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Effect of plant growth regulators and spacing on growth and yield of chickpea (*Cicer arietinum* L.)

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Abstract
The present investigation entitled "Effect of Plant Growth Regulators and Spacing on Growth and Yield of Chickpea (*Cicer arietinum* L.)" was conducted during *rabi* 2023-24 at Kalaghat Agriculture Farm, MS Swaminathan School of Agriculture, Shoolini University, Solan. The soil of experimental field was sandy loam in texture, slightly alkaline in reaction with EC in safer range, high organic carbon and available phosphorus, medium available nitrogen, and potassium. The field experiment was laid out in Split plot design assigning three row spacing (S_1) 15 cm, (S_2) 30 cm and (S_3) 45 cm in main plot and plant growth regulators in subplot *viz*. (G_0) Control, (G_1) NAA @ 40 ppm, (G_2) Mepiquat chloride @ 250 ppm and (G_3) Chlormequat chloride @ 500 ppm. Thus, a total of 12 treatment combinations were tested in the study and were replicated thrice. Recommended dose of nitrogen, phosphorus and potassium (30:60:30 kg ha^{-1}) through urea, SSP and MOP, respectively were applied at the time of sowing as basal dose. The total rainfall experienced during the crop growing season was 209 mm. GPF-2 variety of chickpea was used for sowing. The results concluded that among spacing (S_3) 45 cm exerted higher crop growth parameters *viz*. plant height (cm), number of branches plant^{-1}, dry matter accumulation, number of nodules plant^{-1} and dry weight of nodules (mg), which was statistically at par with spacing (S_2) 30 cm. In case of yield attributes and yield *viz*. number of pods plant^{-1}, number of seeds pod^{-1}, seed index (g) was recorded higher under spacing (S_3) 45 cm, while yield kg ha^{-1} (grain, stover and biological yield), was registered higher in spacing (S_2) 30 cm. While in case of plant growth regulators (G_1) NAA @ 40 ppm recorded higher crop growth parameters *viz*. plant height (cm), number of branches plant^{-1}, dry matter accumulation, number of nodules plant^{-1} and dry weight of nodules (mg), yield attributes and yield *viz*. number of pods plant^{-1}, number of seeds pod^{-1}, seed index (g), yield kg ha^{-1} (grain, stover and biological yield) over rest of the treatments.

Keywords: Growth performance, yield improvement, crop management, regulatory effects

Introduction
Pulses to their higher protein and oil content than cereals, are the most significant component of a vegetarian diet. They play a significant role in nutritional requirements, due to their abundance in energy-boosting minerals and vitamins. Referred to as "rich man's vegetable" and "poor man's meat," they complement the cereal-heavy diet of the primarily vegetarian masses and serve as nutrient-rich fodder for cattle. They are rich in protein and numerous critical amino acids particularly lysine. Chickpea (*Cicer arietinum* L.), is a diploid (2n= 14, 16 chromosomes) belongs to the family *Fabaceae*, subfamily *Faboideae*. Itis the largest food legume produced in South Asia. Due to nutritional or economic considerations, chickpea is one of the most easily accessible plant protein sources with an average of 21 g of protein, 61 g of carbohydrates, 6 g of fat, 24 mg of sodium, 875 mg of potassium and 364 calories per 100 grams. Tryptophan, isoleucine, lysine and other total aromatic amino acids are abundant in the proteins of cooked and germinated chickpea. There are a lot of unsaturated fatty acids in its lipid component. It is utilized as a green manuring crop because of its deep root structure which aids in adhering soil particles and reducing soil erosion. Through symbiosis, it fixes atmospheric nitrogen (60 kg ha^{-1} year^{-1}) and improves soil fertility (Negi *et al*., 2023) [12].

The chemicals known as plant growth regulators (PGRs) are used to change the way plants grow. For example, they can be used to increase branching, decrease shoot growth, remove extra fruit or change the maturity of the fruit. They are anticipated to be crucial in removing obstacles that prevent biological productivity from manifesting itself, especially in pulse crops (Varshitha *et al.*, 2022) [23]. The 1930s saw the first recognition of PGRs' significance. Since then, scientists have identified both natural and artificial substances that change the size, shape and function of crop plants. These days, particular PGRs are employed to alter the rate and pattern of crop growth at different phases of development ranging from germination to harvest and post-harvest preservation (Navya *et al.*, 2021) [11]. Environmental elements like as light, temperature, moisture, nutrients, and others have an impact on the effectiveness of plant growth regulators (Salunke *et al.*, 2008) [19]. Applying adequate amounts of naphthalene acetic acid (NAA) increases the production of adventitious roots and improves rooting activities, which increases the uptake of nutrients. It also increases cell division and enlargement, which increases plant growth (Varshitha *et al.*, 2022) [23].

Mepiquat chloride is a growth retardant chemical that aids in delaying the hormone gibberellic acid's generation in plants (Arteca, 1996) [1]. Using this technique, plants' chlorophyll content is increased, plant height is decreased and cell elongation is prevented. In these circumstances, mepiquat chloride's chemical causes the plant to grow shorter and shorter. Transmit metabolites from leaves and stems to fruit development between nodes, assisting in the growth of crop harvests. Performance and the number of pods per unit area are directly related. Plant species, cultivars, chemical concentration, timing of chemical administration, and other factors all affect how plant growth retardants work (Singh *et al.*, 2020) [21].

Cycocel, also known as chlormequat chloride, is a growth retardant that shortens the distance between nodes, lowers plant height, modifies the source-sink relationship and promotes photosynthate translocation towards the sink. It has also been reported that foliar spraying of chlormequat chloride aids in the achievement of higher assimilatory rates which in turn leads to higher production of dry matter. Additionally, cyclocel makes plant stems stronger and shorter. It has also been claimed that applying CCC boosts the synthesis of protein, lipids, and chlorophyll. Even though plant growth retardants have a lot of potential, it is important to carefully plan their application and proper assessment, taking into account factors such ideal concentrations, application stage, species specificity, and appropriate seasoning (Giakwad *et al.*, 2022) [7].

Plants per unit area have a direct impact on crop growth and output. One of the main causes of low yield in chickpeas is improper plant population. Crop yield is often negatively impacted by too low and excessive plant population after a certain point. Proper plant spacing in the field is to be chosen in order to maximize the rate of photosynthesis, aeration, and light penetration into the plant canopy (Singh *et al.*, 2023) [20]. Achieving the ideal plant population density is crucial for achieving potential yields, since it has a direct impact on the growth and development of chickpea plants as well as those of other crops like groundnut and sesame. Previous research indicates that chickpea yields exhibit remarkable stability throughout a broad spectrum of population densities. By starting lateral branches, the plants are able to occupy available area and make up for thin stands and poor emergence. Increasing row spacing significantly influenced of growth, yield attributes and yield characters. The required spacing varies according on the genotype's growth pattern. Thus, maintaining spacing is necessary to achieve a better yield (Veeramani, 2019) [24].

Materials and Methods

The experiment was concluded during *rabi* of 2023-24 at Kalaghat Agriculture Farm (Located at an elevation of 1270 meters above mean sea level lying between latitude 30º 51’26.9 N and longitude 77º 09’29.6 E), MS Swaminathan School of Agriculture, Shoolini University of Biotechnology and Management Sciences, Solan under the mid-hill zone of Himachal Pradesh. The field experiment laid out in Split plot design assigning three row spacing (S_1) 15 cm, (S_2) 30 cm and (S_3) 45 cm and plant growth regulators in subplot *viz*. (G_0) Control, (G_1) NAA @ 40 ppm, (G_2) Mepiquat chloride @ 250 ppm and (G_3) Chlormequat chloride @ 500 ppm. Thus, a total of 12 treatment combinations were tested in the study and were replicated thrice. Recommended dose of nitrogen, phosphorus and potassium (30:60:30 kg ha^{-1}) through urea, SSP and MOP, respectively were applied as basal dose. The total rainfall experienced during the crop growing season was 209 mm. GPF-2 variety of chickpea was used for sowing. The soil of experimental field was sandy loam in texture, slightly alkaline in reaction with EC in safer range, high organic carbon and available phosphorus, medium available nitrogen, and potassium. Observation related growth, yield attributes and yield were recorded by standard procedure. In order to test the significance of result, standard statistical method based on the analysis of variance technique as suggested by (Panse and Sukhatme 1967) [14] was employed. The treatment differences were compared with the critical difference (CD) at 5% level of significance to ascertain their significance.

Results and Discussion

Effect of spacing on growth parameters of chickpea

Because of different row spacing, growth parameters such as plant height, number of branches $plant^{-1}$, dry matter accumulation, number of nodules $plant^{-1}$, and dry weight of nodules changed significantly. The growth parameters of chickpea recorded at harvest is represented in Table 1. As the data revealed significantly higher plant height (46.47 cm), maximum number of branches (16.74 $plant^{-1}$), dry matter accumulation (7.99 g $plant^{-1}$), no. of nodules (8.53 $plant^{-1}$) and dry weight of nodules (15.03 mg $plant^{-1}$) at harvest was noticed under spacing (S_3) 45 cm which was statistically at par with spacing (S_2) 30 cm. This might be due to reason that at wider row spacing the plant growth was better as compare to narrow row spacing that leads to greater room for plants to grow for healthy root development. Also at wider spacing the rate of photosynthesis was high among plants. Poor plant growth among narrow spacing might result from the inter and intra-plant competition for space, nutrients, water, light, and other resources. Higher light exposure and enhanced nutritional availability to plants have also improved photosynthetic activity, which has led to higher dry weight. Similar results were also reported by Gadade *et al*. (2018) [6]; Mohanta and Singh (2021) [10]; Kumar *et al*. (2021) [9] and Pandey *et al*. (2022) [13].

Effect of plant growth regulators on growth parameters of chickpea

It is well known that plant growth regulators control a plant's metabolism, influence stem elongation, make leaves more green, and indirectly influence flowering without harming the plant. Significantly higher plant height (46.03 cm) was recorded under treatment (G_1) NAA @ 40 ppm while lowest plant height (38.38 cm) was recorded under treatment (G_2) Mepiquat chloride @ 250 ppm (Table 1). This might be due to the reason that NAA is member of the auxin group and is therefore important for the development of plant roots, the increase in plant height caused by foliar application of NAA may be the result of increased cell elongation, cell division, and growth-enhancing properties of this hormone. The decrease in plant height due to application of chlormequat chloride and mepiquat chloride might be due to its growth retarding nature and increasing plant compaction by increasing number of branches. In case of other growth parameters such as number of branches (16.72 plant^{-1}), dry matter accumulation (7.78 g plant^{-1}), number of nodules (8.81 plant^{-1}), and dry weight of nodules (14.44 mg plant^{-1}) significantly higher results were noticed under treatment (G_1) NAA @ 40 ppm followed by (G_2) Mepiquat chloride @ 250 ppm, (G_3) chlormequat chloride @ 500 ppm and at last by (G_0) control. The foliar application of NAA could also result in enhanced photosynthetic activity, improved photosynthate mobilization, and increased membrane permeability. Similar results were also reported by Aslam *et al*. (2010) [2]; Rajesh *et al*. (2014) [18]; Singh *et al*. (2018) [22] and Singh *et al*. (2020) [21].

Effect of spacing on yield attributes and yield of chickpea

Data in Table 2 revealed that yield attributes number of pods plant^{-1} (26.53) was found to be significantly higher in spacing (S_3) 45 cm which was statistically at par with spacing (S_2) 30 cm. However number of seeds pod^{-1}, seed index (weight of 100 seeds) was found to be higher in (S_3) 45 cm. This might be due to the reason that increased vigor and strength acquired by the plants as a result of improved photosynthetic activities with enough light availability and the supply of nutrients in optimum quantity and also wider crop spacing results in improved crop development, more plant space, and less rivalry between plants for nutrients and moisture which ultimately leads to higher yield attributes. Similar results were also reported by Pandey *et al*. (2022) [13] and Choudhary *et al*. (2023) [5]. However, in case of yield (kg ha^{-1}) as the data revealed in Table 3, significantly higher grain yield (1096.98 kg ha^{-1}), stover yield (2142.00 kg ha^{-1}), and biological yield (3238.98 kg ha^{-1}) was recorded under spacing (S_2) 30 cm over rest of the treatments. This might be due to the reason that even if the number of pod plants^{-1} was found to be highest in wider crop spacing, the lower plant population prevented it from making up more yield and also the growth parameters of spacing (S_2) 30 cm was statistically at par with the spacing (S_3) 45 cm and plant population was also optimum in 30 cm spacing so these are the major factors which ultimately leads to higher yield over rest of the treatments. Similar results were reported by Bavalgave *et al*. (2009) [3]; Kumar *et al*. (2021) [9]; Pradhan and Singh (2022) [17] and Choudhary *et al*. (2023) [5].

Effect of plant growth regulators on yield attributes and yield of chickpea

Data in Table 2 and 3 revealed that significantly higher number of pods (27.78 plant^{-1}), grain yield (1082.44 kg ha^{-1}), stover yield (2086.67 kg ha^{-1}), and biological yield (3169.11 kg ha^{-1}) was noticed under treatment (G_1) NAA @ 40 ppm over rest of the treatments. The reason for higher yield attributes under NAA might be due to the reason that it is responsible for cell elongation and division and also reduce flower and pod dropping which enhanced the pod and fruit setting, which ultimately leads to higher yield (kg ha^{-1}) of chickpea. Similar results were reported by Prabhakar, (2002) [16]; Rajesh *et al*. (2014) [18]; Chandewar *et al*. (2016) [4]; Gnyandev *et al*. (2019) [8] and Pawar *et al*. (2022) [15].

Table 1: Effect of row spacing and plant growth regulators on growth parameters of chickpea at harvest

Treatments	Growth parameters				
	Plant height (cm)	No. of branches plant^{-1}	Dry matter accumulation (g plant^{-1})	Number of root nodules plant^{-1}	Dry weight of nodules (mg plant^{-1})
Main Plot (Row Spacing)					
S_1: 15 cm	34.92	11.48	6.02	3.90	7.55
S_2: 30 cm	42.96	15.54	7.38	7.92	13.99
S_3: 45 cm	46.47	16.74	7.99	8.53	15.03
S.Em±	0.90	0.36	0.16	0.21	0.39
LSD (*p*=0.05)	3.53	1.43	0.63	0.83	1.51
Sub Plot (Plant Growth regulators)					
G_0: Control	41.93	11.35	6.27	4.13	9.83
G_1: NAA @ 40 ppm	46.03	16.72	7.78	8.81	14.44
G_2: Mepiquat chloride @ 250 ppm	38.38	15.40	7.26	7.38	12.49
G_3: Chlormequat chloride @ 500 ppm	39.46	14.86	7.13	6.81	12.00
S.Em±	0.77	0.33	0.14	0.19	0.38
LSD (*p*=0.05)	2.30	0.98	0.44	0.57	1.14
Interaction	NS	NS	NS	NS	NS

Table 2: Effect of row spacing and plant growth regulators on yield attributes of chickpea at harvest

Treatments	Yield attributes		
	No. of pods plant^{-1}	No. of seeds pod^{-1}	Seed index (g)
Main Plot (Row Spacing)			
S_1: 15 cm	13.45	1.85	15.22
S_2: 30 cm	25.02	2.01	15.27
S_3: 45 cm	26.53	2.05	15.31
SEm±	0.61	0.04	0.02
LSD (*p*=0.05)	2.38	NS	NS
Sub Plot (Plant Growth regulators)			
G_0: Control	14.88	1.88	15.21
G_1: NAA @ 40 ppm	27.78	2.03	15.31
G_2: Mepiquat chloride @ 250 ppm	23.29	2.01	15.28
G_3: Chlormequat chloride @ 500 ppm	21.69	2.00	15.27
S.Em±	0.59	0.04	0.02
LSD (*p*=0.05)	1.75	NS	NS
Interaction	NS	NS	NS

Table 3: Effect of row spacing and plant growth regulators on yield and harvest index of chickpea at harvest

Treatments	Yield (kg ha^{-1})			
	Grain yield	Stover yield	Biological yield	Harvest index (%)
Main Plot (Row Spacing)				
S_1: 15 cm	851.50	1717.92	2569.42	33.13
S_2: 30 cm	1096.98	2142.00	3238.98	33.86
S_3: 45 cm	959.42	1914.92	2874.33	33.37
S.Em±	22.60	37.90	58.91	0.45
LSD (p=0.05)	88.72	148.83	231.33	NS
Sub Plot (Plant Growth regulators)				
G_0: Control	812.98	1676.11	2489.09	32.66
G_1: NAA @ 40 ppm	1082.44	2086.67	3169.11	34.15
G_2: Mepiquat chloride @ 250 ppm	1012.56	1985.89	2998.44	33.76
G_3: Chlormequat chloride @ 500 ppm	969.22	1951.11	2920.33	33.18
S.Em±	19.72	31.59	41.48	0.43
LSD (p=0.05)	58.59	93.86	123.23	NS
Interaction	NS	NS	NS	NS

Conclusion

Among the row spacing, (S_3) 45 cm recorded significantly higher growth and yield attributes which was statistically at par with spacing of (S_2) 30 cm over (S_1) 15 cm. In case of yield (grain, stover and biological) was significantly improved with row spacing of (S_2) 30 cm over the rest of spacing during course of study. Application of (G_1) NAA @ 40 ppm recorded significantly higher growth parameters, yield attributes and yield (kg ha^{-1}). Overall the combination of 30 cm spacing with application of NAA @ 40 ppm is suitable for higher yield of chickpea under mid hills of Himachal Pradesh Conditions.

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