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Response of plant growth regulators on growth characters and yield of chickpea (*Cicer arietinum* L.)

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Abstract
The experiment was conducted in the Department of Crop Physiology, CSAUA&T, Kanpur in pots during Rabi season 2020-21 to study the effects of foliar application of IAA, GA, NAA & Kinetin at different concentrations on physiology of growth, and development of chickpea (Var. KGD-1168) in complete randomized design with 9 treatments *viz.*, control, IAA 25 ppm, IAA 50 ppm, GA 25 ppm, GA 50 ppm, NAA 25 ppm, NAA 50 ppm, Kinetin 5 ppm, & Kinetin 10 ppm in five replications. Foliar application of GA 50 ppm recorded highest plant height. Maximum number of branches was recorded in the plants treated with IAA 50 ppm. Maximum increase in leaf area per plant were recorded by IAA 5o ppm. Maximum increment in TDM (mg/g/day) was shown by plants treated with IAA 50 ppm. Maximum number of flowers were recorded by IAA 50 ppm treated plants. Maximum grain yield per plant was recorded by foliar application of IAA 50 ppm closely followed by NAA 50 ppm.

Keywords: PGR, IAA, GA, NAA, Kinetin

Introduction
Chickpea (*Cicer arietinum* L.) is the largest food legume produced in South Asia. It also comes at the third spot in food legume production globally, right after common bean (*Phaseolus vulgaris* L) and field pea (*Pisum sativum* L). Its common name is Bengal gram, Garbanzo and, Egyptian pea. It is a member of the Fabaceae family. It is a herbaceous annual with a long taproot system, enabling it to withstand dry conditions. Chickpea is the major source of protein for millions of people especially in a developing country mainly due to food preferences or economic reasons. It is one of the most easily accessible plant protein resources. On average Chickpea seeds (amount per 100 grams) contain about 19 g protein, 61 g total carbohydrates, 6 g total fat, 24 mg sodium, 875 mg potassium, 364 calories (Source: USDA). Cooked and germinated chickpea have proteins rich in amino acids such as lysine, isoleucine, tryptophan, and total aromatic amino acids. Its lipid fraction is high in unsaturated fatty acids. Its deep root system helps in binding soil particles thus, preventing soil erosion and hence being used as a green manuring crop. It fixes atmospheric nitrogen (60 Kg/ha/year) through symbiosis resulting in improved soil fertility. The total area, production, and yield of chickpea in India are 10.17 mha, 11.35 mt, and average 1116 Kg/ha respectively. The leading states in chickpea production (2019-2020) are Rajasthan, Maharashtra, and Madhya Pradesh with 2.66kg/ha, 2.60 Kg/ha, and 2.40 Kg/ha yield respectively. The total area, production, and yield of chickpea in Uttar Pradesh are 0.62 mha, 0.85 mt, and 1371 Kg/ha respectively. (Source: Directorate of economics and statistics, DoA, C&FW).

Plant growth regulators play an important role in plant growth and development. They include organic molecules which at low concentration exert a profound influence on physiological processes. They are both growth promoters and growth retardants. The importance of these PGR’s makes them an emerging tool in agricultural production. The major types of plant regulators include auxin, gibberellin, cytokinin, ethylene and abscisic acid. Recently brassinosteroids have also shown role as a plant growth regulator. Beside these six important plant growth regulators, there are some hormones like signaling agents are also present in the plants like jasmonic acid, salicylic acid, and the polypeptide systemin. These signaling agent also play an important role in plant growth and development. Auxin was the first plant hormone to be discovered. It was successfully isolated by F.W Went by avena curvature test. Its principal role is enlargement of plant cells. Auxin, appears to be actively distributed throughout the entire plant, more than any other PGR.

IAA (Indole-3-acetic acid) is the most widely distributed natural auxin plant. The physiological effects of auxin in plants includes cell elongation, phototropism and gravitropism, apical dominance, promotion of lateral and adventitious roots formation, floral bud development, fruit development, and delaying of onset of leaf abscission. NAA (1-Naphthaleneacetic acid) is a synthetic growth regulator which belongs to the auxin family. It promotes root growth in plants, therefore used as rooting agent. It is used commercially in tissue culture. Gibberellins are the plant height regulators. It regulates the natural elongation growth of plants. The major physiological effects of gibberellins are stem growth stimulation in dwarf and rosette plants, transition regulation from juvenile to adult phase, floral initiation and sex determination in plants, promotion of fruit set and seed germination. Gibberellins has important commercial role in fruit and brewing industry. Apical bud and young leaves are the principal sites of gibberellins biosynthesis. GA_3 is one of the most frequently used gibberellic acid, which has significant application in increasing the stem length, number of flowers per plant, and pod setting induction. Cytokinin mainly function as cell division regulators in plants. Zeatin is the most prevalent cytokinin in higher plants and it is also considered as most active among all cytokinin. Both auxin and cytokinin differs from other PGRs in one important aspect i.e., they both are required by plants for viability. The important biological roles of cytokinin in plant includes regulation of cell division in shoots and roots, delaying senescence, chloroplast development promotion, and promotion in cell expansion in leaves and cotyledons. Kinetin is a plant growth regulator of cytokinin type having primary role in extending plant life by promoting cell division and cell enlargement.

PGRs are capable of improving the physiological efficiency of plants including the photosynthetic ability of plants and the effective partitioning of the photo-assimilates in different sinks in the plants. They can modify plant growth and development in numerous ways under normal condition. So, it is necessary to investigate the various physiological effects of these plant growth regulators on chickpea. To meet the increased demand for food grain of rapidly growing population, there are many yields boosting agronomic techniques like application of certain plant growth regulators which needs due attention.

Materials and Methods

Experimental Site

The experiment entitled "Effects of plant growth regulators on growth and yield of chickpea" was conducted in a pot culture during rabi season 2020 in the wire net house in pot in the Department of Crop Physiology, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur. The details of the materials used and procedures in the experimentation are described below. The soil which is selected for the experiment was of sandy loam texture which is taken from the top 30 cm of the adjacent from the soil. The pot soil was sandy loam free from roots and shoots. The experiment was conducted in complete randomized design with 9 treatment and 5 replications. The treatment and their doses adopted were control, IAA @ 25 ppm, IAA @ 5O ppm, GA @ 25 ppm, GA @ 50 ppm, NAA @ 25 ppm, NAA @ 50 ppm, Kinetin @ 5 ppm, Kinetin @ 10ppm

Location and climatic conditions

Whole investigation was completed in the department of crop physiology, CSAUA&T, Kanpur. Geographically, the site of experiment is situated at the latitude of 80^0, 24^0 East and an altitude 127 meter above mean sea level in Genetic Alluvium soil in summer and severe cold winter. The mean annual precipitation is about 80 cm, which is mainly received through monsoon rain. Throughout the experiment period, data on weather condition were collected from Meteorological Observatory.

Pot soil characteristics

The soil which is selected for the experiment was of sandy loam texture which is taken from the top 30 cm of the adjacent from the soil. The pot soil was sandy loam free from roots and shoots.

Experimental Details

In each pot in small lots 8 kg air-dried soil was taken and compacted after each filling. The pots were irrigated two days before sowing. Uniform doses of nitrogen and phosphorus per hectare was applied. The seeds of chickpea variety - KGD 1168 was obtained from Legume section, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur.

Preparation of Growth Regulators Solutions and Spraying

The desired quantities of each growth regulator i.e., IAA, Cytokinin, NAA, and GA_3 were weighed on a single pan Automatic Electric Balance. The IAA, and NAA were first dissolved in a few drops of ethyl alcohol and their alcoholic solution was kept in a stopped flask. GA_3 was first dissolved in water and the volume was made up to 1ooo ml. cytokinin was first dissolved in a few drops of HCl and then volume was made up to 1000 ml with the help of distilled water. A few drops of teepol were added as wetting agent to each solution followed by vigorous shaking. The solution, thus prepared was carefully sprayed on the plants with the help of 2 liter hand sprayer and ½ liter of the solution was sprayed on the leaf foliage in each treatment, two times after sowing the first spraying was done at pre-branching stage (35 DAS) and second spraying at pre-anthesis stage. Control plants were given spray treatment with distilled water only. Caution was always taken to clean the sprayer by rinsing several times with distilled water and finally with the solution intended for the next spray in order to avoid residual effect of the previous hormones.

Observations

The different stages of chickpea plant taken here for studying purpose are branching stage, flowering stage, pod formation stage, seed development stage, and maturity or harvesting stage. The observations were recorded at successive stage of crop growth i.e., during the branching, flowering, pod formation, seed development and maturity stage of the plant, which happened to occurs at 40, 65, 90, 115, and at harvesting stage.

Result and Discussion

With the help of these findings, we tried to found out whether these growth regulators besides influencing various physiological, morphological, and biological changes can also be utilized effectively in enhancing the growth, yield, and grain quality in chickpea.

The results acquired during the experiment revealed the considerable influence in both physiological and morphological characters of the chickpea with the help of these growth regulators.
The different growth characters of chickpea like plant height, number of branches per plant, leaf area per plant, TDM per plant were found to be profoundly affected by these growth regulators.

Effect of different PGRs on plant height
It has been found that the foliar application of GA @ 50 ppm treatment significantly increases the plant height at all the successive stages of growth. Apart from this GA @ 25 ppm also showed similar results but showed slight lesser height increment in comparison to GA @ 50 ppm. After GA, the most effective growth regulator found in this respect is IAA @ 50 ppm and IAA @ 25 ppm, which also showed significant increment in plant height but somewhat failed to pick-up the level attained by GA. Other growth regulators i.e., NAA and Kinetin showed very little increase in plant height over control. The least effective in this aspect is found out be Kinetin @ 5 ppm. These findings confirm the observations recorded by Ahmed *et al*. (2010) [1] and Rafique *et al*. (2021) [35] in mungbean and chickpea plant respectively.
It has been observed that foliar application of IAA @ 50 ppm caused significant increase in number of branches which is closely followed by NAA @50 ppm, and IAA @25 ppm respectively. Here, kinetin @5 ppm showed least increase in the number of branches per plant over control. These findings go into agreement with the earlier findings reported by Udensi *et al.* (2013) [47] and Singh *et al.* (2017) [43] in pigeon pea and lentil respectively.

Effect of different PGRs on leaf area
Maximum significant increase in leaf area per plant (cm^2) was showed by IAA @ 50 ppm over control. It was closely followed by NAA @ 50 ppm, and IAA @ 25 ppm respectively. Least increase in this aspect was shown by growth regulator Kinetin @ 5 ppm over control in all the crop growth stages. These finding confirms the earlier work reported by Rohamare *et al*. (2013) [37] and Keykha *et al.* (2014) [19] in ajwain and mungbean crops respectively.

Effect of different PGRs on TDM
All the PGRs showed significant increase in the Total dry matter (TDM) production at different stages of plant growth over control. The maximum increment in this aspect was shown by the growth regulator IAA @ 50 ppm closely followed by NAA @50 ppm, and IAA @25 ppm over control. Here, kinetin @5 ppm was found to be least effective in improving the total dry matter (TDM) production of whole plant over control. Similar observations were made by Elangbam *et al.* (2017) [10] and Islam *et al.* (2021) [16] in chickpea and mungbean respectively.

Effect of different PGRs on RGR
All the growth regulators showed significant effect on the RGR value of the plant at different stages of growth. Among all the PGRs used, maximum value of RGR was shown by the NAA @ 25 ppm between 40-65 DAS period. It was closely followed by Kinetin @ 10 ppm, and IAA @ 25 ppm respectively. During the growth period of 65-90 DAS, IAA @ 50 ppm found to be most effective in influencing the RGR value of the plant, which was closely followed by GA @50 ppm, and IAA @ 25 ppm over control. In both the growth periods of plant i.e., between 40-65 DAS, & between 65-90 DAS, the least influencing growth regulator in aspect of increasing RGR value is found to be Kinetin @ 5 ppm.

Effect of different PGRs on flowering
Among all the PGRs used, GA @ 50 ppm was found to be most effective in inducing early flowering in plants by almost 6 days earlier than control. It was closely followed by the application of GA @ 25 ppm, NAA @ 25 ppm, and NAA @50 ppm respectively by inducing flowering in plants by almost 5 days earlier than control plants. These finding confirms the observations made by Yadav *et al.* (2017) [48] and Kumari *et al.* (2018) [22] in Strawberry (*Fragaria x ananassa* Duch) cv. Winter Dawn and in sub-tropical crops respectively. The results obtained from the data showed that application of growth regulators IAA @ 50 ppm and IAA @ 25 ppm showed delayed in flowering by 4-5 days in comparison to control plants.

Effect of different PGRs on plant maturity
Among all the PGRs used, most effective results were obtained by the application of GA @ 50 ppm which decreases the time period in attaining maturity by 6 days in comparison to control. It was closely followed by the application of GA @ 25 ppm, NAA @ 25 ppm, and NAA @ 50 ppm showing decrease in time period in attaining maturity by 5, 4, and 3 days respectively in comparison to control. The results obtained here indicated that application of growth regulators IAA @ 50 ppm and IAA @ 25 ppm showed delay in attaining maturity by 4 and 3 days respectively in comparison to the control. All the PGRs applied showed significant increase in the number of flowers per plant. Among all of these growth regulators, maximum increase in flowers number was shown by IAA @ 50 ppm over control. It was closely followed by the growth regulators NAA @ 50 ppm and IAA @ 25 ppm. Least effective growth regulator in this aspect is GA @ 25 ppm, which showed least increase in number of flowers per plant over control. These findings confirm the earliar work reported by Udensi *et al.* (2013) [47], Resmi and Gopalakrishnan (2014) [34], & Menaka *et al.* (2018) [30] in pigeon pea, yard long bean, and chickpea respectively.

Effect of different PGRs on plant grain yield
All the PGRs applied significantly increased the grain yield per plant over the control with most effective results obtained with the application of IAA @ 50 ppm. It was closely followed by the application of NAA @ 50 ppm and IAA @ 25 ppm respectively. Among all these growth regulators, Kinetin @ 5 ppm was found to be least effective in increasing the grain yield per plant over control. These findings go in agreement with the earlier observations reported by Chauhan *et al*. (2018) [6] and Islam *et al*. (2021) [16] in chickpea and mungbean crop respectfully.
After all the observations made by this experiment, we can now say that foliar application of plant growth regulators i.e., IAA, NAA, GA, and Kinetin at different concentrations are able to affect all the aspects of plant life including growth, and development. It seems to be important to understand the primary action and function of these growth regulators in plant.
The specific responses made by the plant growth regulators

are somewhat depends on their concentration and type of plant tissue involved. A growth regulator extremely effective in bringing one particular kind of response in plants is might be ineffective in bringing out another kind of response. Same goes out with the effect of growth regulators at different concentrations. A growth regulator at particular concentration may be most effective in bringing a particular response in plants but may act differently at another concentration, bringing entirely opposite response in plants. These findings go in agreement with the findings made by Mazid (2014) [23] and Chauhan *et al.* (2018) [6] in chickpea plants.

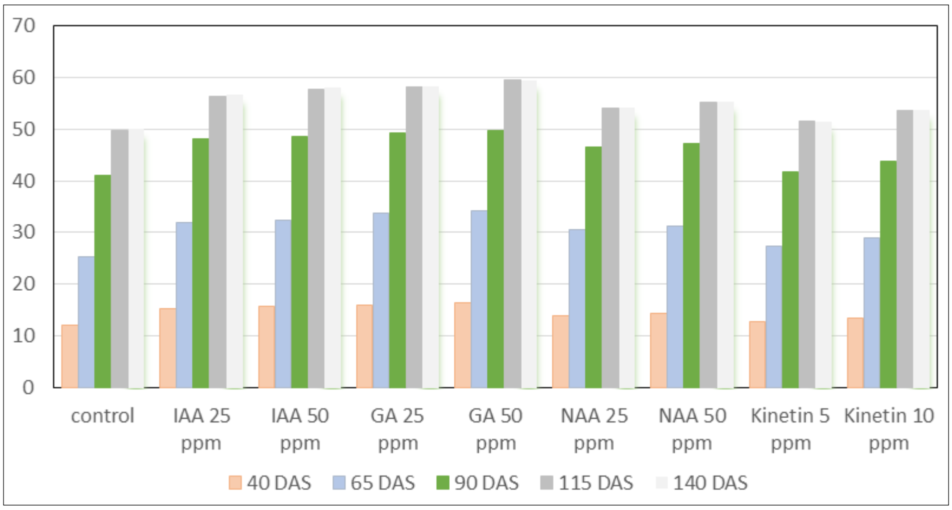

Fig 1: Effect of growth regulator on plan height at different growth stages

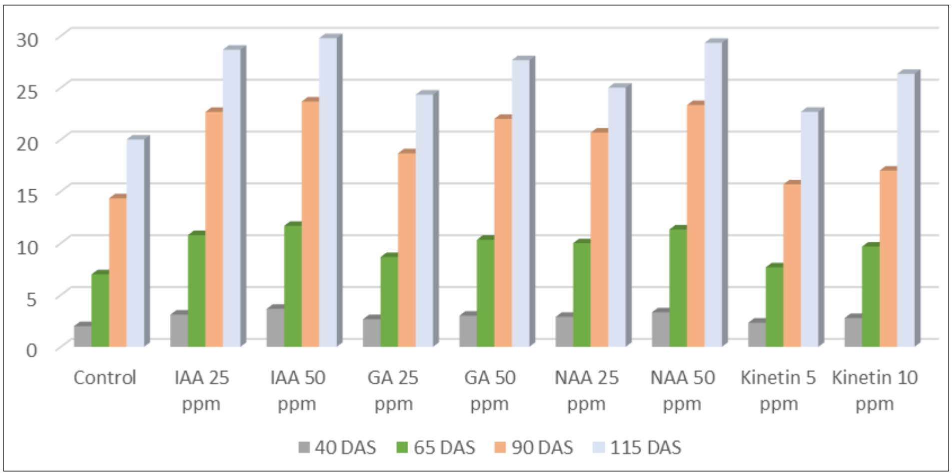

Fig 2: Effect of growth regulators on number of branches per plant at different stages of growth

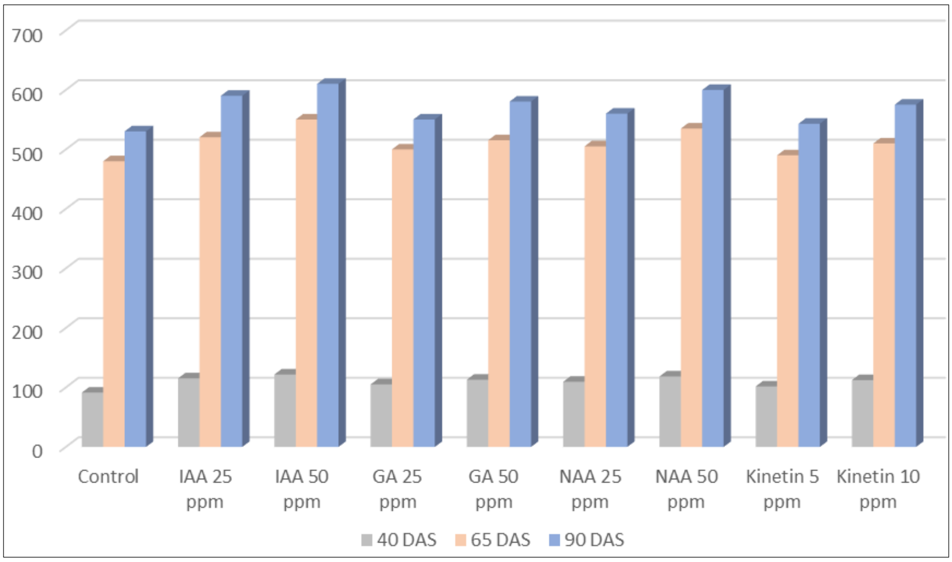

Fig 3: Effect of growth regulators on leaf area (sq cm) per plant at different growth stages

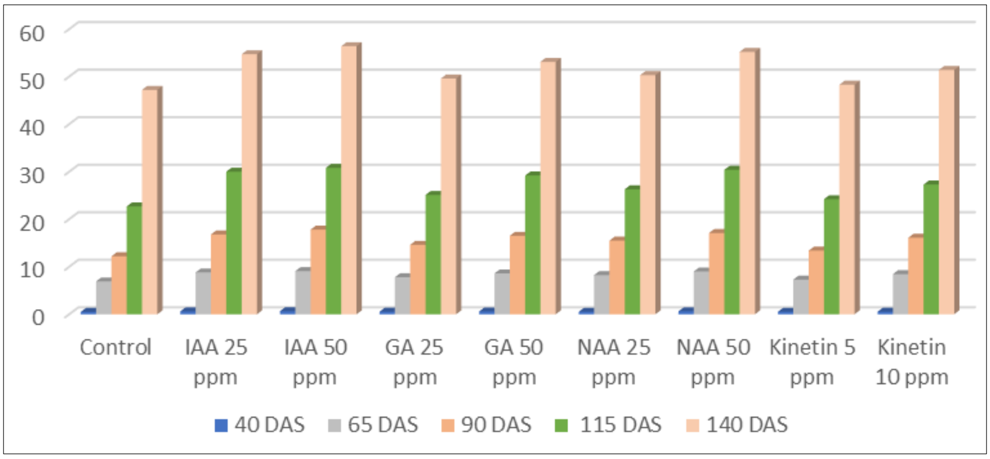

Fig 4: Effect of growth regulators on TDM production per plant at different growth stages

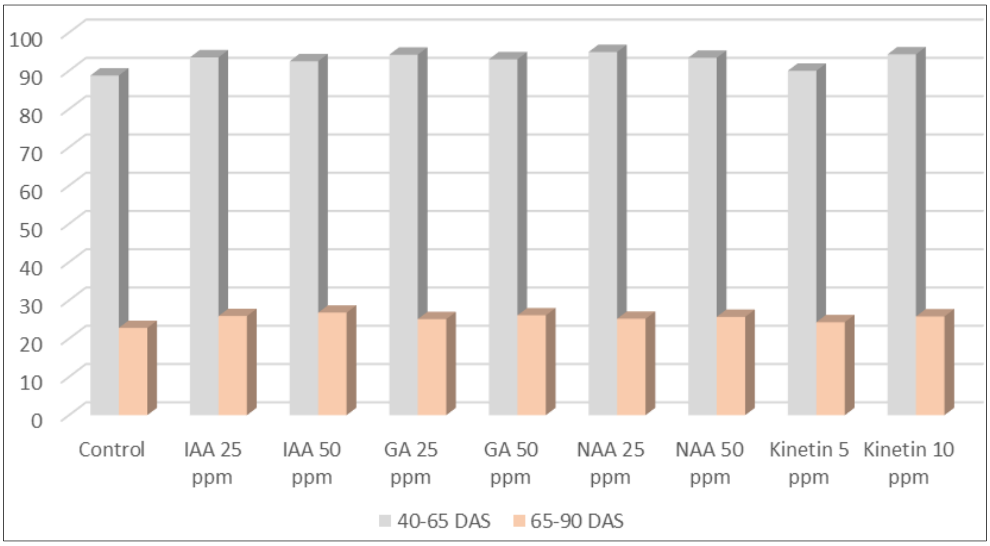

Fig 5: Effect of growth regulator on relative growth rate (RGR) (mg/g/day)

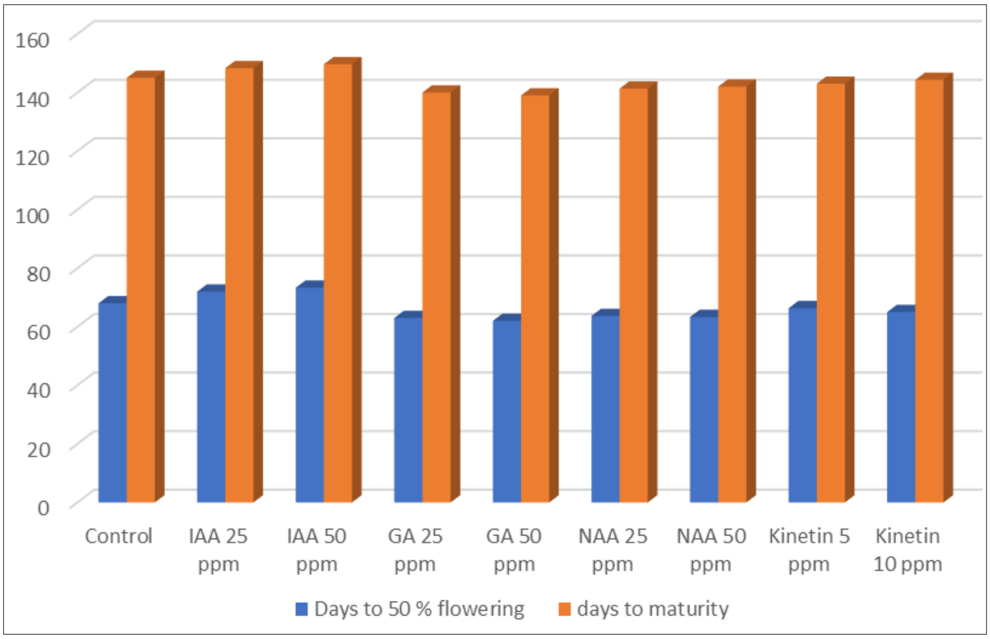

Fig 6: Effect of growth regulator on flowering or maturity (days)

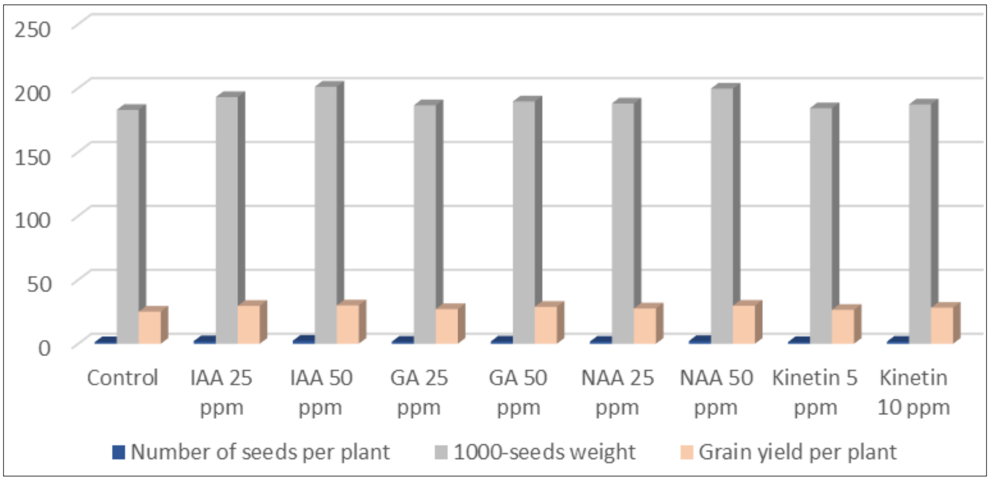

Fig 7: Effect of growth regulators on yield and its attributes

Conclusion

Hence, based upon the findings of present investigation it can be concluded that use of IAA @ 25 ppm would be rewarded best in enhancing growth characters and yield of chickpea.

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