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Yield and quality responses of chickpea to varying doses and application timings of mepiquat chloride

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ABSTRACT

Plant growth regulators (PGR) can provide positive increases in yield and quality parameters by directing plant physiology. This research was conducted under Kahramanmaraş conditions during the 2018 production season to determine the effects of "Pix" plant growth regulator (active ingredient: 1,1-dimethylpiperidinium chloride) on yield, morphological components, and quality characteristics of the local 'Aksu' chickpea (*Cicer arietinum* L.) variety. The study was established in a randomized block experimental design with 3 replications, testing 4 different PGR doses (50, 100, 150, and 200 ppm) and 3 different application periods (initial flowering, 15 days after the first application, and 15 days after the second application). Research results revealed that the effects of PGR applications on physiological maturity duration, plant height, first pod height, 100-grain weight, and grain yield were statistically significant (at 0.05 and 0.01 levels). The highest grain yield was obtained from the 2nd period applications (219.5 kg da⁻¹), and in the context of period x dose interaction, from the 50 ppm dose applied in the 2nd period (230.3 kg da⁻¹). While 3rd period applications stood out for 100-grain weight (44.67 g), no clear statistical trend was observed for flowering duration, number of branches per plant (5.0-5.9), number of pods per plant (30.6-34.6), and protein ratio (22.23-22.76%). The findings demonstrate that using PGRs at the correct period and dose holds significant potential for yield management in chickpeas.

Keywords: Chickpea, Plant Growth Regulator, Mepiquat Chloride, Grain Yield, Agricultural Characteristics

1. Introduction

Along with global population growth, the demand for basic nutrients is increasing day by day (Scholz *et al.*, 2026) [1]. To ensure a balanced diet, it is important to consume plant and animal-based foods together. An individual with an average weight of 70 kg needs to consume approximately 70 g of protein daily, of which 40 grams should be plant-based (Akçin, 1988) [2]. Legumes play a critical role in this process (Uçar *et al.*, 2021) [3]. Compared to cereal crops, edible grain legumes contain 2 to 2.5 times more protein (Şehirli, 1988) [4]. Legume plants alone provide 22% of the plant-based proteins consumed by people worldwide (Wery *et al.*, 1983) [5]. Furthermore, chickpea (*Cicer arietinum* L.) is distinguished by its high nutritional value, providing protein, dietary fiber, essential minerals such as calcium, magnesium, phosphorus, potassium, iron, and zinc, as well as vitamins including folate, thiamine, riboflavin, and niacin (Jukanti *et al.*, 2012; Kumar *et al.*, 2025) [6, 7]. The combined presence of protein, complex carbohydrates, fiber, and bioactive compounds contributes to its potential role in supporting dietary quality and reducing the risk of metabolic disorders (Begum *et al.*, 2023) [8]. Although chickpea seeds contain antinutritional factors, appropriate processing and cooking methods can substantially reduce their adverse effects and improve nutrient utilization (Jukanti *et al.*, 2012) [6].

Chickpea (*Cicer arietinum* L.), for which Turkey is one of the genetic centers, is an indispensable part of agricultural areas due to its tolerance to harsh climate conditions and its ability to fix free nitrogen into the soil via its nodules (Egeli & Co., 2016) [9]. It has a high tolerance against climate stress caused by global warming, and according to 2017 data, it has a massive share in human nutrition with a global production of 14.7 million tons (FAO, 2018) [10]. In Turkey, the harvested chickpea area covers a very large potential in the 2018 statistics (TÜİK, 2019) [11]. Chickpea is ranked as the second most important food grain legume worldwide after common bean and is cultivated in more than 50 countries for its protein-rich seeds (Smýkal *et al.*, 2014). Beyond its nutritional and economic value, its symbiotic nitrogen-fixation capacity supports soil fertility, enhances the sustainability of crop rotations, and strengthens its role in low-input agricultural systems (Smýkal *et al.*, 2014; Sahruzaini *et al.*, 2020) [12].

One of the modern ways to increase yield per unit area is the use of "Plant Growth Regulators (PGR)". The performance of regulators, which prevent crop losses by modulating growth, is highly dependent on the species and ecology (Khan *et al.*, 2018) [13]. This specific study aimed to discover the optimum application dose and period of a growth regulator containing 1,1-dimethylpiperidinium chloride (Pix) as its active ingre

dient on the chickpea plant (Aksu variety) in the Kahramanmaraş ecology, and to examine the variations in yield and protein ratio.

2. Materials and Methods

The research was carried out in the experimental field of the Field Crops Department of Kahramanmaraş Sütçü İmam University in 2018. The experimental area has a loamy-calcareous structure at a depth of 0-30 cm, is poor in organic matter (2.08%), and has a pH level of 7.28 (Yılmaz, 2018) [14]. The 'Aksu' chickpea variety used in the study has a ram-head grain type and a semi-erect form.

In the study, the Pix (1,1-dimethylpiperidinium chloride) plant growth regulator was applied as a suspension at doses of 50, 100, 150, and 200 ppm, in 3 different periods:

1st Period: At the initial flowering stage (04.05.2018)

2nd Period: 15 days after the first application (18.05.2018)

3rd Period: 15 days after the second application (01.06.2018)

Physiological observations, first pod height, branch and pod numbers, 100-grain weight, grain yield per decare (kg da^{-1}), and protein ratio (%) characteristics were determined. The obtained data were subjected to variance analysis (ANOVA) in a randomized block experimental design using the JMP software, and group differences were separated by Duncan's multiple range test (in accordance with the standard agricultural research methodology applied by).

3. Results and Discussion

3.1. Effects on morphological and growth parameters physiological maturity and plant height

As the doses increased, a shortening tendency was detected in the physiological maturity duration, decreasing to 93.4 days at 200 ppm. For plant height, a statistical difference at the 0.05 level was found. The longest plant height (53.5 cm) was obtained from the 1st period applications. Conversely, increasing application doses significantly reduced plant height, presumably because mepiquat chloride inhibits gibberellin biosynthesis and thereby restricts cell division, cell elongation, and internode development (Wang *et al.*, 2020) [15]. This response indicates that the intensity of vegetative growth suppression depended on both the applied dose and application period, as reported in other legume studies in which moderate mepiquat chloride treatments reduced stem elongation without providing additional advantages at higher doses (Elkoca *et al.*, 2006) [16]. Therefore, the reduction in plant height should be evaluated together with yield and reproductive traits, since excessive growth regulation may compromise overall crop performance.

First Pod Height: The highest value for the first pod height, which is vital for mechanization during harvest, reached up to 31.7 cm in the 3rd period applications and at the 150 ppm dose. Accordingly, the increase in first pod height under the third-period, 150 ppm treatment should be interpreted as a treatment-specific morphological response rather than a general improvement in canopy structure. This distinction is agronomically important because an elevated first pod position may facilitate combine harvesting, whereas excessive growth regulation can adversely affect reproductive development; therefore, PGR effects should be evaluated jointly using plant height, first pod height, and subsequent yield components (Elkoca *et al.*, 2006) [16].

3.2. Effects on yield and yield components number of branches and pods per plant

Statistical analyses revealed that PGR application and its periods did not make a statistically significant difference ($P > 0.05$) on the number of branches (avg. 5.4) and pods (avg. 32.5). It was observed that increasing doses suppressed branch formation; the highest number of branches (6.2) was obtained from the 1st period 50 ppm dose. This pattern indicates that mepiquat chloride modified vegetative growth without producing a statistically reliable improvement in branch or pod formation. The apparent suppression at higher doses may reflect a shift in assimilate allocation and reduced internode development, whereas the relatively favorable response to the 50 ppm treatment ap-

plied during the first period suggests that moderate regulation at the onset of flowering may preserve reproductive potential. Similar dose- and stage-dependent responses have been reported in pea, where low-dose application at early blooming produced more favorable yield-related effects than later or higher-dose treatments (Elkoca *et al.*, 2006) [16]. Accordingly, the absence of significant differences in this experiment indicates that the observed numerical trends should be interpreted cautiously and evaluated together with grain yield and other yield components.

100-Grain Weight: The effect of application periods was significant (at 0.05), and especially the 3rd period applications (44.67 g) promoted the formation of larger grains. This response may indicate that the late application altered source-sink relations during seed development, allowing a greater proportion of assimilates to be retained in individual grains. Comparable responses have been attributed to the capacity of mepiquat chloride to modify cell expansion and prolong nutrient accumulation in developing seeds, although the magnitude of this effect may vary according to genotype and environmental conditions (Qureshi *et al.*, 2024) [17].

Grain Yield (kg da^{-1}): Period ($p < 0.05$) and Period $\times$ Dose interaction ($p < 0.01$) created critical differences statistically. While the average yield was 209.8 kg da^{-1} , the applications made in the second period provided the most successful result (219.5 kg da^{-1}). In the dose parameter, the highest grain yield was observed in the plots where the 50 ppm dose was applied in the 2nd period (230.3 kg da^{-1}). However, the high rate of regulator application (e.g., 150 ppm) in the 3rd period (late period) reduced the yield to levels of 139.4 kg da^{-1} , causing a regression in the plant. This pronounced reduction suggests that excessive growth inhibition during the later developmental stages may disrupt assimilate partitioning between vegetative sources and reproductive sinks, thereby restricting seed filling and reducing overall productivity. A similar stage-dependent response has been reported in pea, where early-bloom applications produced more favorable yield outcomes than applications during early pod filling, while higher mepiquat chloride rates provided no consistent additional benefit (Elkoca *et al.*, 2006) [16].

3.3. Grain quality: protein ratio (%)

In protein ratio analyses, differences in dose and application periods did not create a clear group separation at the 5% significance level. Although not strictly statistical, the highest grain biochemical content numerically was measured as 23.02% with the 1st period 200 ppm PGR application. The general experimental average was stabilized at around 22.37% in terms of protein, demonstrating that the genetic character remained dominant. This stability suggests that, although plant growth regulators effectively modified plant architecture and yield formation, they had a limited influence on the biochemical processes governing nitrogen accumulation in the seeds. The absence of a significant treatment effect further indicates that protein concentration was primarily determined by genotype and the crop's nutritional and symbiotic nitrogen status rather than by mepiquat chloride application alone (Khan *et al.*, 2018) [13]. Therefore, the numerical variation observed among treatments should be considered insufficient to support a consistent improvement in chickpea grain protein quality under the conditions of this experiment.

4. Conclusion

According to the results, it was determined that the use of mepiquat chloride-based PGR in chickpea cultivation in the Kahramanmaraş ecology, especially when applied at specific doses and windows, regulated the morphological parameters of the plant (plant height and physiological development), and optimized the yield in favor of the farmer (230.3 kg da^{-1}) during the grain production process (mostly in the 2nd period and at 50-100 ppm doses). However, late period applications or high dose limits such as 150-200 ppm suppress the vegetative/reproductive development of the chickpea, negatively affecting the yield. Although chemical stability generally showed limited variation for branch, pod numbers, and protein ratios (avg. 22%),

it is concluded that growth regulators have a serious reserve in optimized agricultural systems; and to use them effectively, it is recommended to continue experimental designs for different locations in the coming years.

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