Effect of different ethephon doses on grain yield and yield components of in barley (Hordeum vulgare L.)

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Abstract: This study was carried out under supplementary irrigated conditions in the Harran Plain in 2008-2009 and 2009-2010 growing seasons. The study aimed to assess the effects of various ethephon doses on durum wheat and barley cultivars. Nine ethephon dosages (0, 240 g/ha, 360 g/ha, 480 g/ha, 600 g/ha, 720 g/ha, 840 g/ha, 960 g/ha, 1080 g/ha) were applied in the study. The results of the combined analysis of two years indicated that the highest grain yield was recorded for Sur-93 cultivar with 4365.63 kg/ha in 600 g/ha ethephon application, while the lowest grain yield of barley was obtained from land race black barley with 1978.00 kg/ha (in control application). The result revealed that ethephon had positive effect on to grain yield. There was not any statistical significant between 960 g/ha and 1080 g/ha ethephone doses in terms of grain yields for land race black barley cultivar. When the years and barley cultivars is evaluated together, the highest grain yield is obtained with 960 g/ha dose of ethephon. Results showed that ethephon application to barley shortened plant height and increased 46% of barley yield, and the effects of ethophone varied were connected to cultivar specific. In addition Sur-93 600 g/ha, and a land race black barley cultivar 960 g/ha could be recommended.

Keywords: Barley, ethephon, yield, quality, lodging

Arpa Bitkisinde Farklı Etephon Dozlarının Tane Verimi ve Verim Komponentleri Üzerine Etkisi

Öz: Bu çalışma, 2008-2009 ve 2009-2010 yetişirme sezonlarında Harran Ovası ilave suylanan koşullarda yürütülmüştür. Bu çalışma ile farklı dozlardaki ethephon uygulamalarının makarunluk buğday ve arpa çeşitleri üzerine etkilerini belirlemek amaçlanmıştır. Denemede 9 ethephon dozu (0, 240 g/ha, 360 g/ha, 480 g/ha, 600 g/ha, 720 g/ha, 840 g/ha, 960 g/ha, 1080 g/ha) uygulanmıştır. Iki yıl birleşik analiz sonuçlarına göre arpa bitkisinde de artan ethephon dozlarına paralel olarak tane veriminde artış meydana gelmiştir. Sur-93 arpa çeşitinde en yüksek tane verimi 600 g/ha ethephon uygulamasında 4365.63 kg/ha iken en düşük tane verimi Yerli arpa çeşitinde 960 g/ha ethephon uygulamasında 1978.00 kg/ha olmuştur. Yerli arpa çeşitinde 960 g/ha ile 1080 g/ha ethephon uygulamaları arasında istatistik açıdan bir farklılık görülmemiştir. Yıllar ve çeşitler birlikte değerlendirilirliğinde arpa döneminde en yüksek tane verimi 600 g/ha ethephon uygulamasında elde edilmiştir. Sonuç olarak, arpa ethephon uygulamasının bitki boyunun kısalttığı ve verimi %37-46 yükselttiği, çeşit göre uygulanan dozun değiştiği anlaşılmıştır. Yerli arpa çeşitinde 960 g/ha, Sur-93 çeşitinde 600 g/ha ethephon uygulamalarının tavsise edilebilir ve ekonomik anlamda en uygun uygulamalar olduğu söylenebilir.

Anahtar kelimeler: Arpa, ethephon, verim, kalite, yatma

1. Introduction

Barley, based on the production area (26.1 million ha) and total yield (7.4 mil. ton), is the second important cereal following wheat in Turkey. In southeast of Turkey, barley has been produced on 372,030.5 ha and total produced grain yield was 556,876 ton (Anonim 2020). Compared to wheat, early maturation of barley allows cultivation of a second crop within the same season which is very important in irrigated areas such as Harran Plain. Barley as a winter cereal is widely planted in southeast of Turkey. However, barley is very sensitive to lodging and even under normal precipitation and fertilization conditions lodging is widely observed and it causes significant yield reduction. Therefore,
lodging prevention would make significant contribution to the region and the state economy.

Lodging causes yield reduction by reducing plant growth, reduced photosynthesis and prevented carbohydrate assimilation. Severe lodging generally occurs prior spiking stage which causes 27-40% yield reduction while lodging during kernel maturation causes 20% yield reduction (Rademacher 2009). Lodging is major risk and issue for intensive cereals production and it causes reduced yield and low quality cereals.

Plant growth regulators (PGR) have been applied to cereals from sowing to harvest to increase yield and quality of cereals in Turkey and around the world (Karakus and Koker 2007; Rademacher 2009), reported that some of the PGR reduce plant height, stabilize shoot, auricle and other plant parts growth and increase resistance against lodging by improving plant root development. Ethephon has been reported as one of the PGR that reduces cereals lodging.

In this study, we intended to determine the effect of etephon on lodging reduction of barley cultivars Sur-93 and a local barley cultivars.

2. Materials and Methods

The study was conducted in Şanlıurfa - Harran plain during 2008-2009 and 2009-2010 growing seasons. Climate data about the growing seasons of the study was conducted has been given in Table 1. In this study, Sur 93 and a local barley cultivar were used as plant materials. Both barley cultivars, during high precipitation and under irrigated conditions, have been shown to be highly susceptible to lodging. The study was carried out as split plot experimental design with four replications. Main plots were barley cultivars while Ethephon [(2-chloroethyl) phosphoric acid] dosages were the subplots. Applied etephon dosages were 0, 240, 360, 480, 600, 720, 840, 960 and 1080 g/ha.

Ethephon was applied to foliar with a backpack sprayer according to Feekes’ scale at 8-9 stages during flag leaf development (Akkaya 1994). Untreated (control) plants were treated with water only. Screens were placed in between plots to prevent drift of the applications. Each plot was 5 m long and covered 6 rows of the crops. There was 20 cm spacing between the rows.

Table 1. Some monthly climatic values of Şanlıurfa belong to research years of 2008-2010.

| Month      | 2008-2009 |            | 2009-2010 |            |
|------------|-----------|------------|-----------|------------|
|            | Temperature (°C) | Precipitation (mm) | Moisture (%) | Temperature (°C) | Precipitation (mm) | Moisture (%) |
| November   | 14.1      | 35.3       | 62.4      | 12.2       | 35.5       | 62.6        |
| December   | 7.0       | 37.7       | 58.6      | 10.1       | 121.2      | 73.4        |
| January    | 5.8       | 29.8       | 59.1      | 8.4        | 95.7       | 68.8        |
| February   | 8.0       | 56.6       | 72.2      | 9.1        | 23.5       | 67.4        |
| March      | 10.0      | 55.3       | 65.6      | 13.8       | 42.7       | 55.7        |
| April      | 15.8      | 48.8       | 53.0      | 17.4       | 26.2       | 46.7        |
| May        | 22.8      | 4.7        | 33.6      | 24.0       | 7.1        | 34.3        |
| June       | 29.6      | 9.2        | 29.2      | 29.4       | 0.5        | 31.2        |
| Average/Total | 14.14 | 337.4      | 50.09     | 15.53      | 352.4      | 55.01       |

Placing density was 600 seeds / m² and seeds were sown with a seeder. The seeds were sown during 2008-2009, 2009-2010 growing seasons within month of October. All plots were irrigated with sprinklers until soil water holding capacity is reached.

During irrigations water runoff was not allowed. The plots were re-irrigated when 40% of the soil moisture was used up to restore the soil moisture (Rawlins, 1976). During sowing 15-15-15 compound fertilizer was applied based on 80 kg NPK / ha. Based on soil analysis, P and K fertilizers were applied at 80 kg/ha rate during planting while N fertilizer was applied at 180 kg/ha throughout of the vegetative growth. Half of the N fertilizer was applied during planting while the other half was applied during tillering stage. Granstar (%75 tribenuron methyl) herbicide was applied at 1.5 kg/ha rate to control broadleaf weeds and İlloxan (284 g / L diclofop methyl) was applied to control grasses. Barleys were harvested in June for both years. The
recorded data were analyzed using ANOVA and means were separated by LSD.

### Table 2. The Results of Variance Analysis

| Source of variation | DF | Grain yield | Plant height | Lodging | Kernels/Spike | 1000-kernel weight |
|---------------------|----|-------------|--------------|---------|----------------|-------------------|
| Year                | 1  | 160981.501  | 49.351       | 311.103 | 2.176          | 84.671            |
| One year            | 6  | 512.840     | 2.577        | 41.639  | 4.595          | 1.807             |
| Cultivar            | 1  | 492900.306  | 2155.281     | 9529.182| 603.112        | 129.880           |
| Year x Cultivar     | 1  | 22397.617   | 14.887       | 3336.012| 0.012          | 2.007             |
| Error               | 6  | 503.625     | 11.038       | 86.246  | 1.865          | 0.608             |
| Ethephon            | 8  | 35656.723   | 2556.516     | 7611.927| 372.373        | 192.893           |
| Year x Ethephon     | 8  | 1417.001    | 11.730       | 35.266  | 0.065          | 2.176             |
| Cultivar x Ethephon | 8  | 4181.356    | 154.492      | 1263.735| 13.714**       | 14.086            |
| Year x Cultivar x Ethephon | 8  | 499.725     | 5.327        | 71.475  | 0.057          | 1.812             |
| Error               | 96 | 604.962     | 5.495        | 19.019  | 1.181          | 1.275             |
| General             | 143| 7514.000    | 172.400      | 714.994 | 26.903         | 23.340            |

*: Significant at P=0.05, **: Significant at P=0.1

### 3. Results and Discussion

#### 3.1. Grain yield (kg/ha)

Yield of Sur 93 cultivar was 2557.5 kg/ha during 2008-09 growing season when it was not treated with ethephon while 600 g/ha ethephon treated Sur 93 barley cultivar produced 3874.5 kg/ha (Table. 3). During 2009-2010 growing season yield increased proportional to the rates of applied ethephon. The cultivars produced 2947 kg/ha when not treated with ethephon while 600 g/ha ethephon treated barley plants produced 4856.75 kg/ha. Increased rate of ethephon (600, 720, 840, and 960 g/ha) did not significantly increased yield while 1080 g/ha ethephon slightly reduced yield. Although the differences were not statistically significant, yield gradually decreased as ethephon rate increased from 600 to 960 g/ha (Figure 1). The yield decreased after the 600 g/ha doses.

### Table 3. Grain yield values of barley varieties in different ethephon applications and LSD groups.

| Cultivar     | Ethephon Dose (g ha⁻¹) | 2008-2009 Average | 2009-2010 Average | Average   |
|--------------|------------------------|-------------------|-------------------|-----------|
| Sur-93       | 0                      | 2557.50 C*a       | 2947.00 d         | 2752.25 d |
|              | 240                    | 3360.50 b         | 4347.50 c         | 3854.00 c |
|              | 360                    | 3584.75 ab        | 4410.75 bc        | 4001.75 bc|
|              | 480                    | 3807.50 a         | 4734.50 ab        | 4271.00 a |
|              | 600                    | 3874.50 a         | 4856.75 a         | 4365.63 a |
|              | 720                    | 3831.75 a         | 4850.50 a         | 4341.13 a |
|              | 840                    | 3797.50 a         | 4836.50 a         | 4317.00 a |
|              | 960                    | 3766.75 a         | 4807.00 a         | 4286.87 a |
|              | 1080                   | 3663.50 ab        | 4709.00 ab        | 4186.25 ab|
| Cultivar average |                    | 35826.9 A         | 4500.83 A         | 4041.76 A |
| Local Barley  | 0                      | 1887.50 f         | 2068.50 e         | 1978.00 e |
|              | 240                    | 2337.25 e         | 2512.50 d         | 2424.88 d |
|              | 360                    | 2521.75 de        | 2873.50 e         | 2697.63 c |
|              | 480                    | 2632.25 de        | 3047.50 bc        | 2839.88 d |
|              | 600                    | 2657.00 cde       | 3070.00 bc        | 2863.50 c |
|              | 720                    | 2692.50 bcd       | 3185.75 bc        | 2939.13 bc|
|              | 840                    | 3020.25 ab        | 3228.75 b         | 3124.50 b |
|              | 960                    | 3221.50 a         | 3960.50 a         | 3591.00 a |
|              | 1080                   | 2988.00 abc       | 3784.50 a         | 3386.25 a |
| Cultivar average |                    | 2662.00 B         | 3081.28 B         | 2971.64B |

Year LSD: 9.157, Cultivar LSD: 9.157 Year x Cultivar LSD: 12.950, Cultivar x Dose LSD: 24.442, Year x Cultivar x Dose LSD: 34.566. Within columns, means followed by same letter do not differ significantly at p=0.05 (LSD)
In regard to the interactions between barley cultivars and ethephon rates, control (untreated) plants of the local barley produced the lowest grain yield (1887.50 kg/ha) while the highest grain yield (3874.50 kg/ha) produced by Sur-93 and ethephon (600 g/ha) combination in 2008-2009 while during 2009-2010 the lowest yield (2068.50 kg/ha) was produced by local barley cultivar when untreated with ethephon and the highest yield (4856.75 kg/ha) was produced by Sur-93 cultivar and ethephon (600 g/ha) combination. Based on average yield, Sur-93 cultivar produced higher (3582.69 and 4500.83 kg/ha) yield in both years compared to the local cultivar (2662.00 and 3081.28 kg/ha). The results indicated that Sur-93 and the local cultivar responded differently to the applied rates of ethephon. Sur-93 grain yield increased proportionally as ethephon applied ethephon rates increased up to 600 g/ha while the local cultivar grain yield proportionally increased as applied ethephon concentration increased up to 960 g/ha.

Ethephon applications reduced plant height and lodging but increased grain yield Sur-93 produced the highest grain yield of 4365.63 kg/ha when treated with ethephon 600 g/ha while the local cultivar produced the highest yield of 3591.00 kg/ha. Regression analysis of Sur-93 and ethephon concentrations indicated that regression equation was as \( y = 284.1 + 0.4271x - 0.0003x^2 \) \( (R^2 = 0.974) \) (Figure 1) while regression equation of the local cultivar and ethephon concentrations was as \( y = 208.8 + 0.133x \) \( (R^2 = 0.929) \) (Figure 2)

The barley cultivars included in this study were tall cultivars but susceptible to the lodging. Rainy seasons, irrigation and application of N fertilizers cause overly growing of already tall varieties and worsen lodging during spike development stage. Ethephon application prevent plant lodging by reducing plant height, and reduced lodging improve grain development that lead increased yield.

Previously it has been reported that ethephone application reduces plant height thus increases grain yield (Lundgaard 1984; Szirtes et al. 1986; Wiersma et al. 1986; Penckowski et al. 2009; Radamacher 2009).

Especially local barley cultivars are susceptible to lodging which is the main cause of reduced grain yield in the region. Ethephone treated plants produced greater grain yield compared to untreated plants.

Figure 1. Barley grain yields of Sur-93 and Local Cultivar with different ethephon doses  
Şekil 1. Farklı etephon dozlarında Sur-93 ve Yerli Arpa çeşitlerinin tane verimleri
3.2. Plant Height (cm)

Height of Sur-93 was reduced proportional to ethephon concentration during the trials of in 2008-2009 and 2009-2010 seasons. During growing season of 2008-2009, average plant height of untreated Sur-93 cultivar was 102.55 cm while ethephon treated height of the cultivar was 58.3 cm. During growing season of 2009-2010, plant height of untreated and ethephone treated of Sur-93 variety was similar to the previous season (Table 4).

During the growing season of 2008-2009, ethephon application up to 840 g/ha significantly reduced plant height of the local barley variety to 62.3 cm, however, increased concentrations ethephon such as 960 and 1080 g/ha did not significantly affect plant height. During growing season of 2009-2010, results of ethephon
applications were similar to the previous season. The results showed that applied ethephon concentrations up to 840 g/ha were effective in reducing plant height (58.500 cm) while higher concentrations such as 960 and 1080 g/ha did not significantly affect plant height. During growing season of 2008–2009, in regard to barley plants and ethephon rates interaction, Sur-93 x 1080 g/ha ethephon interaction produced the lowest plant height (58.3 cm) while the highest (102.55 cm) plant height was recorded from Sur-93 and 0 g/ha ethephon interaction.

In 2009–2010, the shortest plant height (58.95 cm) was obtained from Sur-93 and ethephon (840 g/ha) interaction and the tallest plant height (98.950 cm) was observed from Sur-93 x 0 g/ha ethephon interaction.

Average results of a 2-year study indicated that plant height of Sur-93 varied from 58.625 cm (1080 g/ha ethephon application) to 100.550 cm (0 g/ha ethephon application). Plant height was reduced as ethephon concentration increased. However, height of plants treated with either 960 or 1080 g/ha ethephon was not significantly different. The local barley cultivar height ranged from 59.575 cm (1080 g/ha ethephon application) to 85.063 cm (0 g/ha ethephon). Local barley height was not significantly different at 840, 960 and 1080 g ha⁻¹ ethephon application. In both years, local barley height decreased as ethephon concentration increased (Figure 4).

Regression analysis of average plant height of 2 years and ethephon application indicated that regression equation for Sur-93 cultivar was determined as y=106.9–5.675x and (R² = 0.985) while for local barley cultivar was determined as y=85.68–3.220x ve R² = 0.874 (Figure. 4).

Previous studies have indicated that barley plant height can be reduced with application of ethephon (Lunsgaard 1984 and 1986; Szirtes et al. 1986; Lloversas et al. 1990; Ege 1991; Stulova and Egorov 1991; Ma and Smith 1992; Stobbe et al. 1992; Webster et al. 1993).

### Table 4. Plant height values, lodging values of barley varieties in different ethephon applications and LSD groups.

| Cultivar | Plant height (cm) | Lodging (%) |
|----------|------------------|-------------|
|          | 2008-2009 | 2009-2010 | Average | 2008-2009 | 2009-2010 | Average |
| Sur-93   |            |           |         |           |           |         |
| 0        | 80.875 e   | 78.275 s  | 81.000 b | 80.875 e  | 78.275 s  | 81.000 b |
| 240      | 82.000 c   | 79.525 s  | 82.500 b | 65.625 d  | 62.500 c  | 65.625 d |
| 360      | 83.500 e   | 81.000 b  | 84.000 a | 70.500 c  | 67.000 b  | 70.500 c |
| 480      | 85.000 e   | 82.625 c  | 86.500 b | 72.000 d  | 68.500 b  | 72.000 d |
| 600      | 86.500 e   | 84.000 b  | 88.000 a | 73.500 c  | 69.500 b  | 73.500 c |
| 720      | 88.000 f   | 85.500 a  | 90.000 b | 75.000 d  | 70.000 c  | 75.000 d |
| 840      | 89.500 g   | 87.000 a  | 92.000 c | 76.500 e  | 71.500 b  | 76.500 e |
| 960      | 90.000 g   | 88.500 a  | 93.000 d | 78.000 f  | 72.000 c  | 78.000 f |
| 1080     | 91.500 g   | 90.000 a  | 95.000 e | 79.500 g  | 73.000 b  | 79.500 g |
| Average  | 89.000     | 87.500    | 92.000   | 78.000    | 72.500    | 78.000   |
| Local barley |         |           |         |           |           |         |
| 0        | 86.650 a   | 83.475 a  | 88.000 a | 99.375 a  | 99.375 a  | 99.375 a |
| 240      | 88.000 b   | 77.950 c  | 89.500 b | 70.000 e  | 62.000 f  | 70.000 e |
| 360      | 90.500 c   | 82.625 c  | 92.000 b | 72.500 d  | 64.000 e  | 72.500 d |
| 480      | 92.000 d   | 75.775 c  | 93.500 a | 74.000 c  | 66.000 f  | 74.000 c |
| 600      | 94.000 e   | 78.375 c  | 95.000 b | 75.500 d  | 68.000 g  | 75.500 d |
| 720      | 95.500 f   | 80.975 c  | 96.500 a | 77.000 e  | 70.000 h  | 77.000 e |
| 840      | 97.000 g   | 83.575 c  | 98.000 b | 78.500 f  | 72.000 i  | 78.500 f |
| 960      | 98.500 h   | 85.175 c  | 99.500 a | 80.000 g  | 74.000 j  | 80.000 g |
| 1080     | 100.000 i  | 86.775 c  | 101.000 a| 81.500 h  | 76.000 k  | 81.500 h |
| Cultivar average | 71.708 | 69.894 | 70.801 B | 35.000 A | 26.964 B | 30.982 B |
| Year average | 75.256 | 74.085 | 74.085 | 39.032 | 42.213 | 39.032 |

Plant Height: Çeşit LSD:1.396, Çeşit x Doz LSD:2.329, Yıl x Çeşit LSD: 3.294
Lodging: Çeşit LSD:4.297, Yıl x Çeşit LSD:6.077, Çeşit x Doz LSD:4.349, Yıl x Çeşit x Doz LSD: 6.150
*: Within columns, means followed with same letter do not differ significantly at P=0.05 (LSD).
3.3. Lodging

Lodging of Sur-93 barley cultivar in 2008-2009 was 61.25% when it was treated with ethephone, however, no lodging was recorded when plants treated with 960 and 1080 g/ha ethephone. In 2009-2010, lodging of untreated plants decreased but still more than 50% of plants lodged while no lodging of treated plants was observed. In both years, reduced plant height was proportional to the increased ethephon rates (Table 4).

In 2008-2009, lodging of local barley ranged from 7.5% (plants treated with 1080 g/ha ethephone) to 98.75% (untreated plants with ethephone). In 2009-2010, lodging of the local cultivar varied from 5% (plants treated with 1080 g/ha ethephone) to 100% (untreated plants with ethephone). Lodging of the local barley cultivar reduced as applied ethephon concentration increased.

During the growing season of 2008-2009, regarding lodging and ethephon rates, the highest (98.75%) lodging rate of the local barley cultivar was recorded at 0 g/ha ethephone application while the lowest lodging (0%) was recorded at interactions of Sur-93 treated with 960 and 1080 g/ha rates of ethephon. In 2009-2010, the lodging was like the previous growing season. The highest lodging (100%) was observed from the local barley cultivar and 0 g/ha ethephon interaction while the lowest lodging (0%) was observed from Sur-93 and 960 - 1080 g/ha ethephon interactions.

Based on average of 2 years lodging value of Sur-93 varied from 0% when plants treated with 960 and 1080 g/ha to 58.75% when untreated with ethephon. Plant lodging reduced proportionally to the concentrations of ethephon, however, the highest reduction of lodging was between 480 and 600 g/ha ethephon applications while lodging reduction of 960 and 1080 g/ha was not significantly different. Height of the local barley was ranged from 59.57 cm when plants treated with 1080 g/ha ethephone to 85.06 cm when plants was not treated with ethephon. Although plant height gradually reduced as ethephon rate increased the effect of ethephon rates from 840 to 1080 g/ha ethephone was significantly different. In both years, plant height was reduced as applied ethephon rate increased (Figure 4). Regression of lodging rate and applied ethephon rates were significant and regression between Sur-93 and ethephon rates was determined y=62.06-7.593x and (R² =0.940) and regression between the local variety and
ethephon rates was \( y = 101.2 - 11.10x \) and \( R^2 = 0.959 \) (Figure 5).

In this study, applied ethephon rates reduced lodging by reducing plant height. Previous studies also have indicated that ethephon application would reduce lodging by reducing plant height (Szirtes et al. 1986; Ma and Simith 1992; Havazvidi 1992; Stobbe et al. 1992; Bridger et al. 1995; Rajala et al. 2001; Rajala et al. 2002; Tripathi et al. 2004; Haskins and Mcmullen. 2007; Radamacher 2009; Pavlista et al. 2010; Wiersma et al. 2011).

Figure 5. Percentage of lodging at different rates of ethephon application during 2008-2009 and 2009-2010 growing seasons.

Barley cultivars added to this study were susceptible to lodging. Susceptible barley cultivars when irrigated and fertilized lodging especially during spike stage become a serious problem. Kernel of lodged plants cannot develop well thus kernels become light-weighted. In this study, applied ethephon rates reduced plant height and therefore delayed spiking which helped better development of heavy kernels. These results agree with the previous studies (Dziamba 1986; Stobbe et al. 1992; Akcura 2001; Aral 2001; Tripathi et al. 2004; Rajala et al. 2002; Auskalniene 2005; Ramburan and Greenfield 2007).

4.4. Thousand Kernel Weight

Thousand-kernel weight of Sur-93 ranged from 37.30 g when treated with 240 g/ha ethephon to 47.035 g when treated with 960 g/ha ethephon during 2008-2009 (Table 5). Although 1000-kernel weight increased as applied ethephon rate increased, ethephon rates higher than 840 g/ha did not increase kernel weight significantly. Thousand-kernel weight of Sur-93 ranged from 37.942 g when treated with 0 g/ha ethephon to 45.812 g when treated with 840 g/ha ethephon during 2009-2010. The increase in ethephon rate from 840 to 1080 g/ha did not cause any significant change in thousand kernel weight. Although 1000-kernel weight increased as applied ethephon rate increased, ethephon rates higher than 720 g/ha did not significantly increase the kernel weight. The difference between ethephon doses 840, 960, 1080 was found insignificant.

Thousand kernel weight of the local barley cultivar ranged from 31.563 g when plants were not treated with ethephon to 40.228 g when plants treated with 1080 g/ha ethephon. Thousand kernel weight did not increase significantly when plants were treated with 960 and 1080 g/ha ethephon.
**Table 5.** Thousand kernel weight values of barley varieties in different ethephon applications and LSD groups.

| Cultivar | Thousand kernel weight (g) | 2008-2009 | 2009-2010 | Average |
|----------|----------------------------|------------|------------|---------|
| Sur-93   |                            |            |            |         |
| 0        | 37.230 d                   | 37.942 d   | 37.586 e   |         |
| 240      | 37.228 d                   | 39.200 cd  | 38.214 e   |         |
| 360      | 37.718 d                   | 39.678 c   | 38.698 e   |         |
| 480      | 37.793 d                   | 40.345 b   | 40.469 d   |         |
| 600      | 40.070 c                   | 43.413 b   | 41.743 c   |         |
| 840      | 46.705 a                   | 45.812 a   | 46.259 a   |         |
| 960      | 47.035 a                   | 45.040 a   | 46.068 a   |         |
| 1080     | 46.658 a                   | 44.500 ab  | 45.579 a   |         |
| Local barley |                        |            |            |         |
| 0        | 31.563 e                   | 31.928 e   | 31.745 f   |         |
| 240      | 33.185 d                   | 33.610 d   | 33.398 e   |         |
| 360      | 33.137 cd                  | 34.295 cd  | 33.806 de  |         |
| 480      | 33.903 bcd                 | 34.500 cd  | 34.201 de  |         |
| 600      | 34.577 bcd                 | 34.723 cd  | 34.650 cd  |         |
| 720      | 34.893 bc                  | 35.803 c   | 35.348 cd  |         |
| 840      | 35.340 b                   | 39.730 b   | 37.535 b   |         |
| 960      | 39.396 a                   | 43.305 a   | 41.451 a   |         |
| 1080     | 40.228 a                   | 44.638 a   | 42.433 a   |         |
| Cultivar average | 35.178                  | 36.948    | 36.063 B   |         |
| Year average          | 38.296 B                  | 39.830 A   |            |         |

Year LSD:0.318, Cultivar LSD:0.318, Cultivar x Dozage LSD: 1.122, Year x Cultivar x Dozage LSD: 1.587; *: Within columns, means followed with same letter do not differ significantly at P=0.05 (LSD).

In regard to 1000-kernel weight from barley cultivars and ethephon interaction, the lowest 1000-kernel weight was recorded from interaction of the local barley and 0 g/ha ethephon application while the highest 1000-kernel weight (47.035 g) was recorded in Sur-93 with 960 g/ha ethephon application in 2008-2009. In 2009-2010, the lowest 1000-kernel weight (31.928 g) was from the untreated local barley. The highest 1000-kernel weight (45.812 g) was from interaction of Sur-93 and 840 g/ha ethephon application (Table 5).

Average 1000-kernel weight of 2 years varied from 31.745 g (local barley x 0 g/ha ethephon) to 46.259 g (Sur-93 x 840 g/ha ethephon). Thousand-kernel weight increased as applied ethephon rate increased. Thousand-kernel weight of the local barley increased as applied rates of ethephon increased. No significant difference of 1000-kernel weight detected when the applied ethephon rate increased from 960 to 1080 g/ha (Figure 5).

Regression analysis based on average 1000-kernel weight of 2 years indicated that regression equation between 1000-kernel weight and ethephon rates for Sur-93 barley was y=35.88+1.235x (R² = 0.931) while the equation for local barley was y=29.77+1.258x (R² = 0.875) (Figure 6). Lodging is a serious cause of poorly kernel development of barley cultivars. Applied ethephon rates well developed kernels thus increased 1000-kernel weight of the barley cultivars. Results of this study indicated similar results that were reported previously.

**Figure 6.** Thousand-kernel weight of barley cultivars treated with different rates of ethephon during the growing seasons of 2008-2009 ve 2009-2010.

**Şekil 6.** 2008-2009, 2009-2010 yetiştirme sezonlarında farklı etephon dozu uygulamalarında arpa çeşitlerinin bin tane ağırlığı degerleri ve LSD grupları

Regression analysis based on average 1000-kernel weight of 2 years indicated that regression equation between 1000-kernel weight and ethephon rates for Sur-93 barley was y=35.88+1.235x (R² = 0.931) while the equation for local barley was y=29.77+1.258x (R² = 0.875) (Figure 6). Lodging is a serious cause of poorly kernel development of barley cultivars. Applied ethephon rates well developed kernels thus increased 1000-kernel weight of the barley cultivars. Results of this study indicated similar results that were reported previously.
(Dziamba 1986; Stobbe et al. 1992; Akçura 2001; Tripathi et al. 2004; Rajala et al. 2002; Auskalniene 2005).

4. Conclusion

Grain yield of Sur-93 and the local barley cultivars were 2752.25 kg/ha, 4365.63 kg/ha and 1970.00 kg/ha, 3591.00 kg/ha, respectively. Ethephon application up to 600 g/ha significantly increased grain yield of Sur-93 barley. The grain yield of barley did not significantly increase with 720 g/ha ethephon application and higher doses. Grain yield of the local barley significantly increased by ethephon application up to 840 g/ha. There was no statistical difference between the doses after the 840 kg dose.

Ethephon application reduced plant height and numbers of kernels but caused well kernel development thus 1000-kernel weight was increased. The recorded highest grain yield due to ethephon applications was 4365.63 kg/ha for Sur-93 when treated with 600 g/ha ethephon while the recorded highest grain yield for the local barley was 3591.00 kg/ha when treated with 960 g/ha ethephon. The lodging of barley cultivars decreased with the increase in ethephon application rate. The highest lodging rate was recorded in control treatments, while the lowest lodging ratio was obtained with the highest ethephon dose.

References

Akçura M (2001). Effect of different doses of ethephon, chloromequat chloride and ethephon + chloromequat chloride on yield and yield components in a bread wheat (Triticum aestivum L.) genotypes in Kahramanmaraş conditions. University of Sütçü İmam, Master’s thesis, Kahramanmaraş-Turkey.

Akkaya A (1994). Wheat breeding course text. Kahramanmaraş Sütçü İmam University Faculty of Agriculture Publications, p. 225, Kahramanmaraş.

Anonim (2020). Agricultural Products Development Markets. Barley. Januray No: BU-01 Unpublished

Aral M (2001). The effect of ethephon dose applied to durum wheat (Triticum durum L., etc.) on yield and yield components. University of Ankara, Master thesis, Ankara-Turkey.

Auskalniene O (2005). The influence of modal mixtures with other plant growth regulators on the grain yield and productivity of winter wheat. Žemdirbyste, Moksodarbai. 90: 48-60.

Bridger GM, Klinck HR, Smith DL (1995). Timing and rate of ethephon application to two-row and six-row spring barley. Agronomy Journal. 87(6): 1198-1206.

Dziamba S (1986). The effect of flordimex t on yields of triticale, rye and wheat as related to the level of mineral fertilization. Acta-Agraria-et-Silvestria. 25: 141-156.

Ege H (1991). Research on the effects of plant growth regulators (Ethephon, CCC, RSW 0411) on some agronomic morphological and anatomical features in barley varieties. Ege University Institute of Science, thesis, Izmir-Turkey.

Haskins B, McMullen G (2007). Crop canopy management through nitrogen and plant growth regulators. IREC Farmers' Newsletter, p. 4, Australia.

Havazvidi EK (1992). The effect of growth regulators on lodging, development and grain yield of tall spring wheats in Zimbabwe. Seventh regional wheat workshop for eastern, central and southern Africa. P. 369-375. , Cimmyt.

Karakus C, Koker R (2007). Use of plant growth regulators (bgd) in agriculture and hormone risk. University Students 2. Environmental Problems Congress Congress Book, p. 163-175, Istanbul.

Lloveras J, Gomez-Ibarlucea C, Carreiras W, Bueno J, Casal L (1990). The effect of growth regulaiwheat from galicia (n.,w.,spain). Investigacion-Agraria-Produccion-Y-Proteccion-Vegatales. 5: 89-101.

Lundgaard J (1984). Terpal CA new growth regulator for straw shortening in cereals. 1-Danske Plantavaernskonference-Ukrudt, Ucrudt: 153-166.

Ma BL, Smith DL (1992). Post-anthesis ethephon effects on yield of spring barley. American Society of Agronomy. 84: 370-374.

Pavlista AD, Hergert GW, Baltensperger DD, Knox S (2010). Reducing height and lodging of winter wheat. Crop management, 9(1): 1-7.

Penckowski LH, Zagoneu J, Fernandes CE (2009). Nitrogen ve Growth Reducer In High Yield Wheat. Acta Scientiarum: Agronomy 31(3): 473-479.

Rademacher W (2009). Control of lodging in intense European cereal production. Proceedings of the 36th Annual Meeting of the Plant Growth Regulation Society of America, 2-6 August, p. 61-69, USA.

Rajala A, Peltonen-Sainio P (2001). Plant growth regulator effects on spring cereal root and shoot growth. Agronomy Journal. 93: 936-943.

Rajala A, Peltonen-Sainio P, Onnela M, Jackson M (2002). Effects of applying stem-shortening plant growth regulators to leaves on root elongation by seedlings of wheat, oat and barley: mediation by ethylene, Plant Growth Regulation. 38: 51-59.

Ramburan S, Greenfield PL (2007). Use of ethephon and chloromequat chloride to manage plant height and lodging of irrigated barley (cv. puma) when high rates of on-fertiliser are applied. South African Journal of Plant and Soil. 24(4): 181-187.

Rawlins SL (1976). Measurement of water content and the state of water in soils. p.1-55. In: Water Deficits And Plant Growth. Academic Pres, NY, 4: 1-55.

Stobbe EH, Moes J, Bahry RW, Visser R, Iverson A (1992). Environment, cultivar, and ethephon rate interactions in barley. Argonomy, 84: 789-794.
Sutulova V.I, Egorov I.V (1991). Cultivar specificity in response of spring wheat to treatment with growth regulator, 2: 119-126.

Szirtes V, Szirtes J, Varga S, Balassa J, Mate I (1986). Hormone centered theory and practice of the application of foliar fertilizers in winter wheat and other cereals. Developments in plant and soil sciences. 22: 346-377.

Tripathi SC, Sayre KD, Kaul JN (2003) Fibre analysis of wheat genotypes and its association with lodging: effects of nitrogen levels and ethephon. Cereal Research Communications. 31 (3-4): 429-436.

Webster JR, Jackson LF (1993). Management practices to reduce lodging and maximize grain yield and protein content of fall-sown irrigated hard red spring wheat. Field Crops Research. 33(3): 249-259.

Wiersma DW, Oplinger E S, Guy SO (1986). Environment and cultivar effects on winter wheat response to ethephon plant growth regulator. Agronomy Journal. 78: 761-764.

Wiersma JJ, Dai J, Dungan BR (2011). Optimum timing and rate of trinexapac-ethyl to reduce lodging in spring wheat. Agronomy Journal. 103(3): 864-870.