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# Chemical weed control strategies for sweet corn in Türkiye's diverse production areas

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**Abstract:** Sweet corn production in Türkiye is failing to match growing demand from consumers and the food industry. Weeds severely limit sweet corn production, yet only a single herbicide is registered in Türkiye. Due to labor costs, hand weeding is no longer affordable and growers are demanding cost-effective weed control strategies for sweet corn production. Nine treatments including preemergence (PRE) and/or postemergence (POST) herbicides were tested across the country's diverse growing environments. Compared to the weedy control, all treatments increased the number of marketable ears. Only two treatments—s-metolachlor plus terbuthylazine followed by isoxaflutole plus cyprosulfamide plus theincarbazone-methyl and dimethenamid followed by mesotrione plus nicosulfuron—provided consistent late-season weed control and fully protected crop yield. This study quantifies the value that additional herbicide registrations in Türkiye could have for controlling problematic weeds in the country's sweet corn production.

**Key words:** Sweet corn (*Zea mays* L. var. *rugosa* or *saccharate*), weeds, herbicide, yield

## 1. Introduction

Growing worldwide demand for fresh and processed sweet corn has driven increased cultivation of the crop in recent years. While Türkiye has produced sweet corn for nearly a century, consumption of the crop has mirrored global trends. Türkiye's cultivation has increased in the Central Anatolia, Marmara, Aegean, and Mediterranean regions due to favorable soil and climatic conditions (Arslan and Williams, 2015) and hybrids adapted to these conditions (Turgut, 2000; Bozokalfa and Eşiyok, 2006; Ugur and Maden, 2015; Eser and Soylu, 2020). Currently, sweet corn represents approximately 10% of all corn grown in Türkiye.[1] Approximately 63,000 ha are grown for the processing market, while 12,000 ha are grown for the fresh market. The fact that Türkiye now imports approximately 900 t of sweet corn annually is a testament to demand outstripping the nation's production.

A major threat to sweet corn production is weed interference (Sandhu et al., 1999; Idziak et al., 2022). Weeds compete with sweet corn for nutrients, light, and water, causing a significant reduction in growth and yield (Wilson et al., 2010; Dittmar, 2012). Weeds cause 15% to 85% yield losses in sweetcorn in late and early sowing, respectively (Williams, 2006; Simić et al., 2012). The critical period for weed control in sweet corn spans the 2- to 10-leaf stages (Tursun et al., 2016). Despite the availability of several herbicides in the USA, the leading sweet corn producing country, weed interference causes >50% yield losses in sweet corn fields (Williams et al., 2008). Sweet corn is susceptible to weed interference because it has been selected for eating quality and disease resistance traits, rather than competitiveness with weeds (Williams, 2010; Pataky et al., 2011). Numerous studies have shown that season-long weed control is important to maximize crop yield (Sikkema et al., 2008; Robinson et al., 2013).

Weed control in sweet corn production relies on herbicides in many countries; however, only a single herbicide product (s-metolachlor plus terbuthylazine) is registered for use in sweet corn in Türkiye. This is partially due to a lack of understanding of 1) the effectiveness

[1] Turkish Statistical Institute (2022). Bitkisel Üretim İstatistikleri (online) (in Turkish). Website https://biruni.tuik.gov.tr/medas/?kn=92&locale=tr [accessed 13 January 2022].

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of preemergence (PRE) herbicides in arid climates, 2) the ability to make postemergence (POST) herbicide applications in rainy seasons, 3) the efficacy of selected herbicides on certain problematic weeds, and 4) the trade-off between herbicide efficacy and cost. Nonetheless, growers desire chemical weed control systems because historic approaches (i.e. interrow cultivation and hand weeding) are no longer sustainable due to labor availability, high cost, and impracticality. Therefore, the objective of this study was to identify the most economically effective weed control treatment(s) for Türkiye's diverse environments where sweet corn is grown.

Integrated weed management (IWM) in sweet corn aims for the judicious use of herbicides with nonchemical tactics such as highly competitive hybrid varieties and mechanical control strategies. This study contributes to better IWM systems in Türkiye's sweet corn production.

## 2. Materials and methods

To capture a wide range of growing conditions, field experiments were conducted at 4 sites between 2018 and 2021 in the Marmara (Bursa), Central Anatolia (Eskişehir and Konya), and Southeastern Anatolia (Şanlıurfa) regions (Table 1). In Eskişehir and Konya, sweet corn is grown as a main crop. In Bursa and Şanlıurfa, sweet corn is grown as a second crop.

Meteorological data were officially taken from the General Directorate of Meteorology from the soil preparation period to harvest at all sites (Table 2). Average temperatures in Bursa, Şanlıurfa, Eskişehir, and Konya were 24.8, 26.2, 18.4, and 18.1 °C, respectively. This means that the sites growing sweet corn as a second crop were approximately 7 °C warmer than the main crop sites. Precipitation in Şanlıurfa was approximately one-third to one-fourth than that of the other sites. It should be noted that sweet corn was irrigated in all experimental sites.

### 2.1. Materials

Challenger (Bayer) and Overland (Syngenta) sweet corn varieties were used because of their popularity among farmers and processors. PRE herbicides were s-metolachlor plus terbuthylazine (Primextra Opti, Syngenta Crop Protection AG, Basel, Switzerland), dimethenamid-p (Spectrum, BASF Corporation, Research Triangle Park, NC, USA), and dimethenamid-p plus terbuthylazine (Akris, BASF SE, Ludwigshafen, Germany). POST herbicides were tembotrione (Laudis, Bayer AG, Leverkusen, Germany), isoxaflutole plus cyprosulfamide plus thiencarbazone methyl (Adengo, Bayer AG), florasulam plus 2,4-dichlorophenoxyacetic acid (Resital Duo, Hektaş Trading Inc., Kocaeli, Türkiye), and mesotrione plus nicosulfuron (Monett, Hektaş Trading Inc.). Aside from s-metolachlor plus terbuthylazine, the herbicides were chosen from those registered in field corn in Türkiye that were preferred by farmers (Table 3).[2]

### 2.2. Experimental approach

The experimental design was a randomized complete block design with four replications. Plots measured 2.8 m wide (4 × 70 cm rows) and 10 m long. Blocks were separated by a 1.4 m buffer. A total of 11 treatments were tested, including: three PRE-only herbicides, three POST-only herbicides, three combinations of PRE + POST herbicides, a weed-free control, and a weedy control (Table 3). The herbicide treatments represented single and multiple herbicide sites of action.

The market price of each herbicide was obtained by averaging the price from Turkish pesticide dealers in 2020

[2] T.C. Tarım ve Orman Bakanlığı (2023). Bitki Koruma Ürünleri Veri Tabanı (online) (in Turkish). Website https://bku.tarimorman.gov.tr [accessed 28 December 2023].

**Table 1.** Basic information about experimental sites, sweet corn variety, planting date, dates of herbicide applications, and harvest date.

| Site | Year | Latitude/ longitude | Soil texture | Organic matter | Irrigation | Sweet corn variety | Planting date | PRE date | POST date | Harvest date |
|---|---|---|---|---|---|---|---|---|---|---|
| Bursa | 2018 | 40°15′14″N, 28°37′65″E | Clayey | 1.36 | Drip | Challenger | July 4 | July 5 | July 20 | September 20 |
| Eskişehir | 2019 | 39°45′38″N, 30°57′29″E | Loamy | 1.10 | Drip | Overland | April 27 | April 30 | June 1 | August 13 |
| Konya | 2019 | 39°1′28″N, 31°47′26″E | Loamy | 1.47 | Sprinkler | Challenger | April 27 | April 29 | June 2 | August 14 |
| Şanlıurfa | 2021 | 36°54′09.7″N, 38°55′00.5″E | Clayey | 1.11 | Sprinkler | Challenger | July 1 | July 2 | July 26 | August 22 |

**Table 2.** Meteorological data across the sites (minimum, maximum, average temperatures, and precipitation).

| Site | Minimum temperature (°C) | | | | | | |
|---|---|---|---|---|---|---|---|
| | April | May | June | July | August | September | Mean |
| Bursa | - | - | 17.9 | 19.9 | 20.9 | 17.3 | 19.0 |
| Şanlıurfa | - | - | 15.8 | 19.9 | 18.1 | 12.6 | 16.6 |
| Eskişehir | 5.2 | 9.3 | 14.3 | 13.3 | 14.2 | - | 11.3 |
| Konya | 3.0 | 8.5 | 13.9 | 13.2 | 14.4 | - | 10.6 |
| | Maximum temperature (°C) | | | | | | |
| | April | May | June | July | August | September | Mean |
| Bursa | - | - | 30.3 | 32.3 | 31.7 | 29.7 | 31.0 |
| Şanlıurfa | - | - | 34.5 | 38.6 | 36.9 | 31.9 | 35.5 |
| Eskişehir | 16.4 | 25.2 | 29.3 | 30.2 | 31.5 | - | 26.5 |
| Konya | 16.7 | 24.5 | 28.9 | 29.9 | 30.8 | - | 26.2 |
| | Average temperature (°C) | | | | | | |
| | April | May | June | July | August | September | Mean |
| Bursa | - | - | 23.8 | 26.2 | 26.0 | 23.1 | 24.8 |
| Şanlıurfa | - | - | 25.8 | 29.6 | 27.3 | 22.1 | 26.2 |
| Eskişehir | 10.3 | 16.9 | 21.0 | 21.4 | 22.4 | | 18.4 |
| Konya | 9.5 | 16.5 | 20.7 | 21.5 | 22.3 | | 18.1 |
| | Precipitation (mm) | | | | | | |
| | April | May | June | July | August | September | Mean |
| Bursa | - | - | 36.2 | 41.0 | 1.0 | 60.2 | 34.6 |
| Şanlıurfa | - | - | 18.2 | 11.0 | 4.8 | 6.6 | 10.2 |
| Eskişehir | 43.6 | 15.5 | 56.3 | 19.9 | 10.1 | - | 29.1 |
| Konya | 18.1 | 32.3 | 94.4 | 30.2 | 25.2 | - | 40.0 |

(Table 3). The cost of each treatment was calculated by summing the product of the herbicide use amount and market price for each treatment. For the hand weeded control, the hand weeding cost ($160.5/ha) was included in the treatment cost.[3]

Prior to planting, fields were plowed and tilled with a cultivator. The crop was sown with a pneumatic seeder one week later. The growers' common practices for fertilization and irrigation were followed at each site. PRE herbicides were applied 1–3 days after sowing. POST herbicides were applied 2–4 weeks after the PRE application. Herbicides were applied with a compressed air backpack sprayer with an operating width of 1.5 m and nozzles that delivered 300 L of spray volume per hectare at 3 atm pressure.

### 2.3. Data collection

Weed response was evaluated 2 weeks after POST treatment (2 WAT) and at harvest using three metrics. Density of weeds were determined by counting individuals of each weed species in four 0.25 $m^2$ (50 × 50 cm) quadrats in each plot. Visual estimates of weed control were recorded using a scale of 0 (no control) to 100 (complete control). Visual estimates of weed cover were recorded using a scale of 0 (no weeds) to 100 (complete weed canopy closure).

Sweet corn performance was determined by measuring plant height at the time of harvest and yield of marketable ears. Ten randomly selected sweet corn plants per plot were measured for height from the soil surface to plant apex. Ears were harvested when kernel moisture was

[3] Turkish Statistical Institute (2022). Bitkisel Üretim İstatistikleri (online) (in Turkish). Website https://biruni.tuik.gov.tr/medas/?kn=92&locale=tr [accessed 13 January 2022].

**Table 3**. Weed management treatments for sweet corn tested at the four sites.

| Treatment number | Treatment | Site of action[a] | Timing | Rate (g ai/ha) | Cost ($/ha) |
|---|---|---|---|---|---|
| 1 | MET + TER | 15, 5 | PRE | 1.25 + 750 | 27.0 |
| 2 | DIM | 15 | PRE | 576 | 17.3 |
| 3 | DIM + TER | 15, 5 | PRE | 840 + 750 | 34.2 |
| 4 | TEM | 27 | POST | 88 | 67.6 |
| 5 | ISO + CYP + THI | 27, 0, 2 | POST | 79 + 53 + 32 | 33.8 |
| 6 | FLO + 2,4 D | 2, 4 | POST | 5 + 362 | 4.3 |
| 7 | DIM fb TEM | 15, 27 | PRE + POST | 576 fb 44 | 51.1 |
| 8 | MET + TER fb ISO + CYP + THI | 15, 5, 27, 0, 2 | PRE + POST | 1.25 + 750 fb 39.5 + 26.5 + 16 | 43.9 |
| 9 | DIM fb MES + NIC | 15, 27, 2 | PRE + POST | 576 fb 75 + 30 | 33.5 |
| 10 | Weed-free control (DIM + HW) | 15 | PRE | 576 | 160.5 |
| 11 | Weedy control | - | - | - | - |

CYP, cyprosulfamide; DIM, dimethenamid; fb, followed by; FLO, florasulam; HW, hand weeding; ISO, isoxaflutole; MET, s-metolachlor; MES, mesotrione; NIC, nicosulfuron; TEM, tembotrione; TER, terbuthylazine; THI, thiencarbazone.

[a] 2, acetolactate synthase inhibitors; 4, auxin mimics; 5, photosystem 2 inhibitors; 15, long chain fatty acid inhibitors; 27, 4-HPPD inhibitors; 0, unknown.[4]

[4] Weed Science Society of America (2016). Herbicide Mechanism of Action (MOA) Classification List (online). Website http://wssa.net/wssa/weed/herbicides [accessed 30 December 2016].

approximately 76%. Ears were considered marketable when they exceeded 4.4 cm in diameter, including husk leaves. Marketable ears were picked from the central two rows of each plot over a 6 m length. Total number and mass of marketable ears were recorded.

Sweet corn growers were compensated for the mass of marketable ears harvested from each field. An economic analysis was conducted to evaluate the growers' gross profit margin in relation to crop yield and herbicide treatment cost. For this analysis, we assumed sweet corn price was \$135/metric ton. Profit margin of each treatment was calculated as the product of marketable ear mass and sweet corn price, minus the treatment cost.

Days to flowering and maturity, and harvest date of fresh ears were also recorded. In addition, the total temperature required for harvesting was measured in growing degree days (GDD) for the year of the experiment at each site. GDD was determined using a base temperature ($T_b$) of 10 °C, daily maximum ($T_{max}$), and minimum ($T_{min}$) temperatures from a nearby weather station. The total temperatures required for harvesting at each location were calculated by the formula from McMaster and Wilhelm (1997):

$$GDD = \Sigma\left(\frac{T_{max}+T_{min}}{2}\right) - T_b.$$

### 2.4. Data analysis

Weed control, weed cover, weed density, crop plant height, ear number, ear mass, and profit margin met the assumptions of analysis of variance (ANOVA). All data were analyzed with a mixed effects model, where treatments were considered fixed effects, and replicates nested within the site were considered random effects. Treatment differences were determined at a $\alpha = 0.05$. Separation of least square means was performed using the protected LSD test. Analyses were conducted using JMP Pro version 11 (SAS Institute Inc., Cary, NC, USA).

## 3. Results

Across the experiments, 31 genera and 35 species of weeds from 18 plant families were identified. However, seven weed species dominated the weed communities: three annual broadleaves, two annual grasses, one perennial grass, and one perennial broadleaf. Field bindweed was the most common species, dominating the weed community in three of the four sites whereas the other dominant species were recorded in a single field (Table 4).

### 3.1. Weed control

All herbicide treatments provided some level of weed suppression. Weed control at 2 WAT ranged from 55.6% to 87.0% (Table 5). A similar range of weed control was observed at harvest. Only two treatments—s-metolachlor plus terbuthylazine followed by isoxaflutole plus cyprosulfamide plus theincarbazone-methyl (MET + TER fb ISO + CYP + THI) and dimethenamid followed by mesotrione plus nicosulfuron (DIM fb MES + NIC)—provided consistent late-season weed control comparable

**Table 4.** Dominant weed species at the four sites in the field study.

| Scientific name | Common name | EPPO code | Site* | | | |
|---|---|---|---|---|---|---|
| | | | B | E | K | Ş |
| *Amaranthus blitoides* L. | Mat amaranth | AMABL | | | x | |
| *Chenopodium album* L. | Common lambsquarters | CHEAL | | | x | |
| *Convolvulus arvensis* L. | Field bindweed | CONAR | | x | x | x |
| *Seteria verticillata* (L.) P.B. | Bristly foxtail | SETVE | | x | | |
| *Sorghum halepense* (L.) Pers. | Johnsongrass | SORHA | | | | x |
| *Triticum aestivum* L. | Bread wheat | TRZAX | x | | | |
| *Solanum nigrum* L. | Black nightshade | SOLNI | | x | | |

*B, Bursa; E, Eskişehir; K, Konya; Ş, Şanlıurfa.

**Table 5.** Overall weed control, cover, density at two weeks after POST treatment and at harvest in response to treatments[a].

| Treatment number | Treatment | Weed control (%) | | Weed cover (%) | | Weed density plants m$^{-2}$ | |
|---|---|---|---|---|---|---|---|
| | | 2 WAT | Harvest | 2 WAT | Harvest | 2 WAT | Harvest |
| 1 | MET + TER | 66.2 cd | 80.1 cd | 30.6 cde | 17.6 de | 41.3 cde | 19.9 cde |
| 2 | DIM | 55.6 e | 67.8 e | 40.6 b | 30.2 c | 46.8 bcde | 23.7 bcd |
| 3 | DIM + TER | 63.1 de | 83.8 bc | 34.3 bcd | 17.1 de | 40.2 cde | 19.0 cde |
| 4 | TEM | 60.3 de | 54.7 f | 35.1 bc | 44.2 b | 56.4 bc | 32.4 b |
| 5 | ISO + CYP + THI | 67.2 cd | 74.0 de | 28.5 cde | 23.8 cd | 57.3 bc | 22.0 bcd |
| 6 | FLO + 2,4 D | 62.7 de | 48.3 f | 33.1 bcd | 53.0 b | 63.6 b | 25.4 bc |
| 7 | DIM fb TEM | 72.6 c | 71.0 de | 31.5 bcd | 31.1 c | 48.6 bcd | 22.2 bcd |
| 8 | MET + TER fb ISO + CYP + THI | 81.8 b | 91.8 ab | 25.0 de | 9.6 ef | 33.4 def | 12.3 de |
| 9 | DIM fb MES + NIC | 87.0 b | 87.8 abc | 21.6 e | 17.1 de | 28.8 ef | 13.9 cde |
| 10 | Weed-free control | 97.9 a | 95.4 a | 3.3 f | 3.4 f | 17.3 f | 9.9 e |
| 11 | Weedy control | 0.0 f | 0.0 g | 80.4 a | 79.3 a | 107.5 a | 51.9 a |

[a] Means separation within columns using LSD comparison test at α = 0.05.
MET, s-metolachlor; TER, terbuthylazine; DIM, dimethenamid; TEM, tembotrione; ISO, isoxaflutole; CYP, cyprosulfamide; THI, thiencarbazone methyl; FLO, florasulam; fb, followed by; MES, mesotrione; NIC, nicosulfuron; WAT, weeks after POST treatment.

to the weed-free control. Similar results were observed for weed cover and weed density (Table 5).

### 3.2. Sweet corn performance

#### 3.2.1. Vegetation periods of sweet corn

The days to flowering and maturation vary depending on whether sweet corn was grown as the main or second crop, the climate of the region, and the year of production. Vegetation related values were very similar at the main crop sites Eskişehir and Konya (Table 6), both of which share similar climatic conditions in the Central Anatolia region. On the contrary, the second crop sites Bursa and Şanlıurfa showed differences in GDD, maturation, and days to flowering but not for other parameters. Şanlıurfa showed signs of early flowering (44–49 days) and later maturation (77 days) compared to Bursa (55–57 days and 71 days, respectively).

Sweet corn plants were generally shorter compared to the weed-free control but taller than the weedy control (Table 7). Only two treatments (MET + TER fb ISO + CYP + THI and DIM fb MES + NIC) resulted in plants similar in height to the weed-free control. No crop injury was observed in any of the treatments.

**Table 6.** Vegetation period of sweet corn at the four sites.

| Growth parameters | Second crop | | Main crop | |
|---|---|---|---|---|
| | Şanlıurfa (2021) | Bursa (2018) | Eskişehir (2019) | Konya (2019) |
| Flowering (days) | 44–49 | 55–57 | 71–74 | 71–74 |
| Maturation (days) | 77 | 71 | 101 | 102 |
| GDDs (°C) | 2259.1 | 1980.3 | 2208.9 | 2193.9 |
| Planting date | July 1 | July 4 | April 27 | April 27 |
| Harvest date | September 22 | September 20 | August 13 | August 14 |

GDDs: growing degree days.

**Table 7.** Plant height, ear number, ear yield, and profit margin of sweet corn in response to treatments[a].

| Treatment number | Treatment | Plant height (cm) | Ear number (number/ha) | Ear mass (t/ha) | Profit margin ($/ha, %) |
|---|---|---|---|---|---|
| 1 | MET + TER | 167 bcd | 36,384 c | 12.15 b | 1615 a, 75.7 |
| 2 | DIM | 167 bcd | 40,129 abc | 12.37 b | 1654 a, 80.0 |
| 3 | DIM + TER | 169 bcd | 43,055 ab | 12.89 ab | 1708 a, 85.9 |
| 4 | TEM | 165 cd | 36,309 c | 12.53 ab | 1626 a, 76.9 |
| 5 | ISO + CYP + THI | 168 bcd | 37,971 abc | 13.25 ab | 1757 a, 91.2 |
| 6 | FLO + 2,4D | 160 d | 37,649 bc | 12.16 b | 1639 a, 78.3 |
| 7 | DIM fb TEM | 163 cd | 38,120 abc | 12.30 b | 1611 a, 75.3 |
| 8 | MET + TER fb ISO + CYP + THI | 180 a | 37,922 bc | 13.29 ab | 1752 a, 90.6 |
| 9 | DIM fb MES + NIC | 172 abc | 43,552 ab | 14.44 ab | 1917 a, 108.6 |
| 10 | Weed-free control | 175 ab | 44,196 a | 14.79 a | 1838 a, 100.0 |
| 11 | Weedy control | 146 e | 25,902 d | 6.78 c | 919 b |

[a] Means separation within columns using LSD comparison test at α = 0.05.
MET, s-metolachlor; TER, terbuthylazine; DIM, dimethenamid; TEM, tembotrione; ISO, isoxaflutole; CYP, cyprosulfamide; THI, thiencarbazone methyl; FLO, florasulam; fb, followed by; MES, mesotrione; NIC, nicosulfuron.

All herbicide treatments protected sweet corn yield to some extent compared to the weedy control (Table 7). Several treatments had comparable ear numbers and mass to the weed-free control, including MET + TER fb ISO + CYP + THI and DIM fb MES + NIC.

All herbicide treatments resulted in improved profit margins compared to the weedy control (Table 7). All herbicides resulted in yield gain from $1611/ha to $1912/ha and profit margins 75–109% compared to the weedy control. Treatment costs varied between $4.32 and $67.57/ha according to product costs in 2020 in Türkiye (Table 3), leading to favorable profit margins for all treatments. For instance, the cost of florasulam plus 2,4-dichlorophenoxyacetic (FLO + 2,4 D) was only $4/ha while the yield gain was $1639/ha, giving a relatively low profit margin of 78% compared to the weedy control. DIM fb MES + NIC provided the most consistent weed suppression and crop yield metrics. The treatment cost was moderate ($34/ha) relative to other treatments and the profit margin was the highest.

**4. Discussion**

The objective of this study was to identify the most cost-effective weed control treatment(s) for Türkiye's diverse environments where sweet corn is grown. To capture a wide range of growing conditions, four field studies were conducted from 2018 to 2021 at sites in the Marmara, Central Anatolia, and Southeastern Anatolia regions where sweet corn is grown as a main and second crop. Using herbicides registered for use in Türkiye corn fields, we tested nine chemical weed control treatments containing the herbicides the most preferred by sweet corn growers. We used a mixed statistical model to identify the most robust treatment(s) across the diverse environments. Moreover, we included an economic analysis to compare the weed control treatments.

While a total of 35 weed species were observed across the four sites, seven species dominated the field studies, with field bindweed being the most common. A grass species was dominant at three sites. The diverse weed communities observed in the field experiments highlights the need for broad-spectrum weed control, including the ability to selectively control grassy weeds in a grass crop like sweet corn.

The treatment effects varied for weed species at different densities in the fields. Some of the dominant species were listed on some herbicide labels, while other species were not. For example, mat amaranth, field bindweed, and bristly foxtail were missing from the labels. The dominant species were very similar to those reported in an earlier study (Tursun et al., 2016). Two treatments provided the best weed control and density reduction: MET + TER fb ISO + CYP + THI and DIM fb MES + NIC. These treatments are known to be effective against some of the dominant weed species, and this could explain why they performed so well. For example, common lambsquarters, bristly foxtail, and black nightshade are listed on MET + TER fb ISO + CYP + THI labels, while common lambsquarters, black nightshade, field bindweed, and johnsongrass are listed on DIM fb MES + NIC labels. Moreover, less dominant weed species that were found in the field trials were also listed on the labels. Some of the treatments also controlled species that were not listed on the labels. According to our field observations, MET + TER fb ISO + CYP + THI controlled mat amaranth and field bindweed despite not being listed on the labels. Similarly, DIM fb MES + NIC controlled bristly foxtail and mat amaranth.

Combinations of PRE + POST herbicides were more effective than relying on PRE-only or POST-only applications. Moreover, multiple active ingredients within PRE or POST application generally performed better than single active ingredient applications of PRE or POST. In the USA, sequential applications of PRE and POST herbicides are used in the majority of fields (Williams et al., 2010). Combinations of PRE herbicides require less rainfall for successful control than the herbicides applied individually (Landau et al., 2021). To increase efficacy and weed control spectrum, a 4-hydroxyphenylpyruvate dioxygenase (HPPD)-inhibitor herbicide is commonly applied with a photosystem 2 (PS 2)-inhibitor (Jhala et al., 2023). Combining herbicides with different mode of action at the time of application is important for improving weed control and delaying the development of herbicide resistance (Evans et al., 2016).

Among the PRE-only treatments, DIM + TER and MET + TER provided consistent late-season weed control of more than 80%. This could be due to the fact that these two treatments contain terbuthylazine, a broad-spectrum herbicide registered for control of most annual grasses and broadleaf weeds (Sahid and Teoh, 1994).

Some herbicides applied in this study are also used in sweet corn fields in the USA, including s-metalochlor, dimethanamid, and mesotrione. The HPPD-inhibiting herbicides mesotrione, tembotrione, and topramezone are important POST herbicides in sweet corn (Williams et al., 2010). However, the single most widely used herbicide in the USA sweet corn production, atrazine, is not available in Türkiye.

Field observations by the authors indicate that sweet corn growers in Türkiye are concerned about crop injury from certain herbicides, including tembotrione. Crop injury was not observed in the current study, probably because the sweet corn seed industry has been addressing herbicide sensitivity by eliminating breeding lines with mutant alleles.

Vegetation related values for main crop sweet corn were similar in Eskişehir and Konya provinces, probably due to the similar climatic conditions at the two locations. On the contrary, huge weather difference between Bursa and Şanlıurfa sites caused differences in GDD, maturation, and days to flowering. The days to flowering both tassel and ear were the lowest in Şanlıurfa site, where the temperatures were high. The abiotic heat stress in the Southeastern Anatolia region accelerated flowering time and maturity despite irrigation efforts.

## 5. Conclusion

While all herbicide treatments resulted in improved gross profit margins over the weedy control, two treatments in particular were the best for weed suppression and crop protection: MET + TER fb ISO + CYP + THI and DIM fb MES + NIC. These combinations of herbicides provided multiple modes of action, and the combination of PRE and POST applications increased the chance of success. Neither of these treatments were the cheapest tested; however, they were among the best treatments for weed control and sweet corn yield. Numerically, DIM fb MES + NIC had the highest profit margin of the treatments that did not require hand weeding. Although several herbicides are registered for use in field corn in Türkiye, only dimethenamid is registered in sweet corn. Clearly, additional herbicide registrations in sweet corn are needed.

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**Conflict of interest**

The authors declare no conflict of interest.

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