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# Dry weight and nutrient uptake of twenty one sweet sorghum genotypes grown in two separate locations of Turkey

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**Abstract**

Sweet sorghum (*Sorghum bicolor L.*) is a type of cultivated sorghums and has been recognized widely as potential alternative source of bio-fuel because of its high fermentable sugar content in the stalk. A substantial variation of dry matter (DM) yield and nutrient uptake information is needed for sweet sorghum genotypes under different climatic and soil conditions. The objectives of this study were (i) to assess the genotypic variation irrespective to dry matter yield and nutrient up take of sweet sorghum genotypes (ii) to investigate nitrogen use efficiency of sweet sorghum genotypes. This field study was conducted in Adana and Urfa location of Turkey for one growing season where twenty one sweet sorghum genotypes were used as testing plant that collected from USA. These twenty one genotypes were selected through screening of forty nine genotypes. The experiment was conducted randomized block design with four replications in both locations. Growth parameters, nutrient up take and nitrogen (N) use efficiency was determined for the twenty one sweet sorghum genotypes. Biomass yield exhibited non-significant differences among genotypes. In contrast, significant differences were observed between Adana and Urfa irrespective to biomass yield. The N use efficiency by several sweet genotypes varies from 385 to 836 kg/ha and 282 to 779 kg/ha in Adana and Urfa locations respectively. Sweet sorghum genotypes responded differently to potassium (K), calcium (Ca) and magnesium (Mg) uptake. The K uptake varies 381 to 1472 and 374 to 1405 kg/ha in Adana and Urfa locations respectively. The Ca uptake also varies 115 to 582 and 115 to 424 kg/ha in Adana and Urfa locations respectively. The Mg uptake varies 81 to 300 and 50 to 226 kg/ha in Adana and Urfa locations respectively. Our results suggest that diverse genotypic variation from different geographical regions should be considered from better sweet sorghum production from the collected sweet sorghum varieties. This study concluded that sweet sorghum genotypes may be used to develop new varieties with higher dry matter production and lower nutrient utilization by these genotypes along with the adaptations of several climatic conditions in Turkey.

**Keywords:** Nitrogen use efficiency, soil type, genomic investigation, environmental condition, ethanol.

**Introduction**

Sweet sorghum (*Sorghum bicolor* var. saccharatum *L.*) belongs to *Poacea* family (Monteiro et. al., 2012). Sweet sorghum (*Sorghumbicolor* var. saccharatum *L.*) is a major crop which produces high yielding green biomass and ethanol against per unit consumption of nutrients, water and time (Vermerris et al., 2017). Cultivation of sweet sorghum on marginal lands with minimal inputs and high energy gain is currently the most auspicious solution to prevent energy crises and reduce $CO_2$ emissions (Tian et al., 2009; Regassa and Wortmann, 2014). Sweet sorghum is also a C4 photosynthesis pathways produce sucrose for energy storage, which is easily convertible to ethanol (Ali et al., 2008). Sweet sorghum is commonly cultivated in tropic and sub-tropic regions of the world (Hassanein et al., 2010). Beside high biomass yield, sweet sorghum is highly resistant against drought, salinity and flooding (Li, 1997; Mastrorilli et al., 1999). Sweet sorghum can also grow diverse climate and soil condition (Teetor et al., 2011). It can also tolerate adverse climatic and edaphic conditions (Ameen et al., 2016). Therefore, it is essential to screen several sweet sorghum genotypes for dry weight and nutrient up take under diverse climatic conditions (Ahmed et al., 2017).

Sweet sorghum has versatile genetic base with near 4000 sweet sorghum cultivars distributed across the world (Grassi et al., 2004). Research interest in sorghum cultivars has been widely tested on the general prospect of sugar and syrup production, total biomass yield and cultivars geographical and soil adaptability features. Due to the fact of the extensive commercial interest in sweet sorghum production, plant residue potentially becomes a significant supplier of biomass. Sweet sorghum genotypes also differ greatly in

their qualities and adaptation to various soil and climatic conditions (Ratnavathi et al., 2010).
Existing sweet sorghum varieties or genotypes has low productivity in Turkey (Kaplan and Kara 2014). It needs to be improved. Climatic conditions also important to quantify existing sweet sorghum yield in Turkey. Our specific objective was to examine the genotypic variability within collected sweet sorghum irrespective to dry weight and nutrient uptake in two locations of Turkey. Therefore, this study were undertaken (1) to evaluate the biomass yield potential and nutrient uptake responses of sweet sorghum genotypes under two locations that differs both soil and climatic conditions (2) to determine the most suitable sweet sorghum cultivars and lines with biomass and nutrient uptake under hot and dry condition in Turkey. We hypothesized that sweet sorghum genotypes will be responded better in Adana locations with respected to dry matter yield, nutrient up take and nitrogen use efficiency than Urfa locations.

## Results

### *Growth response of sorghum genotypes*

Sweet sorghum plant height varies from Adana to Urfa (Table 3). The height of Wary genotypes had 437 cm and the lowest of Gülşeker genotypes was found 267 cm at Adana locations. Similarly, the Grassi sorghum genotypes had 456 cm plant and the Mennonita genotypes were found 291 cm (Figure 1).
In general, shoot dry weight did not differ among genotypes (Figure 2). However, the shoots dry weight of several genotypes significantly ($P \geq 0.01$) between two locations (Table 3). Theis genotypes produced maximum shoot dry weight (77248 kg/ha) and Rox orange produced minimum shoot dry weight (35947 kg/ha) in Adana locations. Similarly, the P1579753 genotypes produced maximum shoot (77887 kg/ha) and the mennonita produces minimum shoot (28240 kg/ha) in Urfa locations.
On average, root dry weight was higher in Adana than Urfa (Figure 3). Root proliferation was highest in P1579753 sorghum genotypes and lowest in Mennonita sorghum genotypes at Adana. Likewise, root proliferation was highest in M81-E sorghum genotypes and lowest in BATAEM-2 sorghum genotypes at Urfa.
Like as before, the root: shoot varies location to location (Table 3). On average, the root: shoot was found in Adana than Urfa (Figure 4). The higher root: shoot was 0.147 in Rox orange and the lowest root: shoot was 0.06 in white orange at Adana. Similarly, the highest root: shoot was 0.127 in white orange and lowest was 0.050 in BATEM-5 at Urfa.

### *Nutrient uptake by several sweet sorghum genotypes*

Two locations significantly ($P \geq 0.05$) differed irrespective to N uptake (Table 4; Table 5). On average, N uptake by several sweet sorghum genotypes were higher in Adana than Urfa locations. The highest N uptake by Tracy genotype was 1123 kg/ha and lowest by UNL-hybrid-5 was 603 kg/ha at Adana locations. Likewise, the highest N uptake by theis genotype was 1267 kg/ha and lowest N uptake by Mennonita genotype was 375 kg/ha at Urfa location.
The P uptake by sweet sorghum genotypes were significantly ($P \geq 0.05$) differed both in locations and genotypes. However, locations and genotypes interaction did not differ (Table 4; Table 5). Several sweet sorghum genotypes taken up more P in Adana than Urfa locations. The Nebraska genotype uptake maximum P (257 kg/ha) and the Dale genotype uptake minimum P (64 kg/ha) at Adana location. The Rox Orange genotype uptake maximum P (203 kg/ha) and White orn genotype uptake minimum P (55 kg/ha) at Urfa location.
Interestingly, the K uptake among location, genotype and location×genotype interaction significantly differed (Table 5). The K uptakes by sweet sorghum genotypes were higher in Adana than Urfa locations with some exceptions. The maximum K uptake was 1472 kg/ha for BATAEM-4 sweet sorghum genotypes and minimum K uptake was 381 kg/ha for Dale sweet sorghum locations at Adana locations. The maximum K uptake was 1405 kg/ha for Rox orange sweet sorghum genotypes and minimum was 374 kg/ha for M81-E sweet sorghum genotypes at Urfa locations.
On average, Ca uptake by several sweet sorghum genotypes was higher in Adana than Urfa locations. At Adana, the highest Ca uptake was 504 kg/ha for Tracy sweet sorghum genotypes. In contrast, the lowest Ca uptake was 115 kg/ha for Dale sweet sorghum genotypes. At Urfa, the highest Ca uptake was 424 kg/ha for Rox orange sweet sorghum genotypes. The lowest Ca uptake was 130 kg/ha for M81-E sweet sorghum genotypes.
In general, Mg uptake by several sweet sorghum genotypes was higher in Adana than Urfa locations. The highest Mg uptake by Gülşeker sweet sorghum genotype was 247 kg/ha and the lowest Mg uptake by Dale sweet sorghum genotype was 81 kg/ha for Adana location. Similarly, the highest Mg uptake by Wary sweet sorghum genotype was 187 kg/ha and the lowest Mg uptake by Mennonita sweet sorghum genotype was 50 kg/ha for Adana location.

### *Nitrogen use efficiency*

On average, nitrogen use efficiency by sweet sorghum genotypes was higher in Adana than Urfa locations (Figure 5). The Grassi genotypes has highest nitrogen use efficiency (836 kg/ha) and BATAEM-2 has lowest nitrogen use efficiency (385 kg/ha) at Adana locations. Similarly, the P1579753 genotypes has maximum nitrogen use efficiency (779 kg/ha) and minimum (282kg/ha) at Urfa locations.

## Discussion

### *Effect of climatic and soil condition on sweet sorghum growth response*

Sweet sorghum growth response significantly ($P \geq 0.05$) differed between two locations (Table 3). The Adana location was better than urfa locations. Adana has a mild climate and nutrient rich soil. Likewise, a study found that sweet sorghum varieties differ widely in their adaptation to various soil and climatic conditions (Laopaiboon et. al. 2009). There were no differences in plant height probably due to

**Table 1.** Genotypes of sweet sorghum used in the study.

| Sl no | Genotype Name | Received organization |
|---|---|---|
| 1 | Cowley | Nebraska University/ABD |
| 2 | Dale, | Nebraska University/ABD |
| 3 | Grassi | Nebraska University/ABD |
| 4 | M81-E | Nebraska University/ABD |
| 5 | Mennonita | Nebraska University/ABD |
| 6 | Nebraska sugarcane | Nebraska University/ABD |
| 7 | P1579753 | Nebraska University/ABD |
| 8 | Ramada | Nebraska University/ABD |
| 9 | Roma | Nebraska University/ABD |
| 10 | RoxOrange | Nebraska University/ABD |
| 11 | Smith | Nebraska University/ABD |
| 12 | SugarDrip | Nebraska University/ABD |
| 13 | Theis | Nebraska University/ABD |
| 14 | Tracy | Nebraska University/ABD |
| 15 | White Orn | Nebraska University/ABD |
| 16 | Wray | Nebraska University/ABD |
| 17 | UNL-hybrid -5 | Nebraska University/ABD |
| 18 | BATAEM-2 | USDA***(OriginChina) |
| 19 | BATAEM-4 | Nebraska University/ABD |
| 20 | BATAEM-5 | Nebraska University/ABD |
| 21 | Gülşeker (Control) | Uludag University. Faculty of Agriculture, Dep.of Field crops. |

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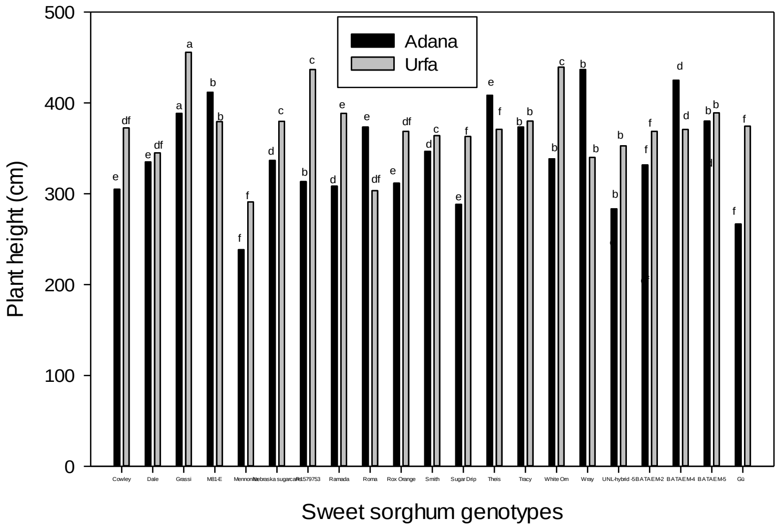


**Fig 1.** Plant height at 89 days after transplanting of several sweet sorghum genotypes that grown in Adana and Urfa locations of Turkey. Data were means of four replicates. Means with the same letter are not significanly different.

**Table 2.** Some Chemical and physical properties of soil at depths of 0–30 cm in Adana and Sanliurfa Location

| Location | Adana | Sanliurfa |
|---|---|---|
| pH (1:2.5 $H_2O$) | 7.40 | 7.6 |
| EC (dS/m) (1:2.5 $H_2O$) | 0.18 | 0.2 |
| OM (%) | 1.16 | 0.67 |
| Total N (%) | 0.11 | 0.059 |
| Available P (mg/kg) | 0.63 | 0.39 |
| CaCo3 (%) | 30.3 | 40.8 |
| Sand (%) | 25.2 | 28.3 |
| Silt (%) | 42.0 | 26.7 |
| Clay (%) | 32.8 | 45.0 |
| Textural class | clay loam | clay |

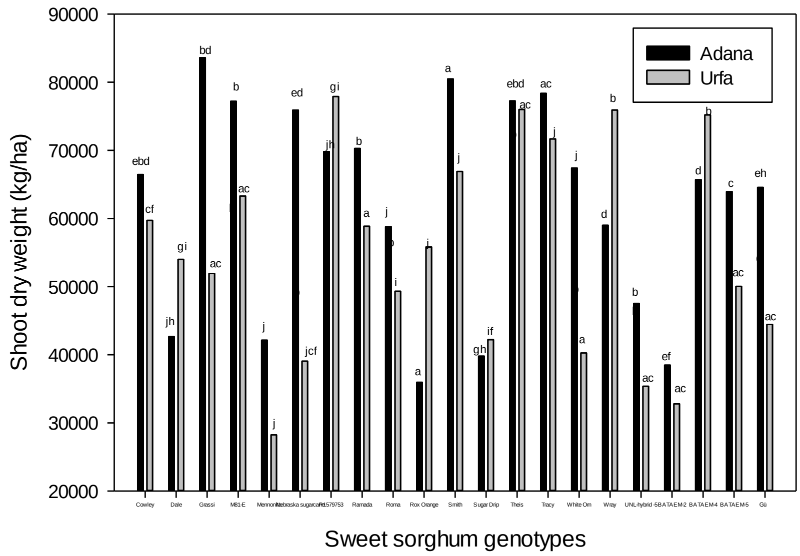


**Fig 2.** Shoot dry weight at 89 days after transplanting of several sweet sorghum genotypes that grown in Adana and Urfa locations of Turkey. Error bar means SE (±4).

**Table 3 .** Level of significance on growth response of sorghum genotypes and locations.

| Source of variation | Plant height | Shoot dry weight | Root dry weight | Root: Shoot |
|---|---|---|---|---|
| Locations | *** | ** | *** | *** |
| Genotypes | n.s. | n.s. | n.s. | n.s. |
| Locations× Genotypes | n.s. | n.s. | n.s. | n.s. |

Where n.s., ** and *** represent probability of > 0.05, ≤ 0.01 and ≤ 0.001. Values were means of three replicates.

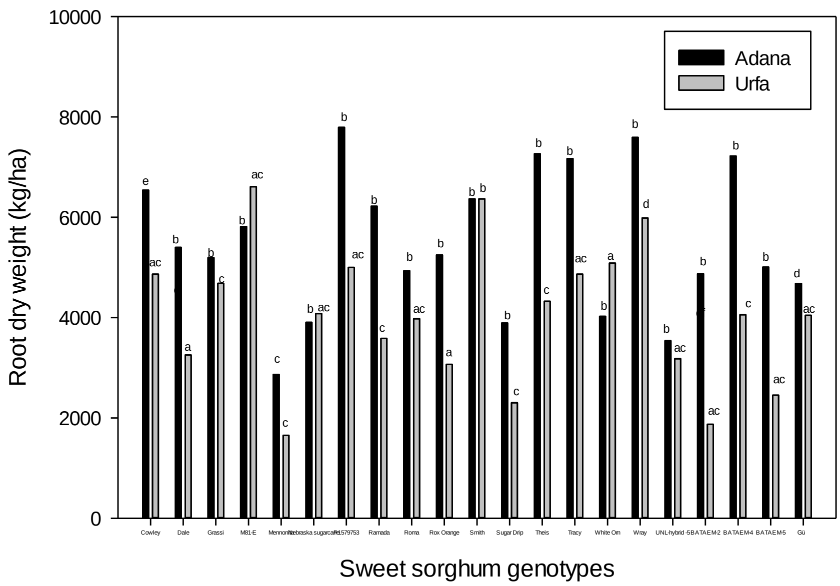


**Fig 3.** Root dry weight at 89 days after transplanting of several sweet sorghum genotypes that grown in Adana and Urfa locations of Turkey. Means with the same letter are not significantly different. Data were means of four replicates.

**Table 4.** Nutrient uptake by several sweet sorghum genotypes in two separate locations.

| Sweet sorghum genotypes | N uptake (kg/ha) | | P uptake (kg/ha) | | K uptake (kg/ha) | | Ca uptake (kg/ha) | | Mg uptake (kg/ha) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Adana | Urfa | Adana | Urfa | Adana | Urfa | Adana | Urfa | Adana | Urfa |
| Cowley | 1016ac | 1009a | 90ij | 92gi | 760dh | 1009bc | 192fh | 261ab | 135fg | 138ab |
| Dale | 752cf | 690c | 64j | 86a | 381fj | 1176a | 115g | 261b | 81h | 127cd |
| Grassi | 1120af | 613b | 149di | 89e | 963eh | 720dg | 301dg | 226cd | 206ef | 108fh |
| M81-E | 1069ae | 755c | 162ei | 69df | 1072gj | 374j | 281fh | 130gh | 238bc | 143df |
| Mennonita | 735f | 375ef | 168fi | 52ci | 727ij | 480hj | 270fh | 185ec | 167gh | 50bd |
| Nebraska | 1556ab | 628bf | 257ac | 73be | 1275df | 703ab | 385df | 153dg | 244df | 80gh |
| sugarcane | 1061a | 1246ac | 117ch | 143a | 810dg | 986bc | 331bd | 312bc | 216bc | 162fh |
| P1579753 | 1069ac | 990ab | 248a | 103cd | 1350ab | 1104ci | 582a | 215c | 243bc | 141eh |
| Ramada Roma | 791bf | 738cf | 213ae | 81bi | 1031ei | 585j | 354eh | 132gh | 243df | 89gh |
| Rox orange | 753af | 973bf | 138ab | 203ch | 558df | 1405dg | 203bd | 424ab | 156bc | 226a |
| Smith | 980ac | 1064bc | 163af | 119fg | 1130bd | 993ab | 447ac | 276fh | 315a | 134bc |
| Sugar Drip | 639ef | 557af | 112gj | 95hi | 544gj | 921dh | 174gh | 224df | 102gh | 111ef |
| Theis | 799ac | 1267ab | 103fj | 112ac | 510hj | 843dg | 315ce | 281bd | 195df | 131bd |
| Tracy | 1123ac | 992af | 174ch | 93ei | 1439bd | 574gi | 504ab | 250a | 237ce | 115ac |
| White Orn | 1054cf | 392bf | 172ei | 55ad | 1077ei | 527eh | 326fh | 136eh | 242ef | 69ce |
| Wray | 864ad | 1059bf | 170ac | 146ij | 1143bc | 1025df | 337bd | 303fh | 244ab | 187ad |
| UNL-hybrid -5 | 603f | 458c | 140jj | 61j | 758j | 418ab | 294fh | 115g | 161gh | 58fh |
| BATAEM-2 | 684df | 590cd | 129ei | 104a | 1035dg | 806afj | 245fh | 209ac | 163ef | 128ac |
| BATAEM-4 | 828ad | 1057bd | 204ac | 100ci | 1472a | 1263eh | 445bd | 178bc | 300a | 151ce |
| BATAEM-5 | 656df | 656bf | 180hj | 92ch | 1385bc | 782ij | 430ac | 251fh | 263ac | 149bc |
| Gülşeker | 1067ae | 769ef | 239ei | 77ab | 1319dh | 386ab | 489ac | 189cd | 247ce | 105ef |

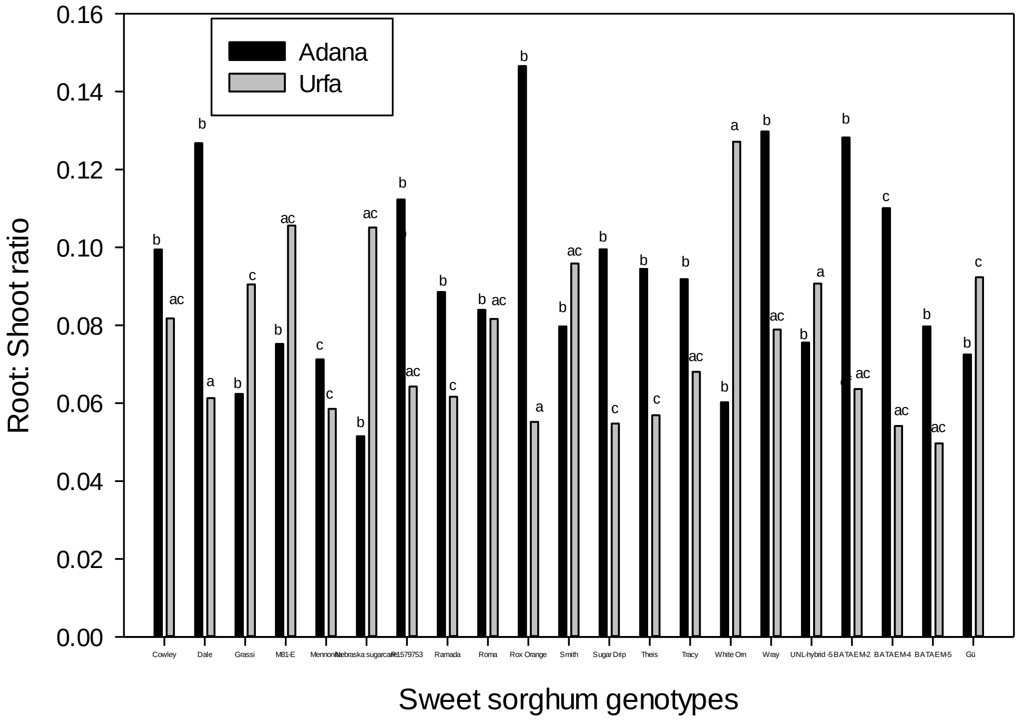


**Fig 4.** Root:Shoot ratio of sweet sorghum genotypes that grown in Adana and Urfa locations of Turkey. Means with the same letter are not significantly different. Data were means of four replicates.

**Table 5:** Level of significance for the main and interactive effect of locations and genotypes on nutrient uptake and nitrogen use efficiency by several sweet sorghum genotypes.

| Source of variation | N uptake | P uptake | K uptake | Ca uptake | Mg uptake | N use efficiency |
|---|---|---|---|---|---|---|
| Locations | * | *** | ** | *** | *** | * |
| Genotypes | n.s. | * | * | ** | ** | n.s. |
| Locations× Genotypes | n.s. | n.s. | *** | *** | * | n.s. |

Where n.s.,*, ** and *** represent probability of > 0.05, ≤ 0.05, ≤ 0.01 and ≤ 0.001. Values were means of three replicates.

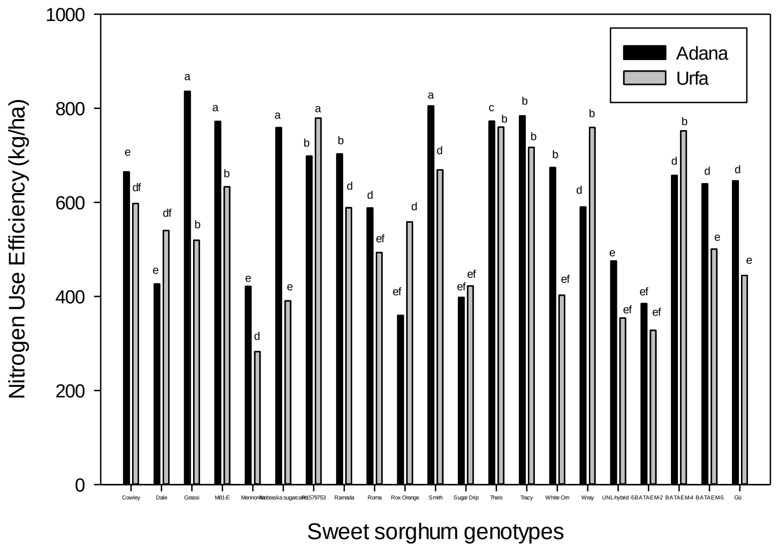


**Fig 5.** Nitrogen use efficiency of several sweet sorghum genotypes that grown in Adana and Urfa locations of Turkey. Mean with the same letter are not significantly different.

environmental condition that prevailed during growth period. Among 21 genotypes tested, there were genotypic variations attributed to genetic background for most of the trails evaluated. A study found that sweet sorghum can be adapted to widely differing climatic and soil conditions (Gnansounou et. al., 2005). Other study also speculated that climate have significant impacts on plant biomass productivity (Clark et al., 1997). Thus, the sweet sorghum is adaptable and can be grown under a wide range of cultivation conditions in marginal areas.

A one year field study was conducted to evaluate sweet sorghum and sorghum × Sudan grass hybrids as feed stocks for ethanol production (Tew et al., 2008). They have evaluated five sweet sorghum genotypes for their yield potential. They found that yield of Theis sweet sorghum genotype was highest among all genotypes. This one year study suggested that choice of sweet sorghum type would depend on environment condition.

Our speculation is that sweet sorghum is a dynamic plant. It can adapt well to changing climatic conditions, as observed in this study. Soil and climatic conditions are influential in sweet sorghum's growth and nutrient uptake. Despite this difference in two locations like Adana and Urfa, above ground biomass and nutrient uptake appear to have similar affects on soil organic carbon stocks. Yet, sweet sorghum is a strong candidate for continued biofuel feedstock research because it almost always produces a yield, except in the most depending on location, soil type, climate, and a plethora of crop management choices.

***Genotypic variations***

Sweet sorghum genotypes did not differ irrespective to growth performance among them. There was no genotypic variation was found irrespective to growth response among all sweet sorghum genotypes (Table 3). However, K, Ca and Mg up take significantly ($P \geq 0.05$) differed among genotypes and locations × genotypes interactions (Table 5). Result showed that several sweet sorghum genotypes had more dry weight in Adana than Urfa locations. Thus, the diverse germplasm of sweet sorghum genotypes possesses great potential for improved performance through breeding and genomic investigation (Salon). No genotypes were consistently superior in root: shoot ratio. Comparison among 21 sweet sorghum genotypes showed that root: shoot ratio was highest in Rox Orange (0.147) and lowest in BATAEM-5 was 0.050 (Figure 4). A study found that M81-E and Theis sweet sorghum genotypes stem yield was almost similar like 103.57 and 100.14 t/ha respectively (Almodares and Hatamipour, 2011). We also found that M81-E and Theis sweet sorghum genotypes shoot dry weight was 77186 and 77248 kg/ha respectively (Figure 2). Nitrogen use efficiency for Grassi, M81-E, Mennonita, Nebraska sugarcane, Ramada, Rom, Smith, White Orn, BATAEM-5 and Gülşeker was higher in Adana than Urfa locations (Figure 5). Accession no. as well as registration of Dale, Tracy, Wary, M81-E, Theis and Smith sweet sorghum genotypes was NSL74333, NSL4029, NSL117772, NSL174431, CSR216 and PI511355 as well as 1973, 1955, 1981, 1983, 1978 and 1988 respectively. All of these genotypes originated from Mississippi, USA except

Smith in Texas, USA. The Pedigree Dale, Tracy, Wary, M81-E, Theis, Smith and Mennonite sweet sorghum genotypes was Tracy/MN 960 (PI 152857), White African (Mer. 51-2)/Sumac, PI 152728 (Mer.57-1)//Brawley /Rio, Brawley// Brawley/Rio, (Wiley/C.P. Special)/(MN1054/White African)/Mn660, Mer. 81-2 (MN 4004/Mer. 61-11) and Old-fashioned cane sorghum with red-hulled seeds, respectively (Ali et al., 2008). There may be possibility that most of the genotypes were same origin Mississippi, USA that causes no much genotypic variation. The plant heights, shoots dry weight, root dry weight and root: shoot ratio were not significant among sweet sorghum genotypes.

***Nutrient uptake***

Nutrient uptake i.e K, Ca and Mg were significantly differed among genotypes, location and location × genotype interaction (Table 5). The K uptake by M81-E genotypes in our study was higher (374 kg/ha Urfa location) compared to 156 kg/ha reported in other study (Heitman et al., 2017). This is likely to be a function of higher dry weight measured in our study. There was a wide range of shoot nutrients concentration found among the sweet sorghum genotypes. Highest nutrients (N, P, K, Ca, Mg) uptake in Adana location (2.1, 0.399, 2.69, 0.83, 0.45 %) respectively with (Rox Orange, Mennonita, BATAEM-2, Ramadaand and BATAEM-4 genotypes). It was highest compared to another location (Urfa) nutrients (N, P, K, Ca, Mg) uptake (1.81, 0.403, 2.7, 0.76 %) respectively with (Gülşeker, BATAEM-2, BATAEM-2, Rox Orange and BATAEM-2 genotypes). Respective increase in nutrients uptake of sweet sorghum can be attribute to the higher biomass production. Growth rate of sweet sorghum genotypes depends upon nutrient concentration, even when quantity of nutrient was not limiting.

A study found that nutrient up take varies for M81-E sweet sorghum genotypes like 52 to 118 kg/ha, 8 to 20 kg/ha and 92 to 115 kg/ha for N, P and K respectively. This could be due to the reason that high dry matter yield support relatively low nutrient up take in sweet sorghum (Heitman et al., 2017). Our findings showed that nutrient up take significantly ($P \geq 0.05$) vary between Adana and Urfa locations (Table 5). This variation in nutrient uptake due to experimental location illustrated the importance of designing biomass production strategies tailored to specific regions (Wight et al., 2012).

***Nitrogen Use efficiency***

Several sweet sorghum nitrogen use efficiency varies from 600 to 900 kg/ha (Figure 5). This is higher than other plants. Because, sweet sorghum is $C_4$ plants can have higher nitrogen-use efficiency than $C_3$ plants (Gardner et al., 1994). Likewise, sweet sorghum belongs to the NADP-malic enzyme (NADP-ME) subtype of $C_4$ plants that often have a lower leaf nitrogen content and a higher nitrogen use efficiency and instantaneous photosynthetic nitrogen-use efficiency (PNUE) than do plants of the NAD-malic enzyme (NADME) subtype (Ghannoum et al., 2005).

Optimizing N rate to realize the full potential of sorghum genotypes can improve nitrogen use efficiency. A few studies on responses of sweet sorghum yield to N rate, conducted for a variety of soil types and environmental conditions, have reported minimal or statistically insignificant effects of increased N application rates on dry mass yield (Wortmann et al., 2010). Nitrogen use efficiency by sweet sorghum is influenced by several factors including nutrient availability, soil water availability, soil organic matter, soil chemical and physical properties, type of previous crop, plant population, and genotype (Wortmann et al., 2007).

**Materials and methods**

*Sources of sweet sorghum genotypes used in this study*

The sources sweet sorghum used in this study shown in Table 1. Most of the genotypes used in this study were collected from the Nebraska University, USA. These genotypes were screened from 49 genotypes.

***Experimental site***

The field experiments were conducted at both at the Eastern Mediterranean Agricultural Research Institute (Adana, 36°51' 35'' K ve 35° 20' 43'' D) and GAP Agricultural Research Institute in Turkey (ŞanlıS anlıurfa, 360 42’ K, 380 58’ D) during the second crop season (from 29$^{th}$ of June to 27$^{th}$ of September) in 2015. Fertilizer application rate at both location of nitrogen and phosphorus (100 N kg ha$^{-1}$ and 50 $P_2O_5$ kg ha$^{-1}$).

***Soil and climatic conditions of experimental site***

Initial soil basic physical and chemical properties were shown in Table 2. As a result of the analyzes made on soil samples taken from 0-30 cm depth in the Adana location where the experiments was conducted: pH value 7.72, average lime content 20%, organic matter 2%, sand 27.8%, clay 31.2% and silt was 41% (Table 1). The average temperature for the June-September period was 27 ºC, the average sunshine duration is 10 hours, the highest temperature average was 33.3 ºC and the average relative humidity was 66% (Anonymous 2017).

The experiment under the conditions of Şanlıurfa was conducted in the Harran soil Series, which has a wide spread area in the region and is located entirely in the research station. These series are soils, alluvial parent material, flat and nearly flat inclined, deep-profiled soils. Typical red profiles are clayey textured and the entire profile was very calcareous (Table 1). A, B, C horizon soils, pH was between 7.3 and 7.8, organic matter content was low, cation exchange capacity was high. The average temperature for the June-September period was 29.5 ºC, the mean sunshine duration is 11.48 hours, the highest temperature was 44.4 ºC and the average relative humidity was around 36.5% (Anonymous 2017).

***Experimental condition***

The experiments were established as four replications, according to the design of random blocks. In sowing, 21 genotypes were made in 4 rows and 70 cm between rows and 15 cm over rows, the sowing density was 150000 plants per hectare. The plot was 2.8 m wide and 0.5 m wide with a total area of plot 14 m$^2$.

***Dry matter accumulation and plant nutrient analysis***

Sorghum was harvested at dough stage (89 days after planting). Randomly selected above ground samples were washed with distilled water and oven-dried at 65°C for 48 hour, ground to pass through 0.5 mm sieve and stored prior to chemical analysis. The N content was determined by the micro-Kjeldahl digestion and distillation method (Knudsen et al., 1982). For the determination of other nutrients (P, K, Ca, Mg) ICPOES was used by dry ashing.
Total uptake of N/P/K/ Ca/ Mg was calculated separately by the following formula:

Uptake of N/P/K/Ca/Mg (kg/ha)=N% P% K% Ca% Mg%
dry matter (kg/ha) X 100

***Fertilizer N recovery (FNR)***

FNR is the proportion of applied fertilizer N that is taken up by the plant. This term is used specifically in conjunction with N studies that measure the amount of recovered N in the plant ((Parr, 1973) defined as fertilizer N use efficiency.) It is calculated as: N-labelled fertilizer recovered/ N-labelled fertilizer applied.

NUE = N Yield (kg/ha)= units harvested biomass/units N supply N applied (kg/ha)

***Statistical analysis***

The 21 sweet sorghum genotypes were evaluated as randomized complete block design with 4 replications. Results were analyzed by two-way analysis of variance (ANOVA) using Genstat $12^{th}$ edition for Windows (Lawes Agricultural Trust, UK). In order to investigate the main and interactive effect of locations and sweet sorghum genotypes on plant height, shoot dry weight, root dry weight, root: shoot ratio, N, P, K, Ca and Mg uptake as well as N use efficiency data were analyzed using the Statistical Analysis System (SAS9.1.3). All the statistical testing was performed based on $P \leq 0.05$ as the critical level for the significance of Tukey's test value.

**Conclusion**

Twenty one sweet sorghum genotypes showed varying susceptibilities to dry matter production and nutrient uptake in two different climatic conditions. In two different climatic conditions, sweet sorghum genotypes nutrient uptake showed a large response in shoot dry weight. Growth rate was dependent upon nutrient concentration, even when quantity of nutrient was not limiting. The N use efficiency by several sweet sorghum genotypes varies 385 to 836 kg/ha and 282 to 779 kg/ha in Adana and Urfa locations respectively. However, this study dealt with single season two locations testing of the potentiality of dry weight and nutrient uptake for identification of promising genotypes for possible breeding programme. More trails on different seasons/locations are needed to confirm these results. Other options like agronomic practices, proper sowing date are also needed to be explored.

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**References**

Anonymous (2017) Turkish State Meteorological Service, Statistics of Directorate Kahramanmaraş.

Ahmed IAM, Yucel C, Yucel D, Öktem A, Ortas I (2017) Dry weight and nutrient uptake of some sweet sorghum genotypes under different climatic conditions of Turkey. 18th International Plant Nutrition Colloquium, Copenhagen, Denmark. p47-49.

Ali ML, Rajewski JF, Baenziger PS, Gill KS, Eskridge KM, Dweikat I (2008) Assessment of genetic diversity and relationship among a collection of US sweet sorghum germplasm by SSR markers. Molecular Breed. 21(4): 497-509.

Almodares A, Hatamipour MS (2011) Planting sweet sorghum under hot and dry climatic condition for bioethanol production. Paper presented at the World Renewable Energy Congress-Sweden; 8-13 May; 2011; Linköping; Sweden.

Ameen A, Yang X, Chen F, Tang C, Du F, Fahad S, Xie GH (2017) Biomass yield and nutrient uptake of energy sorghum in response to nitrogen fertilizer rate on marginal land in a semi-arid region. Bio Energy Res. 10(2): 363-376.

Clark RB, Zeto SK, Baligar VC, Ritchey KD (1997) Growth triats and mineral concentrations of maize hybrids grown on unlimed and limed acid soil. J Plant Nutr. 20(12): 1773-1795.

Gardner JC, Maranville JW, Paparozzi ET (1994) Nitrogen use efficiency among diverse sorghum cultivars. Crop Sci. 34(3): 728-733.

Ghannoum Oula, Evans, John R, Chow, Wah Soon, Andrews, T John, Conroy, Jann P, von Caemmerer, Susanne (2005) Faster Rubisco is the key to superior nitrogen-use efficiency in NADP-malic enzyme relative to NAD-malic enzyme C4 grasses. Plant Physio.137(2): 638-650.

Gnansounou E, Dauriat A, Wyman CE (2005) Refining sweet sorghum to ethanol and sugar: economic trade-offs in the context of North China. Bioresource tech. 96(9): 985-1002.

Grassi, Giuliano, Tondi, Gianluca, Helm, Peter (2004) Small-sized commercial bioenergy technologies as an instrument of rural development. Biomass and Agriculture: Sustainability, Markets Policies. 1, 277.

Heitman, Adam J, Castillo, Miguel S, Smyth T Jot, Crozier, Carl R, Wang, Zan, Heiniger, Ron W, Gehl, Ronald J (2017) Nitrogen fertilization effects on yield and nutrient removal of biomass and sweet sorghum. Agron J. 109(4).

Hassanein MS, Amal GA, Nabila MZ (2010) Growth and productivity of some sorghum cultivars under saline soil condition. J Applied Sci Res. 6(11): 1603-1611.

Kaplan M, Kara R (2014) Sweet Sorghum (Sorghum bicolor L.) Yield parameters as affected by physiological characteristics. Erciyes Üniversitesi Fen Bilimleri Enstitüsü Dergisi. 30(2):115-122.

Knudsen D, Peterson GA, Pratt PF (1982) Lithium, sodium, and potassium. Methods of soil analysis. Part 2. Chemical and microbiological properties (methodsofsoilan2),225-246.

Laopaiboon L, Nuanpeng S, Srinophakun P, Klanrit, P, Laopaiboon P (2009) Ethanol production from sweet sorghum juice using very high gravity technology: Effects of carbon and nitrogen supplementations. Bioresource Tech. 100(18): 4176-4182.

Liu R, Li J, Shen F (2008) Refining bioethanol from stalk juice of sweet sorghum by immobilized yeast fermentation. Renew. Energy. 33: 1130–1135.

Mastrorilli M, Katerji N, Rana G (1999) Productivity and water use efficiency of sweet sorghum as affected by soil water deficit occurring at different vegetative growth stages. European J Agron. 11: 207–215.

Monteiro JST, Havrland B, Ivanova, T (2012) Sweet sorghum (*Sorghum bicolor (L.) Moench*) bioenergy value–importance for Portugal. Renew Energy. *5*3: 113–117.

Parr JF (1973) Chemical and biochemical considerations for maximizing the efficiency of fertilizer nitrogen. J Env Quality. 2(1): 75-84.

Ratnavathi CV, Suresh K, Kumar BS Vijay, Pallavi M, Komala VV, Seetharama N (2010) Study on genotypic variation for ethanol production from sweet sorghum juice. Bio Bioenergy. 34(7): 947-952.

Regassa, Teshome H, Wortmann, Charles S. (2014) Sweet sorghum as a bioenergy crop: literature review. Bio Bioenergy. 64:348-355.

Salon, Paul. The USDA Biofuels Strategic Production Report.

Tian Y, Zhao L, Meng H, Sun L, Yan, J (2009) Estimation of un-used land potential for biofuels development in (the) People's Republic of China. App Eny. 86: 77-85.

Teetor VH, Duclos DV, Wittenberg ET, Young KM, Chawhuaymak J, Riley, MR, Ray, DT (2011) Effects of planting date on sugar and ethanol yield of sweet sorghum grown in Arizona. Indus. Crop Prod. 34(2): 1293-1300.

Tew TL, Cobill RM, Richard EPJ (2008) Evaluation of sweet sorghum and orghum × Sudangrass hybrids as feed stocks for ethanol production. Bioenergy Res. 1(2):147-152.

Vermerris W, Saballos A, Ejeta G, Mosier NS, Ladisch MR, Carpita NC (2007) Molecular breeding to enhance ethanol production from corn and sorghum stover. Crop Sci. 47:142-153.

Wight JP, Hons FM, Storlien JO, Provin TL, Shahandeh H, Wiedenfeld RP (2012) Management effects on bioenergy sorghum growth, yield and nutrient uptake. Biomass Bioenergy. 46, 593-604.

Wortmann CS, Liska AJ, Ferguson RB, Lyon DJ, Klein RN, Dweikat I (2010) Dryland performance of sweet sorghum and grain crops for biofuel in Nebraska. Agron J. 102(1): 319-326.

Wortmann CS, Mamo M, Dobermann A (2007) Nitrogen response of grain sorghum in rotation with soybean. Agron J. 99(3): 808-813.