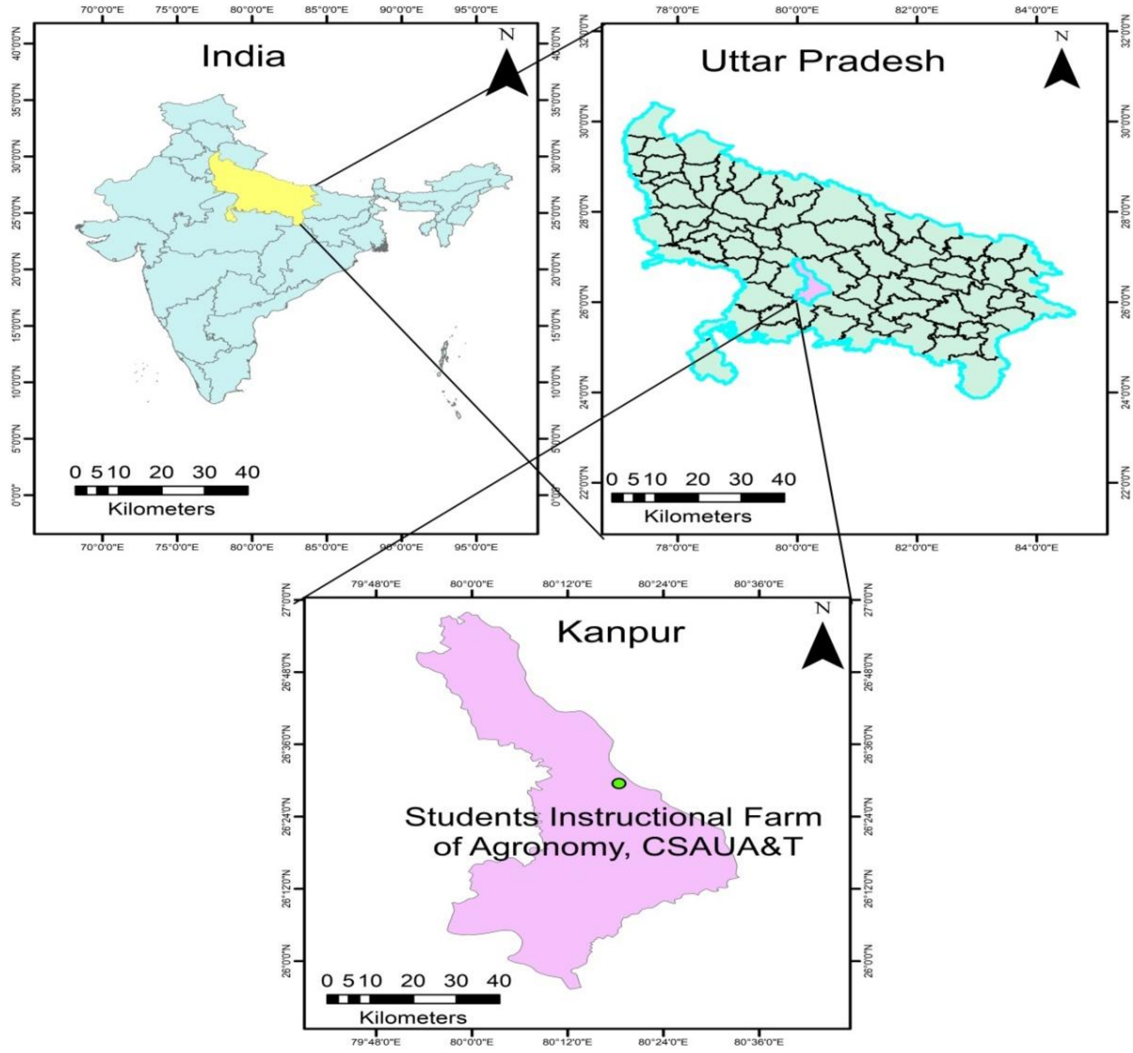


**Fig. 1. Location map of the study area**

## 2.5 Crop Varieties

### 2.5.1 DPL 62 (sheri)

It is also known as Sheri variety of lentil developed by ICAR-Indian Institute of Pulse Research, Kanpur for cultivation in north western plain zones (Punjab, Haryana, Delhi, North Rajasthan and Western Uttar Pradesh) of India. It is medium in plant height, Resistant to rust and wilt, large seeds. Important features are Yield: 22-25 q $ha^{-1}$.

## 2.6 Agronomical Practices Adopted

During the experimental period, the land was first ploughed using a tractor drawn cultivator and then harrowed. Weeds and stubbles were removed and the field was leveled using a leveler and later laid out into plots as per the design. The big clods were broken into fine soil particles and the surface was leveled until the desired tilth obtained. Uniform doses of nitrogen, and phosphorus calculated at the rate of 10 kg nitrogen and 40 kg. Phosphorus per hectare was applied at the time of sowing as basal application. Seeds were sown in the field behind the plough, keeping the rows 30 cm apart and maintaining a depth of 5 cm, as for as possible. The open furrows were planked immediately after sowing. Plant to plant spacing within the rows was maintained at 10 cm. The crop was irrigated and weeded as per seasonal requirements.

## 2.7 Preparation of Growth Regulators, Solutions and Spraying

The desired quantities of each growth regulator *i.e.* TIBA, $GA_3$, Cytokinin, IAA and NAA were weighed on a single pan automatic electric balance (mention the brand). IAA and NAA were firstly dissolved in a few drops of ethyl alcohol and there after the alcoholic solution was made up to 1000 ml with distilled water by stirring and were kept in tightly closed flasks. $GA_3$ was first dissolved in a boiling distilled water and the volume was made up to 1000 ml. Cytokinin and TIBA were directly dissolved in distilled water and volume was made up to 1000 ml. A few drops of 'Teepol' were added as a wetting agent to each solution, followed by vigorous shaking. Thus, the solution was prepared carefully and sprayed on the plants with the help of one litre hand sprayer (automizer) and 1 litre of each solutions was sprayed in each plot (4.5X 3 $m^2$) at 30 days after sowing. Control plots were unsprayed. Caution was always taken to clean the sprayer by rinsing it several times with the solution intended for the next spray in order to avoid any residual effect of the previous spray.

### 2.7.1 Observations

The observations were recorded during the two years of investigation. These included (per plant), plant height, number of branches, leaf are, days to flowering, days to maturity, number of pods, seed weight and seed yield of lentil were determined. Data obtained were exposed to the proper method for statistical analysis of variance (Gomez and Gomez, 1984). The treatment means were compared using the Least Significant Difference (LSD) test at 5% level of probability by using the Factorial Randomized Block Design (FRBD) as obtained by SPSS (Statistical Procedure for Social Studies) Version 10.0, Chicago, IL.

## 3. RESULTS AND DISCUSSION

## 3.1 Plant Height

The data regarding plant height were considerably ($P < 0.05$) influenced by the application of plant growth regulator at all the successive stages of growth. The maximum increase in plant height was recorded by the application of 50 ppm GA followed by 50 ppm IA and NAA (50ppm), respectively over the control during both the years. On the other hand, 50 ppm TIBA reduced the plant height as compared to the control. "The effect once initiated during the early stage of branching continued at subsequent stages of growth viz., flowering, Pod formation, seed development and maturity. Increase in plant height occurring from sprays of GA was well documented in chickpea" [17]. The reduction in plant height of pea plant due to TIBA application was also reported [18]. The reduction in plant height may be attributed to restriction in cell division activity and elongation of sub-apical meristem resulting in shortening of inter-nodal length [17].

## 3.2 Numbers of Branches $Plant^{-1}$

The data of number branches per plant was significantly ($P < 0.05$) and mostly increased by the application of plant growth regulators in both test years. The Maximum number of branches was recorded under 50 ppm TIBA followed by 50 ppm IAA. Application of 50 ppm Cytokinin, on the other hand, led to a reduction in number of branches during both test years. However, the increase in number of branches by TIBA application was reported in a lot of works [18-22].

### 3.3 Leaf Area Plant$^{-1}$

The data pertaining leaf area plant$^{-1}$ was significantly ($P < 0.05$) influenced by the application of plant growth regulator during the test years. The maximum leaf area plant$^{-1}$ was noticed under the application of 50ppm TIBA closely followed by 50 ppm IAA during the test years. While, the minimum leaf area plant$^{-1}$ was recorded in the control. TIBA (50 ppm) produced the maximum leaf. That's, it improves the transport mechanism and utilization process for stimulation of leaf growth. Gainger et al., [23] and Kumar et al. [18], [24] recorded an increase in leaf area due to application of these plant growth regulators on different crops.

### 3.4 Days to Flowering

A perusal of data clearly indicates that application of 50 ppm IAA delayed the flowering by 5 days (70.10 and 70.25) over the control (65.00 and 65.30) days during 2019-20 and 2020-21, respectively. This is statistically significant ($P < 0.05$). The application of 50 ppm $GA_3$ and 25 ppm $GA_3$ induced early flowering which ranged from 4 to 5 days. On the other hand, IAA (50 ppm and 25ppm) also delayed the flowering from 3 to 5 days compared to the control during the test period.

### 3.5 Days of Maturity

The days of maturity of the test lentil variety was delayed by the treatment doses. That's, IAA (50 ppm and 25 ppm) delayed maturity by 4 to 6 days in plants as compared to the control. While the application of $GA_3$ (25 ppm and $GA_3$ & 50 ppm) caused an early maturity by about 5 to 6 days. These results were found statistically significant ($P < 0.05$).

### 3.6 Number of Pods Plant$^{-1}$ and Seeds Pod$^{-1}$

The data regarding number of pods plant$^{-1}$ and seed pod$^{-1}$ was significantly ($P < 0.05$) increased over the control, by sprays of 50 ppm of TIBA, IAA and NAA, seperately. The application of 25 ppm TIBA gave the highest number of pods per plant during the years of the experiment. On the other hand, Cytokinin at 5 ppm gave the lowest number of pods per plant. Similar findings were reported earlier [17,18].

### 3.7 Pod Setting Percentage (%)

The pod setting percentage (%) was increased significantly ($P < 0.05$) by the application of test hormones as compared to the control. The maximum pod setting percentage was recorded by the application of 50 ppm TIBA. A similar effect was also produced by the treatment of 50 ppm IAA followed by 50 ppm NAA. The minimum pod setting was recorded in the treatment of 5 ppm cytokinin.

### 3.8 Seed Yield Plant$^{-1}$

The weight of seeds produced per plant was significantly ($P < 0.05$) increased by the applications of test plant growth regulator during both test years. The highest seed weight per plant recorded was by the application of 50 ppm TIBA followed by 50 ppm IAA and 50 ppm NAA and then 5 ppm Cytokinin and 25ppm IAA.

### 3.9 Test Weight

The Plant growth regulators exerted significant ($P < 0.05$) influence on test weight over the control during both the years. Among the plant growth regulators, the TIBA @ 50ppm produced highest test weight, IAA @ 50ppm proved next in effectiveness, which is followed by NAA @ 50ppm and TIBA @ 25ppm, respectively. While in control treatment recorded significantly lower test weight of grain than all other treatments.

### 3.10 Seed Yield

The overall production of seed yield (kg ha$^{-1}$) was significantly ($P < 0.05$) influenced by the application of plant growth regulator during both the years. The maximum seed yield was found with application of TIBA @ 50 ppm (1500 and 1510 Kg ha$^{-1}$) and over the control (1200 and 1220 Kg ha$^{-1}$) during 2019-20 and 2020-21, respectively. IAA @ 50ppm recorded next highest seed yield (1450 kg ha$^{-1}$ and 1465 kg ha$^{-1}$) during the years 2019-20 and 2020-21, respectively. Application of cytokinin (5ppm) also gave superior effects over control during both the years of experiment. Influence of $GA_3$ in increasing seed yield, has been observed in the present study, and has been described in Chick Pea. Verma et al., [17], Kumar et al., [18] reported increase in seed yield by TIBA application and NAA.

**Table 1. Effect of plant growth regulators on plant height (cm) at different stages of lentil**

| Treatments | Plant height (cm) at 35 DAS | | Plant height (cm) at 60 DAS | | Plant height (cm) at 85 DAS | | Plant height (cm) at 110 DAS | | Plant height (cm) at harvest | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2019-20 | 20120-21 | 2019-20 | 20120-21 | 2019-20 | 20120-21 | 2019-20 | 20120-21 | 2019-20 | 20120-21 |
| Control | 7.35 | 7.37 | 18.23 | 18.26 | 29.12 | 29.18 | 33.30 | 33.40 | 32.85 | 32.86 |
| TIBA @ 25 ppm | 6.35 | 6.40 | 16.65 | 16.50 | 27.70 | 27.25 | 30.75 | 30.70 | 30.15 | 30.20 |
| TIBA @ 50 ppm | 5.10 | 5.12 | 15.12 | 15.16 | 26.15 | 26.12 | 29.30 | 29.35 | 29.10 | 29.25 |
| $GA_3$ @ 25 ppm | 8.75 | 8.85 | 24.45 | 25.50 | 34.20 | 34.26 | 38.20 | 38.45 | 37.40 | 37.28 |
| $GA_3$ @ 50 ppm | 8.85 | 8.95 | 25.56 | 25.62 | 34.65 | 34.68 | 38.90 | 38.96 | 38.12 | 38.15 |
| Cytokinin @ 5 ppm | 7.50 | 7.60 | 22.18 | 22.25 | 30.20 | 31.35 | 34.85 | 33.78 | 34.48 | 33.60 |
| Cytokinin @ 10 ppm | 7.90 | 7.85 | 22.76 | 22.84 | 32.40 | 31.53 | 35.30 | 33.90 | 35.20 | 33.75 |
| IAA @ 25 ppm | 7.50 | 8.63 | 23.68 | 23.85 | 33.10 | 33.65 | 37.40 | 37.75 | 36.72 | 37.50 |
| IAA @ 50 ppm | 8.51 | 8.66 | 24.10 | 24.21 | 33.60 | 34.12 | 37.85 | 38.25 | 37.00 | 38.10 |
| NAA @ 25 ppm | 7.95 | 8.10 | 22.42 | 20.56 | 31.40 | 32.25 | 35.80 | 34.56 | 35.45 | 34.48 |
| NAA @ 50 ppm | 8.35 | 8.45 | 23.26 | 22.34 | 32.45 | 32.45 | 36.60 | 35.65 | 36.50 | 35.55 |
| SE (d) ± | 0.33 | 0.54 | 0.54 | 0.62 | 0.76 | 1.02 | 0.98 | 0.99 | 0.94 | 1.25 |
| C.D at 5 % | 0.69 | 1.13 | 1.14 | 1.28 | 1.60 | 2.14 | 2.04 | 2.66 | 1.96 | 2.62 |

**Table 2. Effect of plant growth regulators on number of branches plant$^{-1}$ at different stages of lentil**

| Treatments | Number of branches plant$^{-1}$ at 35 DAS | | Number of branches plant$^{-1}$ at 60 DAS | | Number of branches plant$^{-1}$ at 85 DAS | | Number of branches plant$^{-1}$ at 110 DAS | |
|---|---|---|---|---|---|---|---|---|
| | 2019-20 | 20120-21 | 2019-20 | 20120-21 | 2019-20 | 20120-21 | 2019-20 | 20120-21 |
| Control | 2.66 | 3.00 | 4.33 | 5.00 | 7.66 | 8.00 | 9.33 | 9.66 |
| TIBA @ 25 ppm | 5.66 | 5.66 | 7.66 | 8.00 | 11.33 | 11.66 | 13.66 | 13.66 |
| TIBA @ 50 ppm | 7.00 | 7.33 | 9.00 | 9.33 | 13.00 | 13.33 | 15.00 | 15.33 |
| $GA_3$ @ 25 ppm | 4.33 | 4.66 | 6.00 | 6.33 | 9.33 | 9.66 | 11.33 | 11.66 |
| $GA_3$ @ 50 ppm | 5.00 | 5.33 | 6.66 | 7.00 | 10.33 | 10.66 | 12.66 | 12.66 |
| Cytokinin @ 5 ppm | 3.33 | 3.66 | 4.67 | 5.66 | 8.33 | 8.33 | 10.00 | 10.33 |
| Cytokinin @ 10 ppm | 4.66 | 5.00 | 6.33 | 6.66 | 10.00 | 10.33 | 12.00 | 13.33 |
| IAA @ 25 ppm | 5.33 | 5.66 | 7.00 | 7.33 | 10.66 | 10.66 | 13.00 | 13.33 |
| IAA @ 50 ppm | 6.66 | 7.00 | 8.66 | 9.00 | 12.66 | 12.66 | 14.66 | 14.66 |
| NAA @ 25 ppm | 3.66 | 4.00 | 5.33 | 5.66 | 8.66 | 8.66 | 10.66 | 10.66 |
| NAA @ 50 ppm | 6.00 | 6.66 | 8.00 | 8.33 | 12.00 | 12.33 | 14.33 | 14.66 |
| SE (d) ± | 0.18 | 0.19 | 0.25 | 0.26 | 0.38 | 0.39 | 0.45 | 0.46 |
| C.D at 5 % | 0.39 | 0.41 | 0.52 | 0.55 | 0.80 | 0.82 | 0.96 | 0.97 |

**Table 3. Effect of plant growth regulators on leaf area plant$^{-1}$ at different stages of lentil**

| Treatments | Leaf area plant$^{-1}$ at 35 DAS | | Leaf area plant$^{-1}$ at 60 DAS | | Leaf area plant$^{-1}$ at 85 DAS | | Leaf area plant$^{-1}$ at 110 DAS | |
|---|---|---|---|---|---|---|---|---|
| | **2019-20** | **20120-21** | **2019-20** | **20120-21** | **2019-20** | **20120-21** | **2019-20** | **20120-21** |
| Control | 34.95 | 35.10 | 55.65 | 55.64 | 60.20 | 60.23 | 70.85 | 71.56 |
| TIBA @ 25 ppm | 43.20 | 43.26 | 69.00 | 69.10 | 75.26 | 75.30 | 84.12 | 84.25 |
| TIBA @ 50 ppm | 44.12 | 44.23 | 70.85 | 70.78 | 77.84 | 77.86 | 86.50 | 86.32 |
| $GA_3$ @ 25 ppm | 36.00 | 36.20 | 61.25 | 61.21 | 70.12 | 70.23 | 80.10 | 80.20 |
| $GA_3$ @ 50 ppm | 41.16 | 41.21 | 63.12 | 63.14 | 70.95 | 70.98 | 82.24 | 82.26 |
| Cytokinin @ 5 ppm | 35.24 | 35.26 | 61.00 | 61.13 | 69.32 | 69.36 | 79.25 | 79.32 |
| Cytokinin @ 10 ppm | 36.14 | 36.23 | 61.56 | 61.57 | 70.24 | 70.28 | 81.32 | 81.42 |
| IAA @ 25 ppm | 42.22 | 42.32 | 67.95 | 67.97 | 74.60 | 74.65 | 83.75 | 83.87 |
| IAA @ 50 ppm | 43.91 | 43.95 | 70.25 | 70.28 | 77.20 | 77.28 | 86.10 | 86.20 |
| NAA @ 25 ppm | 35.85 | 35.86 | 61.10 | 61.15 | 71.30 | 71.60 | 80.00 | 80.13 |
| NAA @ 50 ppm | 43.50 | 43.52 | 69.85 | 69.88 | 76.50 | 76.54 | 84.65 | 84.68 |
| SE (d) ± | 1.02 | 1.32 | 1.50 | 2.2 | 1.81 | 2.51 | 2.03 | 2.83 |
| C.D at 5 % | 2.14 | 2.76 | 3.15 | 4.68 | 3.79 | 5.25 | 4.25 | 5.92 |

**Table 4. Effect of plant growth regulators on days of flowering & maturity, number of pods plant$^{-1}$ and Pod setting at different stages of lentil**

| Treatments | Days of 50% flowering | | Days of maturity | | Number of pods plant$^{-1}$ | | Pod setting percentage | |
|---|---|---|---|---|---|---|---|---|
| | **2019-20** | **20120-21** | **2019-20** | **20120-21** | **2019-20** | **20120-21** | **2019-20** | **20120-21** |
| Control | 65.00 | 65.30 | 130.00 | 131.22 | 104.83 | 105.35 | 52.70 | 52.82 |
| TIBA @ 25 ppm | 66.20 | 66.40 | 130.80 | 130.90 | 146.72 | 148.00 | 62.65 | 62.76 |
| TIBA @ 50 ppm | 67.50 | 67.85 | 131.10 | 131.30 | 160.20 | 160.37 | 65.45 | 65.50 |
| $GA_3$ @ 25 ppm | 60.10 | 60.25 | 125.00 | 125.50 | 127.55 | 128.00 | 56.40 | 56.52 |
| $GA_3$ @ 50 ppm | 59.18 | 59.38 | 124.60 | 124.72 | 134.75 | 135.00 | 58.80 | 58.85 |
| Cytokinin @ 5 ppm | 63.20 | 63.30 | 133.20 | 134.33 | 116.40 | 117.00 | 54.25 | 54.36 |
| Cytokinin @ 10 ppm | 64.60 | 64.82 | 133.50 | 133.68 | 130.65 | 130.80 | 57.35 | 57.40 |
| IAA @ 25 ppm | 68.50 | 68.60 | 134.80 | 135.20 | 139.24 | 140.00 | 60.15 | 60.30 |
| IAA @ 50 ppm | 70.10 | 70.25 | 136.30 | 136.40 | 154.25 | 154.45 | 64.42 | 64.45 |
| NAA @ 25 ppm | 61.80 | 62.00 | 133.34 | 134.00 | 122.45 | 122.70 | 55.28 | 55.38 |
| NAA @ 50 ppm | 62.30 | 62.50 | 132.34 | 133.10 | 150.42 | 150.53 | 63.60 | 63.50 |
| SE (d) ± | 2.32 | 2.33 | 0.53 | 0.73 | 2.55 | 3.08 | 2.15 | 2.15 |
| C.D at 5 % | 4.87 | 4.89 | 1.10 | 1.53 | 5.33 | 6.43 | 4.52 | 4.52 |

**Table 5. Effect of plant growth regulators on seed yield plant$^{-1}$, 1000 seeds weight and seed yield of lentil**

| Treatments | Seed Yield plant$^{-1}$ (g) | | Test weight (g) | | Seed Yield (Kg ha$^{-1}$) | |
|---|---|---|---|---|---|---|
| | 2019-20 | 20120-21 | 2019-20 | 20120-21 | 2019-20 | 20120-21 |
| Control | 1.40 | 1.48 | 22.86 | 23.40 | 1200.00 | 1220.00 |
| TIBA @ 25 ppm | 1.57 | 1.89 | 25.60 | 26.90 | 1398.00 | 1418.00 |
| TIBA @ 50 ppm | 2.02 | 2.10 | 27.32 | 27.39 | 1500.00 | 1510.00 |
| $GA_3$ @ 25 ppm | 1.08 | 1.53 | 23.58 | 25.20 | 1267.00 | 1270.00 |
| $GA_3$ @ 50 ppm | 1.53 | 1.68 | 23.84 | 26.50 | 1284.00 | 1340.00 |
| Cytokinin @ 5 ppm | 1.47 | 1.51 | 23.29 | 24.80 | 1240.00 | 1260.00 |
| Cytokinin @ 10 ppm | 1.27 | 1.60 | 23.60 | 26.10 | 1268.00 | 1310.00 |
| IAA @ 25 ppm | 1.56 | 1.75 | 25.17 | 26.75 | 1370.00 | 1385.00 |
| IAA @ 50 ppm | 1.90 | 2.00 | 26.40 | 27.20 | 1450.00 | 1465.00 |
| NAA @ 25 ppm | 1.70 | 1.55 | 23.35 | 25.80 | 1250.00 | 1283.00 |
| NAA @ 50 ppm | 1.84 | 1.95 | 26.16 | 27.10 | 1435.00 | 1453.00 |
| SE (d) ± | 0.07 | 0.06 | 0.89 | 0.94 | 49.14 | 54.04 |
| C.D at 5 % | 0.16 | 0.13 | 1.88 | 1.98 | 102.54 | 112.76 |

## 4. CONCLUSION

The use of TIBA enhances the yield of Lentil. TIBA at 50 ppm is the optimum concentration for foliar application to, significantly ($P < 0.05$), maximize the growth, yield attributes and seed yield of lentil compared to IAA, NAA and Cytoknin. The observed results encourage farmers to grow the DPL-60 lentil variety with foliar applications of 50ppm TIBA for the best production and profitability.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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