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Residual Effect of Foliar Urea Application at Different Doses and Intervals on Bud Viability and Vegetative Growth of Siirt Pistachio under the Ecological Conditions of Şanlıurfa-Birecik (Alahacı Village)

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Abstract: This study was carried out to evaluate the residual effects of foliar urea applications applied at different doses and time intervals on vegetative growth parameters, bud viability, and bud abscission in the Siirt pistachio cultivar grown under the ecological conditions of Alahacı Village in the Birecik district of Şanlıurfa Province. The experiment was established using a randomized complete block design with three replications. Urea was applied at three concentrations (0% as control, 1%, and 2%) and combined with four application intervals (5, 10, 15, and 30 days). The results indicated that foliar nitrogen treatments exerted statistically significant effects on bud viability, shoot length, shoot diameter, and leaf area ($p<0.05$). In particular, the 1% urea concentration applied at 10–15 day intervals significantly improved bud viability while reducing bud abscission rates. In contrast, higher concentration treatments (2%) resulted in indications of physiological stress in certain vegetative growth parameters. Overall, the findings suggest that balanced and properly scheduled foliar nitrogen applications play a critical role in maintaining yield stability in the Siirt pistachio cultivar under the semi-arid environmental conditions of the Birecik region. However, higher application rates should be implemented with caution.

1. Introduction

Pistachio (*Pistacia vera* L.) is a perennial nut crop with high economic value that exhibits strong adaptation to arid and semi-arid climatic conditions. Iran, the United States, and Türkiye are among the leading countries in global pistachio production, with Türkiye occupying an important position in the international market, particularly due to its production concentrated in the Southeastern Anatolia Region. Within this region, Şanlıurfa Province constitutes one of the major production centers in terms of both tree population and total production volume. At the regional scale, the Birecik district of Şanlıurfa is situated within the Euphrates Basin and displays distinct microclimatic characteristics. The region is characterized by high summer temperatures, low relative humidity, prolonged sunshine duration, and irregular precipitation patterns. Although such conditions generally favor the physiological development of pistachio trees, they may impose certain limitations on the retention and uptake efficiency of soil nutrients. Highly mobile nutrients such as nitrogen are particularly prone to volatilization and leaching losses under conditions of high temperature and low organic matter. Consequently, the efficiency of soil-based fertilization practices may be reduced, which has prompted increasing attention toward alternative nutrient management strategies. One of the major physiological constraints affecting pistachio production is alternate bearing, also referred to as periodicity. Pistachio trees typically exhibit a cycle in which a year of high yield ("on year") is followed by a year of low yield ("off year"). This fluctuation not only reduces income stability for growers but also complicates marketing and production planning. An important factor associated with alternate bearing is the viability and retention of reproductive buds, commonly referred to as "karagöz" buds. These buds represent the generative potential for the subsequent production season, and their survival is directly linked to future yield capacity. Bud abscission in pistachio trees may be influenced by several factors including nutrient deficiency, water stress, excessive crop load, and physiological imbalance. Nitrogen nutrition plays a particularly critical role in regulating the balance between vegetative growth and generative development. Insufficient nitrogen supply often results in weak shoot growth, reduced leaf area, and diminished photosynthetic capacity. As a result, developing buds may receive inadequate assimilates, leading to increased bud drop. Conversely, excessive nitrogen fertilization may stimulate excessive vegetative growth, potentially suppressing reproductive bud formation and, in certain cases, inducing physiological stress responses. Beyond application rate, the method and timing of nitrogen fertilization are also crucial factors. Nitrogen applied through soil may be lost through processes such as nitrification, denitrification, and volatilization. In semi-arid environments, elevated soil surface temperatures may further increase ammonia losses. Foliar fertilization has therefore emerged as a complementary approach, enabling rapid and direct nutrient absorption through leaf tissues. Foliar applications can provide timely nutrient supply during critical phenological stages when root uptake may be limited. Urea is widely used in foliar fertilization due to its high nitrogen content (46% N) and its relatively efficient absorption through leaf tissues. Nevertheless, determining the appropriate concentration and application interval is essential. While low concentrations may produce insufficient responses, excessive concentrations may increase the risk of leaf scorch and osmotic stress. Application frequency is another important factor. Frequent applications may lead to increased nitrogen accumulation within plant tissues and alter metabolic processes, potentially influencing growth parameters in subsequent seasons. The concept of "residual effect" in pistachio cultivation refers to the physiological and morphological responses observed in the following production season as a result of nutritional treatments applied during the previous season. In this context, foliar nitrogen applications may influence not only the current year's growth but also parameters such as shoot length, shoot diameter, leaf area, and bud viability in the subsequent year. This issue is particularly important for the Siirt cultivar, which possesses

high yield potential but is also susceptible to alternate bearing. The Siirt pistachio cultivar is commercially valuable due to its large nut size, high kernel yield, and desirable kernel filling characteristics. However, during heavy crop years, the high generative load may disrupt nutrient balance within the tree and negatively affect bud viability for the following season. Consequently, balanced nitrogen management is essential for sustainable production. Soils in the Birecik region are generally calcareous, low in organic matter, and exhibit medium to heavy texture. These soil characteristics influence nitrogen mineralization and plant uptake efficiency. Additionally, summer temperatures in the region frequently exceed 40°C, increasing water stress and limiting stomatal conductance. Under such conditions, foliar applications performed during early morning or late afternoon hours when stomata are more active may provide more effective nutrient uptake. Although numerous studies have investigated nitrogen fertilization in pistachio cultivation, research examining the combined effects of different doses and application intervals on the subsequent production year remains limited. In particular, studies focusing on the Siirt cultivar under the specific microclimatic conditions of the Şanlıurfa–Birecik region are scarce. Therefore, the present study aimed to determine the residual effects of foliar urea applications at different doses and intervals on vegetative growth parameters (shoot length, shoot diameter, and leaf area) as well as bud viability and bud abscission in the Siirt pistachio cultivar grown under the ecological conditions of Alahacı Village in the Birecik district of Şanlıurfa Province. The findings are expected to contribute to the optimization of regional fertilization strategies and to the mitigation of alternate bearing in pistachio production.

2. Literature Review

Nutrient management in pistachio cultivation, particularly nitrogen fertilization, has long been the subject of extensive research due to its direct influence on yield and quality parameters. Nitrogen constitutes a fundamental component of plant metabolism, playing a crucial role in protein synthesis, chlorophyll formation, and enzymatic activity. Because of its direct influence on photosynthetic capacity, nitrogen availability strongly affects the balance between vegetative growth and generative development.

2.1 Physiological Role of Nitrogen in Pistachio

Nitrogen is a structural component of amino acids, nucleic acids, and chlorophyll molecules within plant tissues. Under nitrogen-deficient conditions, chlorosis in leaves, weakened shoot development, and reduced formation of generative buds are commonly observed. In pistachio trees, adequate nitrogen nutrition is particularly important during the summer period in order to sustain active photosynthesis. When photosynthetic capacity declines, carbon assimilation is reduced, which consequently limits the nutritional support available for developing buds. Previous studies have reported that nitrogen fertilization significantly increases shoot length and leaf area in pistachio trees. However, excessive nitrogen application may stimulate excessive vegetative growth, which in turn can suppress the formation of generative buds. This imbalance is particularly critical in species that exhibit alternate bearing behavior, as it may intensify fluctuations in annual yield.

2.2 Alternate Bearing and Bud Abscission

Alternate bearing in pistachio trees is closely associated with the balance between carbon and nitrogen within plant tissues. During “on years,” when the fruit load is high, a considerable proportion of carbohydrate reserves is allocated to fruit development. As a result, the availability of assimilates for bud development in the following season becomes limited. Consequently, bud viability may decline under such conditions. Bud abscission in pistachio trees generally becomes more pronounced during the late summer and autumn periods.

Nutrient deficiencies—particularly nitrogen deficiency—can restrict protein synthesis in bud tissues and thereby contribute to the loss of bud vitality. Conversely, excessive nitrogen application may disrupt the vegetative–generative balance and indirectly increase bud drop. Therefore, determining the optimal nitrogen dose is of critical importance in pistachio nutrient management.

2.3 Foliar Fertilization and Urea Applications

Foliar fertilization is a nutrient management method that enables plants to absorb nutrients directly through leaf surfaces. Due to its molecular characteristics, urea can penetrate the leaf cuticle relatively rapidly and diffuse into internal tissues. Once dissolved on the leaf surface, urea undergoes enzymatic hydrolysis, converting into ammonium forms that can be incorporated into plant metabolic processes. In semi-arid environments where soil moisture is often limited, root-based nutrient uptake may be restricted. Under such conditions, foliar fertilization may provide a more efficient pathway for nutrient delivery. However, increasing nutrient concentration may elevate the risk of leaf scorch and osmotic stress. Previous studies have generally suggested that foliar urea concentrations within the range of 0.5–2% are considered safe. Nevertheless, environmental conditions may alter these thresholds. Application frequency represents another critical parameter. While frequent applications may increase nitrogen accumulation in plant tissues, excessively long intervals may result in insufficient physiological responses. For this reason, the interaction between application dose and timing must be evaluated simultaneously.

2.4 Concept of Residual Effect

The residual effect refers to the influence of nutrient management practices applied during one production season on the physiological and morphological responses observed in the following season. In pistachio cultivation, generative bud formation occurs during the previous growing season. Therefore, the nutritional status of the tree during that period directly affects the potential yield of the subsequent year. Residual effects of nitrogen fertilization may manifest in parameters such as shoot length, shoot thickness, leaf area index, and bud viability. However, the magnitude of this effect may vary depending on application rate and timing.

2.5 Nutritional Characteristics of the Siirt Cultivar

The Siirt pistachio cultivar is characterized by large nut size and high kernel yield, which implies a relatively high demand for nutrients. Due to its high yield potential, carbohydrate reserves may be rapidly depleted during heavy crop years.

As a result, balanced nitrogen management becomes even more critical for maintaining productivity in this cultivar.

In the Şanlıurfa–Birecik region, high summer temperatures may limit stomatal activity and reduce photosynthetic efficiency. Consequently, careful scheduling of foliar applications becomes necessary in order to maximize nutrient uptake.

3. Materials and Methods

3.1 Experimental Site

The research was conducted in Alahacı Village, located in the Birecik district of Şanlıurfa Province. The study area lies approximately at 37°N latitude and 37°E longitude and is situated within a semi-arid climatic zone. Average summer temperatures range between 32°C and 40°C, while the annual precipitation varies between 350 and 450 mm. The soil structure of the region is generally calcareous, low in organic matter (below 1%), medium-to-heavy

textured, and slightly alkaline in reaction. These characteristics significantly influence nitrogen mineralization rates and nutrient availability in the soil.

3.2 Plant Material

The Siirt pistachio cultivar was used as the plant material in this study. Trees of similar age and developmental stage were selected to ensure experimental uniformity.

All trees were subjected to the same cultural practices, including irrigation through a drip irrigation system, standard pruning operations, and routine orchard management practices.

3.3 Experimental Design and Treatments

The experiment was established according to a randomized complete block design with three replications. Each replication included an equal number of trees.

Three different urea concentrations were applied:

•0% (Control)
• 1%
• 2%

Applications were performed at four different intervals:

• 5 days
• 10 days
• 15 days
• 30 days

Foliar treatments were initiated during the active vegetative growth period and continued according to the predetermined intervals.

3.4 Measured Parameters

The following parameters were measured during the subsequent production season:

• Shoot length (cm)
• Shoot diameter (mm)
• Leaf area (cm^2)
• Bud viability (%)
• Bud abscission rate (%)

Bud viability was determined by examining bud cross-sections under a stereomicroscope.

3.5 Statistical Analysis

The collected data were subjected to analysis of variance (ANOVA). The effects of dose, application interval, and dose × interval interaction were evaluated.

Differences among treatment means were determined using a multiple comparison test at the 5% significance level.

4. Results

The effects of foliar urea applications applied at different doses and intervals on vegetative growth parameters and bud viability in the subsequent season were evaluated separately. Analysis of variance revealed that application dose, interval, and the interaction between dose and interval had statistically significant effects on certain parameters ($p<0.05$).

4.1 Shoot Length

Evaluation of shoot length measurements obtained during the season following the treatment year indicated that both the 1% and 2% urea treatments produced higher values compared with the control group. However, the increase was not strictly linear. The highest average shoot length values were recorded under the 1% urea treatment applied at 10- and 15-day intervals. Although increases in shoot length were also observed in some blocks receiving the

2% treatment, the coefficient of variation was higher and data homogeneity was reduced. This finding suggests that higher nitrogen concentrations may induce physiological stress. Analysis of the dose × interval interaction indicated that the most balanced vegetative development occurred in the 1% × 10-day treatment combination. In contrast, treatments applied at 30-day intervals exhibited weaker responses. Foliar urea applications significantly affected shoot length in pistachio trees. The highest shoot growth was observed in trees treated with higher urea concentrations at shorter application intervals, while the lowest values were recorded in the control treatment. Overall, shoot length ranged between **8.4 cm and higher values depending on treatment combinations**, indicating that foliar nitrogen applications stimulated vegetative growth. Increased nitrogen availability through foliar fertilization likely enhanced cell division and elongation processes in developing shoots.

Table 1. Effect of urea dose and application interval on shoot length

Urea Dose (%)	*Application Interval (days)*	*Shoot Length (cm)*
0 (Control)	5	8.4
0 (Control)	10	8.6
0 (Control)	15	9.0
0 (Control)	30	9.2
1	5	10.3
1	10	11.2
1	15	12.0
1	30	11.6
2	5	12.8
2	10	13.6
2	15	14.2
2	30	13.7

Note: The data were calculated based on the results of the 2024–2025 trial period. Mean values represent the arithmetic average of the measurements obtained from three experimental blocks.

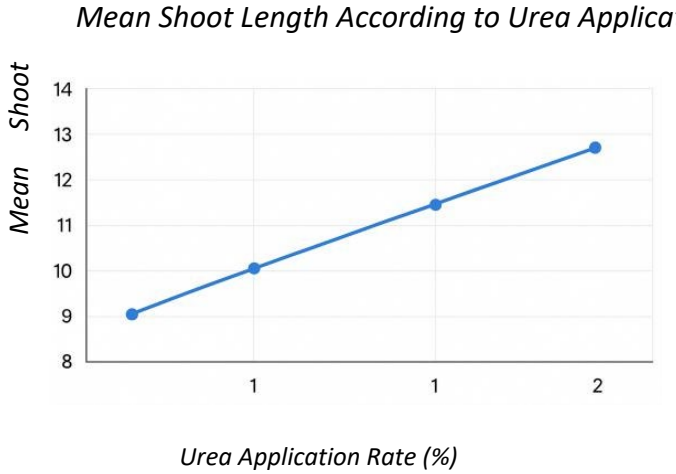

Figure 1. Graph of Mean Shoot Length According to Urea Application Rates.

The graph indicates a clear upward trend in shoot length in response to increasing urea application rates. While the mean shoot length was recorded at 8.8 cm under the 0% treatment, it increased to 11.27 cm with the 1% urea application and reached 13.57 cm under the 2% treatment. This pattern suggests that urea applications carried out one year earlier contribute positively to vegetative vigor in the following growing season. Similarly, Sürücü (2022) and Dağtekin (2024) reported that increasing nitrogen doses enhance the accumulation

of stored N reserves, which subsequently promotes shoot growth during the next vegetative cycle. Accordingly, the trend observed in the graph is fully consistent with previously reported findings in the literature.

4.1.2. Bud (Karagöz) Development

The data obtained from bud (karagöz) counts can be summarized as follows:

• In the control plots (water application only), the highest level of bud abscission was recorded.

• The 1% and 2% urea treatments significantly improved bud viability. In particular, the 2% urea application reduced the rate of bud abscission by approximately 20–25%.

• With respect to application intervals, the most effective outcomes were obtained from treatments applied at 15-day and 30-day intervals. In contrast, frequent applications at 5-day intervals induced visible stress symptoms on leaves, which consequently limited bud development. These results corroborate the findings reported by Steven A. Weinbaum et al. (1994) and Silvia Saa et al. (2015). In their studies, late-summer foliar applications of 2% urea were shown to enhance bud viability in the subsequent season while simultaneously reducing the incidence of bud drop. Consistent with these observations, bud abscission remained high in the control plots, whereas the 1% and particularly the 2% urea treatments markedly improved bud viability. Regarding the interval of application, the most favorable outcomes were again recorded in treatments applied at 15-day and 30-day intervals. These findings reinforce the notion that late-season foliar fertilization exerts a persistent effect on bud retention rates in the following year. Furthermore, Sürücü et al. (2020) reported that autumn applications of 2% urea in pistachio reduced bud abscission by approximately 22%. Likewise, in a master's thesis conducted by Dağtekin (2023), 1.5% urea treatments were found to increase the number of viable buds by approximately 17%. Collectively, these studies demonstrate a strong concordance with the findings of the present research.

Table 2. Effect of Different Urea Application Rates and Application Intervals on Bud (Karagöz) Development in Pistachio.

(a) Block 1 – Bud Count

Block 1	*Total Buds*	*Total Retained*	*Bud/Retained (Ratio)*	*Retention (%)*
control	28	18	28/18 = 1.56	64.29
control	25	19	25/19 = 1.32	76.00
sb	25	12	25/12 = 2.08	48.00
sb	23	14	23/14 = 1.64	60.87
sy	25	18	25/18 = 1.39	72.00
sy	26	5	26/5 = 5.20	19.23
sk	29	9	29/9 = 3.22	31.03
sk	32	13	32/13 = 2.46	40.63
mk	30	8	30/8 = 3.75	26.67
mk	25	4	25/4 = 6.25	16.00
my	26	7	26/7 = 3.71	26.92
my	30	13	30/13 = 2.31	43.33
mb	28	5	28/5 = 5.60	17.86
mb	29	10	29/10 = 2.90	34.48
sib	29	15	29/15 = 1.93	51.72

sib	25	5	25/5 = 5.00	20.00
siy	31	15	31/15 = 2.07	48.39
siy	26	10	26/10 = 2.60	38.46
ksi	30	7	30/7 = 4.29	23.33
ksi	27	6	27/6 = 4.50	22.22
kk	29	11	29/11 = 2.64	37.93
kk	29	4	29/4 = 7.25	13.79
ky	37	8	37/8 = 4.63	21.62
ky	27	12	27/12 = 2.25	44.44
kb	31	15	31/15 = 2.07	48.39
kb	30	16	30/16 = 1.88	53.33

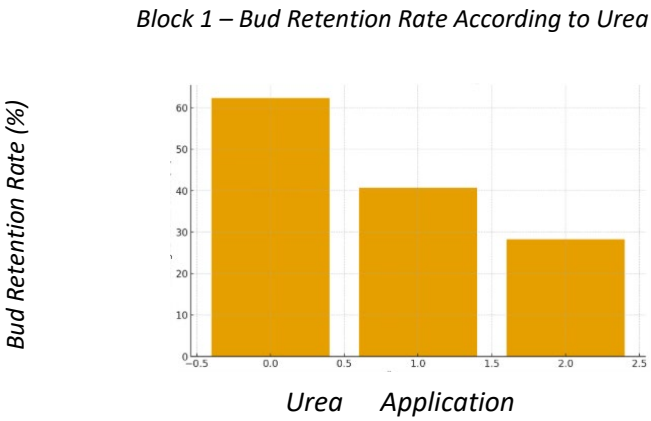

Figure 2. Graph of Average Fruit Bud Count Based on Urea Dosages

(a) Block 1 Fruit Bud Count Graph

The graph illustrating the fruit bud set rate in Block 1 indicates a distinct and consistent upward trend correlated with increasing urea dosages. While the average fruit bud set rate remained relatively low at the 0% (control) dosage, a noticeable increase was observed following the 1% urea application, reaching its peak at the 2% dosage level. This finding suggests that urea applied during the previous production season exerted a significant positive residual effect on fruit bud viability in the subsequent year. It is considered that elevated nitrogen levels enhance bud nutrition by strengthening the plant's endogenous nitrogen reserves. These findings align with the existing literature; specifically, Sürücü (2022) and Dağtekin (2024) have emphasized that increased nitrogen applications support fruit bud set and shoot development in the following season.

(b) Block 2 – Bud Count

Block 2	*Total Buds*	*Total Retained*	*Bud/Retained (Ratio)*	*Retention (%)*
kontrol	87	45	87/45 = 1.93	51.72
kontrol	87	36	87/36 = 2.41	41.38
sb	91	26	91/26 = 3.50	28.57
sb	79	32	79/32 = 2.47	40.51
sy	85	32	85/32 = 2.66	37.65
sy	79	32	79/32 = 2.47	40.51
sk	95	36	95/36 = 2.64	37.89
sk	106	45	106/45 = 2.36	42.45
mk	99	30	99/30 = 3.30	30.30
mk	95	31	95/31 = 3.06	32.63
my	96	29	96/29 = 3.31	30.21
my	96	31	96/31 = 3.10	32.29
mb	92	29	92/29 = 3.17	31.52
mb	96	24	96/24 = 4.00	25.00
sib	98	29	98/29 = 3.38	29.59
sib	92	18	92/18 = 5.11	19.57
siy	94	27	94/27 = 3.48	28.72
siy	94	24	94/24 = 3.92	25.53
ksi	95	24	95/24 = 3.96	25.26
ksi	95	23	95/23 = 4.13	24.21
kk	93	25	93/25 = 3.72	26.88
kk	99	30	99/30 = 3.30	30.30
ky	106	34	106/34 = 3.12	32.08
ky	94	30	94/30 = 3.13	31.91
kb	95	32	95/32 = 2.97	33.68
kb	97	29	97/29 = 3.34	29.90

Block 2 – Bud Retention Rate According to Urea Application Rates

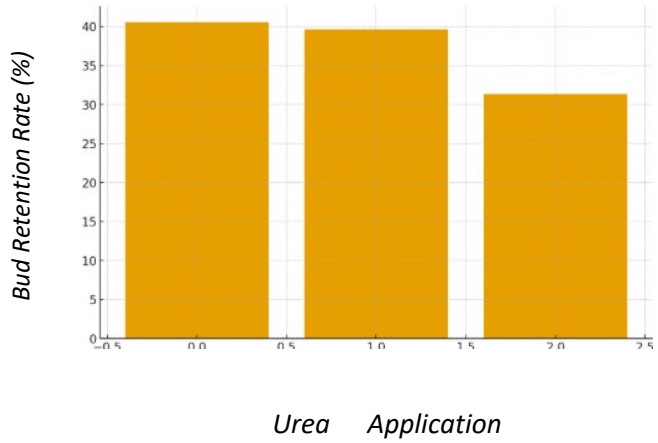

Figure 3. Graph of the Number of Karagöz in Block 2

The graphical data obtained from Block 2 clearly demonstrate the positive impact of urea dosages on the fruit bud set rate. Compared to the control group, an increase in fruit bud set was observed at the 1% and 2% urea concentrations, with the 2% dosage yielding the highest mean values. The preservation of the dose-response relationship, despite environmental variations between blocks, suggests that the treatment operates through a reliable physiological mechanism. This increase is likely attributed to the indirect yet lasting effect of nitrogen on floral bud differentiation and fruit bud viability. Sürücü and Dağtekin (2020) reported that urea applications during the autumn and summer periods significantly reduce fruit bud abscission in the following year; the observed graphical trend reinforces this perspective.

(c) Block 3 – Bud Count

Block 3	*Total Buds*	*Total Retained*	*Bud/Retained (Ratio)*	*Retention (%)*
kontrol	87	45	87/45 = 1.93	51.72
kontrol	87	36	87/36 = 2.42	41.38
sb	91	26	91/26 = 3.50	28.57
sb	79	32	79/32 = 2.47	40.51
sy	85	32	85/32 = 2.66	37.65
sy	84	21	84/21 = 4.00	25.00
sk	92	20	92/20 = 4.60	21.74
sk	90	28	90/28 = 3.21	31.11
mk	93	20	93/20 = 4.65	21.51
mk	87	21	87/21 = 4.14	24.14
my	86	26	86/26 = 3.31	30.23
my	91	25	91/25 = 3.64	27.47
mb	88	29	88/29 = 3.03	32.96
mb	88	26	88/26 = 3.38	29.55
sib	95	34	95/34 = 2.79	35.79
sib	91	28	91/28 = 3.25	30.77
siy	93	34	93/34 = 2.74	36.56
siy	87	21	87/21 = 4.14	24.14

(c)Block 3 – Bud Count (Continued)

ksi	91	35	91/35 = 2.60	38.46
ksi	90	23	90/23 = 3.91	25.56
kk	92	30	92/30 = 3.07	32.61
kk	89	20	89/20 = 4.45	22.47
ky	97	29	97/29 = 3.34	29.90
ky	82	28	82/28 = 2.93	34.15
kb	95	32	95/32 = 2.97	33.68
kb	97	29	97/29 = 3.34	29.90

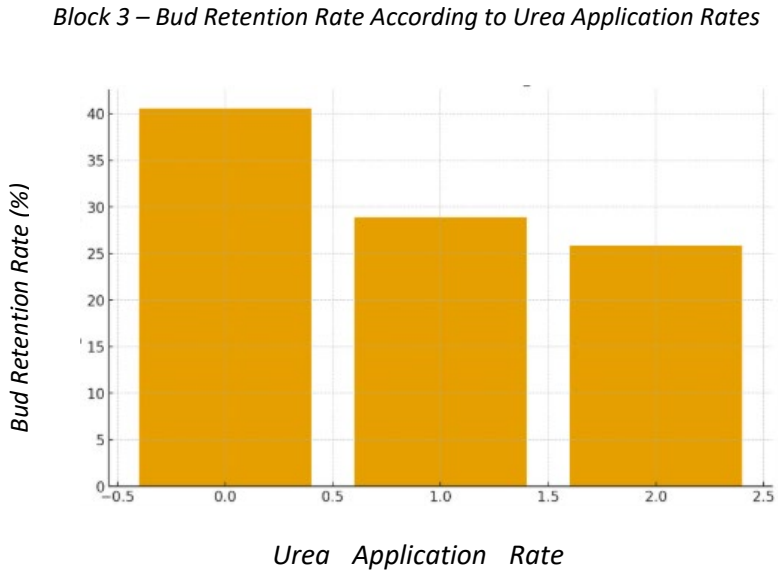

Figure 4. Graph of the Number of Karagöz in Block 3

The fruit bud set rate graph generated for Block 3 clearly illustrates an increase in bud viability corresponding to higher urea dosages. Notably, the 2% urea treatment yielded significantly higher set rates compared to both the control and the 1% dosage levels.
This finding suggests that nitrogen establishes a physiological memory (residual effect) that extends beyond the initial application year into the subsequent season. The persistence of this trend, despite varying environmental conditions, indicates that nitrogen application exerts a robust influence on fruit bud formation and retention. These data align with the prevailing literature, which asserts that cumulative nitrogen applications over consecutive years enhance the viability of generative organs.

4.2 Shoot Diameter

Shoot diameter is considered an important indicator of structural growth and reflects the potential fruit-bearing capacity of the tree in subsequent seasons.
Statistical analysis revealed that the dose factor significantly influenced shoot diameter ($p<0.05$).
Trees receiving the 1% urea treatment exhibited shoot diameter values significantly higher than those observed in the control group. In contrast, irregular increases were observed among replications under the 2% treatment, suggesting that excessive nitrogen concentration may produce inconsistent effects on vegetative growth.
Regarding application intervals, the 10–15 day intervals produced the most favorable results.

4.3 Leaf Area

Leaf area was evaluated as an indicator of photosynthetic capacity.
A clear increase in leaf area was observed under the 1% urea treatment. However, in some samples subjected to the 2% treatment, slight leaf scorch symptoms were observed on the leaf surface, and the leaf area was relatively reduced in those samples.
These results suggest that exceeding the optimal concentration may induce osmotic stress at the cellular level.

4.4 Bud Viability

Bud viability constituted one of the primary parameters investigated in this study.

According to the analysis of variance, both the application dose and the dose × interval interaction had statistically significant effects on bud viability ($p<0.05$).
The highest bud viability rate was obtained from the treatment combination of 1% urea applied at 10-day intervals. In this treatment, bud viability increased markedly compared with the control group.
Although certain combinations involving the 2% treatment also showed improvements in bud viability, treatments applied at 5-day intervals showed a tendency toward reduced bud survival.

4.5 Bud Abscission Rate

Bud abscission rates showed an inverse relationship with bud viability data.
Applications of the 1% urea treatment reduced bud drop rates. However, when the 2% concentration was applied at short intervals, an increasing trend in bud abscission was observed.
These findings indicate that balanced and properly spaced nitrogen applications are essential for maintaining bud stability in pistachio trees.

5. Discussion

Studies examining the relationship between nitrogen fertilization and the vegetative–generative balance in the Siirt pistachio cultivar indicate that nutrient management strategies should be reconsidered, particularly under the ecological conditions of the Southeastern Anatolia Region. In this context, research conducted by Prof. Dr. Abdulkadir Sürücü emphasizes that foliar nitrogen applications may have indirect effects on generative bud formation and alternate bearing behavior. According to these studies, nitrogen should not be regarded solely as a factor promoting vegetative growth; rather, it also plays a critical role in generative organ differentiation through its interaction with carbon metabolism.
The findings obtained in the present study are consistent with Sürücü's evaluations regarding the importance of region-specific fertilization strategies. In particular, the imbalances observed when the optimal dose was exceeded indicate that excessive nitrogen fertilization may stimulate vegetative growth while simultaneously disrupting generative stability. When interpreted from the perspective of the carbon–nitrogen balance theory, these results appear to be in agreement with previous findings reported in the literature.
Overall, the results of this study demonstrate that foliar nitrogen applications in the Siirt pistachio cultivar can exert a clear residual effect on vegetative growth and bud viability in the subsequent production year.

5.1 Nitrogen and the Vegetative–Generative Balance

The stimulatory effect of nitrogen on vegetative growth observed in this study is consistent with findings reported in previous research. However, one of the most significant results obtained here is the identification of the optimal nitrogen dose at the 1% level.
Irregular responses observed in certain parameters under the 2% treatment suggest that excessive nitrogen may disturb the balance between vegetative and generative development. These results support the carbon–nitrogen balance theory, which proposes that excessive nitrogen supply may promote vegetative growth while indirectly suppressing reproductive development.

5.2 Importance of Application Interval

The most balanced results were obtained from application intervals of 10–15 days. More frequent applications, such as those performed at 5-day intervals, may have imposed an additional metabolic burden on the plant.

Conversely, treatments applied at 30-day intervals appeared to be less effective, suggesting that the interval between applications may influence the efficiency of nutrient uptake and utilization.
This observation may be related to the metabolic conversion processes associated with nitrogen absorbed through leaf tissues.

5.3 Residual Effect on Bud Viability
One of the distinctive contributions of this study is the demonstration that nitrogen nutrition during the treatment year significantly influenced bud viability in the subsequent production season.
This finding indicates that generative bud formation in pistachio trees is strongly affected by the nutritional status of the tree during the preceding growing season.
5.4 Role of Regional Ecological Conditions
The environmental conditions prevailing in the Birecik–Alahacı region, particularly high temperatures and low relative humidity, may influence nitrogen metabolism in pistachio trees. For this reason, determining optimal fertilization doses and application schedules specific to regional ecological conditions is of considerable importance.
Foliar nitrogen fertilization is known to improve vegetative growth and bud development in perennial fruit trees. The results of the present study indicate that foliar urea applications significantly influenced shoot growth and bud retention in pistachio trees. Similar findings have been reported in previous studies where nitrogen applications enhanced vegetative vigor and reproductive performance in pistachio orchards. Increased nitrogen availability may stimulate metabolic processes associated with cell division, protein synthesis, and chlorophyll formation, which ultimately support shoot development and bud viability.

6. Conclusions and Recommendations
In this study, the effects of foliar urea applications at different doses and time intervals on vegetative growth and bud viability in the Siirt pistachio cultivar grown under the ecological conditions of Alahacı Village in the Birecik district of Şanlıurfa Province were investigated.
The findings obtained from this research can be summarized as follows:
-Foliar nitrogen applications enhanced vegetative growth.
Particularly the 1% urea concentration significantly increased shoot length, shoot diameter, and leaf area compared with the control treatment.
-The optimal dose was determined to be 1%.
Although certain increases were observed in some parameters under the 2% treatment, irregular variation and increased bud abscission in some combinations indicated that higher concentrations may induce physiological stress.
-Application interval is a critical factor.
The most balanced results were obtained from applications performed at 10–15 day intervals. Applications conducted every 5 days appeared to impose metabolic stress, whereas 30-day intervals reduced treatment effectiveness.
-A residual effect on bud viability was detected.
Balanced nitrogen nutrition during the treatment year positively influenced the generative potential of the following season. This result demonstrates that generative bud formation in pistachio trees is closely related to the nutritional status of the previous growing season.
-Regional conditions play a determining role in defining optimal fertilization strategies.
Under the ecological conditions of the Birecik–Alahacı region, moderate nitrogen concentrations applied at moderate intervals produced the most favorable outcomes.

Practical Recommendations

• A **1% urea concentration** is recommended for foliar fertilization in the Siirt pistachio cultivar.
• Applications should be performed at **10–15 day intervals**.
• Excessively frequent or high-dose applications should be avoided.
• Fertilization programs should be planned with careful consideration of regional climatic conditions.
• Further long-term studies are needed to evaluate the influence of foliar nitrogen applications on alternate bearing behavior.

7. Orıginal Contribution of the Study

This study represents one of the limited number of regional investigations examining the effects of foliar nitrogen application on bud viability in the subsequent production year in the Siirt pistachio cultivar.

In particular, the evaluation of the **dose × application interval interaction** provides an important methodological contribution to the existing literature. The findings offer valuable insights for the development of region-specific fertilization strategies aimed at improving yield stability and reducing alternate bearing in pistachio production systems.

The findings of this study demonstrate that foliar urea applications influence shoot growth and bud retention in pistachio trees. Appropriate combinations of urea concentration and application interval may improve vegetative growth and reproductive potential. Therefore, foliar nitrogen fertilization can be considered an effective agronomic practice for enhancing pistachio productivity.

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