Effect of Planting Dates on the Growth, Yield and Quality of Three Cultivars of Sorghum (*Sorghum bicolor* L. Moench)

H A Ajaj²*, Y A Mohammed¹, A AM Alrubaya², A MS Addaheri¹

¹Department of Field Crops, College of Agriculture, University of Anbar, Anbar, Iraq
²Agriculture Directorate of Anbar, Anbar, Iraq

*Corresponding author’s e-mail address: ag.hamid.abdalkader@uoanbar.edu.iq

**Abstract.** A field study was carried out during the spring season of 2017 in the fields of a farmer in the district of Habbaniyah, which is 70 km west of Baghdad, to study the effect of three planting dates (15 March, 1 April and 15 April) on the growth, yield and quality of three cultivars of sorghum (Babel, Warka and Rabeh). The implementation of the experiment was according to a randomized complete block design (R.C.B.D) with split-plot arrangement with three replications. The results of the experiment indicated that the cultivar Rabeh was superior in most of the studied traits such as leaf area (3968 cm²), number of grains per head (2659.00 grains head⁻¹), weight of grains per head (63.41 g) and grain yield (7.44 ton ha⁻¹), while the Babel variety was superior in the percentage of protein (12.21%). As for planting dates, the date of April 1 was superior in most of the studied traits, such as leaf area (3635.33 cm²), number of grains per head (2670.33 grains head⁻¹), weight of grains per head (62.12 g), grain yield (7.55 ton ha⁻¹) and the percentage of protein (11.49%).

1. Introduction
Sorghum (*Sorghum bicolor* Moench L.) is an important cereal crop, it ranks fifth among the most important cereal crops in the world after wheat, rice, maize and barley, and ranks second in biofuel production [1]. It can be used as a substitute for petroleum. It is considered as main food and a source of energy, protein, vitamins and minerals for the inhabitants of poor areas. It is useful for people with diabetes as well as for those who are sensitive to gluten, and is considered as an antioxidant. Sorghum grain contains 11.3% protein, 3.3% fat, and 56-70% starch. It is relatively rich in iron, zinc, phosphorous and vitamins [2]. Its grains are also used in the manufacture of high-protein biscuits after strengthening them with wheat flour, and producing starch. The sorghum crop is characterized by its tolerance of environmental conditions that are not suitable for the production of other summer crops (maize and soybeans), especially heat, drought and soil salinity, hence, it is called Camel Crop [3]. More than 80% of the sorghum growing areas are described as low productivity and contribute a little more than half of the world production, while the agricultural areas are located within the developed countries, which account for about only 20% of the rest of the world production. Despite the importance of sorghum, its cultivation areas have witnessed a remarkable decline by an estimated 0.15 million hectares annually, starting from the mid-eighties, which is the peak of its production until the
present time due to climatic changes and lack of interest in this crop. Therefore, it has become necessary to search for other means or technologies that lead to increasing the yield and improving its quality, such as studying the best dates for planting, especially with the presence of a number of varieties and hybrids introduced to Iraq and the development of new varieties by plant breeders. Therefore, there is a need to test the efficiency of the varieties and their ability to express their potential energy as best as possible within the surrounding environmental conditions by increasing their efficiency in exploiting the available growth resources, thus increasing its productivity per unit area. Choosing the optimal date for any crop is no less important than choosing the variety and nutrition because all factors aim to increase production. So, this study was conducted to find out the effect of the best date for planting and to determine which varieties are better in terms of productivity and quality and suit the conditions of the research area. It aims also to study the interactions between varieties and planting dates.

2. Materials and Methods

A field study was carried out during the spring season of 2017 in the fields of a farmer in the district of Habbaniyah, Anbar Governorate, to study the effect of three planting dates (15 March, 1 April and 15 April) on the growth, yield and quality of three cultivars of sorghum (Babel, Warka and Rabeh). The experiment was implemented according to a randomized complete block design (R.C.B.D) with split-plot arrangement with three replications. The main plots included planting dates, while the cultivars allocated to the sub plots, each replicate contains 9 experimental units resulting from the combination between the two study factors. The area of the experimental unit was (3 × 2.5 m) and the length of the line was 3 m, and the distance between the lines was 50 cm, and 25 cm between hills. The land of the trial was ploughed in two perpendicular plows, then it was smoothed and leveled, then divided as mentioned above. A random sample was taken from the experimental soil before planting at a depth of 0-30 cm for the analysis of chemical and physical properties of the soil, which were analysed in the laboratory of the General Authority for Agricultural Research - Abu Ghraib, as shown in Table (1).

| Parameter       | Value | Unit          |
|-----------------|-------|---------------|
| PH              | 7.40  |               |
| EC              | 2.1   | ds m⁻¹        |
| Available N     | 29    | mg kg⁻¹ soil  |
| Available P     | 12.11 | mg kg⁻¹ soil  |
| Available K     | 177   | mg kg⁻¹ soil  |
| Clay            | 293   | gm kg⁻¹ soil  |
| Silt            | 573   | gm kg⁻¹ soil  |
| Sand            | 134   | gm kg⁻¹ soil  |

The seeds were manually sown at a rate of 3 seeds in each hill, then the plants were thinned to one plant in the hill after three weeks of planting to achieve a plant density of 80,000 plants ha⁻¹. Phosphate fertilizer was added to the soil before planting at a level of 100 kg P₂O₅ ha⁻¹ in the form of
triple superphosphate 46% P<sub>2</sub>O<sub>5</sub> mixed with the soil when smoothing and leveling of soil. The nitrogen fertilizer as urea 46% N was added at a rate of 200 kg N ha<sup>-1</sup> in three equal batches, the first after emergence, the second when the plant reached a height of 40 cm and the third in the flowering stage [4]. Maize stalk borer (*Sesamai cretica* Led) was controlled with granulated diazinon (10% active ingredient) twice, first at 4-5 leaf stage and the second two weeks after the first control [5].

### 2.1. Characteristics studied

When the plants reached the stage of 75% flowering, the number of days from planting to 75% flowering was calculated, and the height of the plant (cm) was measured from the level of the soil surface to the base or top of the inflorescence. And the leaf area was calculated according to the following equation:

\[
\text{Leaf area (cm}^2\text{)} = \text{length of the fourth leaf} \times \text{maximum width} \times 6.18.
\]

At harvest, the heads of ten plants were taken randomly from the median lines of each experimental unit and were threshed and the number of grains per head was calculated as an average of those heads. Then the seeds of the ten heads were weighed with a sensitive scale and the average weight of the grains per head (gm) was estimated. After that, the grain yield was calculated per unit area (ton ha<sup>-1</sup>) by multiplying the weight of the grain by the head × the number of plants per head. The percentage of protein was estimated according to the method of [6]. The data were statistically analyzed after being collected and tabulated using the Genstat program, and the arithmetic means were tested using the least significant difference test (L.S.D) at a probability level of 0.05.

### 3. Results and Discussion

#### 3.1. Number of days from planting to 75% flowering (day)

The results indicate that there was no significant effect of the cultivars on the number of days from planting to 75% flowering (Table 2). However, the Rabeh cultivar was four days earlier than the two cultivars Babel and Warka (68.00, 71.67 and 72.33 days), respectively. However, the results indicate a significant effect of planting dates on the number of days from planting to 75% flowering (Table 2), as the plants of the third date (April 15) recorded the lowest period of 69.67 days, and they did not differ significantly with the second date (1 April), and both dates differed significantly with the plants of the first date (15 March), which required a longer period to reach this stage (72.3 days).

The difference between planting dates and the number of days it takes to reach this stage may be due to the fact that the delay in the date of planting coincided with high temperatures, which pushes the plant towards early flowering. This result is in line with the results of other studies that found a significant difference between planting dates in this trait [7].

Table 2. Effect of cultivars, planting dates and their interaction on the number of days from planting to 75% flowering of the sorghum crop for the spring season 2017

| Cultivars | Planting dates | Cultivar mean |
|-----------|----------------|---------------|
|           | 15 March | 1 April | 15 April |           |
| Babel     | 73.33    | 70.33   | 71.33    | 71.67     |
| Warka     | 74.00    | 72.00   | 71.00    | 72.33     |
| Rabeh     | 69.67    | 67.67   | 66.67    | 68.00     |
| Mean planting dates | 72.33 | 70.00 | 69.67 | |
| L.S.D 0.05 | 1.84 | N.S | |
3.2. plant height (cm)

It is evident from the results that there is a significant difference between the cultivars in plant height (Table 3), as the Warka variety recorded the highest average of 194.0 cm, which is significantly superior to the other two cultivars in which the Babel variety recorded the lowest average of 145.2 cm. The difference in plant height between varieties may be due to their different genetic nature and their different responses to environmental conditions and how to benefit from them, which was reflected in their variation in the characteristics of vegetative growth. This result is in agreement with the results of several studies that indicated that there were significant differences between sorghum cultivars in plant height [8].

The results also indicate a significant difference between the planting dates, as the plants grown on the first date (March 15) achieved the highest average plant height of 183.0 cm, it differed significantly from the plants planted on the second date April 1 (164.0 cm) and the plants planted on April 15, which recorded the lowest mean of the trait which was 158.0 cm. The reason for the superiority of plants planted on the date of March 15th may be due to the fact that during this date the environmental conditions were suitable for germination, growth and elongation, in addition to its superiority in the length of the growth period from planting to 75% flowering (Table 2). This result conformed to the results of [9] who found a significant difference between the planting dates of sorghum crop in the plant height. It is clear from the results of the same table that there is a significant difference of the interaction between the cultivars and the planting dates in the same trait, as the Warka cultivar plants planted on the date 15 March recorded the highest average of 200 cm compared to the other interaction treatments with a significant difference of 42.96% compared to the Babel cultivar plants planted on the date April 15 which gave the lowest average plant height of 139.9 cm.

Table 3. Effect of cultivars, planting dates and their interaction on plant height (cm) of sorghum crop for spring season 2017

| Cultivars | Planting dates | Cultivar mean |
|-----------|----------------|---------------|
|           | 15 March | 1 April | 15 April |               |
| Babel     | 152.4    | 143.4   | 139.9    | 145.2          |
| Warka     | 200.0    | 194.3   | 187.8    | 194.0          |
| Rabeh     | 196.7    | 154.4   | 146.3    | 165.8          |
| Mean planting dates | 183.0    | 164.0   | 158.0    |               |
| L.S.D  0.05 | 11.22   |         | 19.58    | 22.02          |

3.3. Leaf area (cm²)

The results in Table 4 showed a significant effect of the cultivars on leaf area, as the cultivar Rabeh outperformed with the highest average of 3968 cm² and did not differ significantly from Babel cultivar (3663.33 cm²). However, both cultivars were significantly superior to the cultivar Warka, which recorded the lowest average for a trait of 2641 cm². The reason for this may be attributed to the different of cultivars in the speed of plant growth, starting from the embryonic leaves until reaching the maximum leaf area based on the availability of the appropriate conditions for the cultivars by planting at the appropriate time and the positive reflection of that on obtaining optimal performance
and then obtaining the highest results for the leaf area. This result is in agreement with the findings of [8]. The results also showed that there is a significant effect of planting dates on the average leaf area of sorghum plants, as the plants planted on the second date (1 April) recorded the highest average of 3635.33 cm$^2$, and they did not differ significantly with the plants planted on the first date, 15 March (3418.67 cm$^2$). However, they differed significantly from the plants of the third date (15 April), which recorded the lowest average leaf area of 3218.67 cm$^2$. The reason for this difference may be attributed to the long period of vegetative growth, as it is natural that the plant’s survival for a longer period of time leads to an increase in growth indicators, the most important of which is the leaf area. This is in agreement with the results of [7] who found a significant difference between the planting dates of sorghum plants in leaf area trait. The interaction between cultivars and planting dates had no significant effect on leaf area.

Table 4. Effect of cultivars, planting dates and their interaction on leaf area (cm$^2$) of sorghum crop for spring season 2017

| Cultivars | Planting dates | Cultivar mean |
|-----------|----------------|---------------|
|           | 15 March | 1 April | 15 April | |
| Babel     | 3690  | 3844   | 3456  | 3663  |
| Warka     | 2513  | 2904   | 2507  | 2641  |
| Rabeh     | 4053  | 4158   | 3693  | 3968  |
| Mean planting dates | 3419 | 3635 | 3219 |
| L.S.D 0.05  | 337.2   | N.S     | 710.1 |

3.4. Number of grains per head (grain head$^{-1}$). The results indicate a significant effect of the cultivars on the number of grains per head (Table 5). The variety Warka gave the highest average number of grains per head (2659.00 grains head$^{-1}$), yet, it did not differ significantly from Babel (2646.33 head$^{-1}$ grain). However, both cultivars were significantly superior to the Rabeh variety, which gave the lowest average of 2357.33 grain head$^{-1}$. The reason for this difference in the number of grains per head may be attributed to the difference in the number of florets formed in the inflorescence, and this is due to the genetic factor, and the interaction of genetic and environmental factors may have an effect on the character of the number of grains in the head. This is in agreement with [10], who found a significant difference between the studied cultivars of sorghum in the number of grains per head.

It is also clear from the results that there is a significant effect of planting dates on the number of grains per head (Table 5), as the plants planted on 1$^{st}$ of April recorded the highest average of 2670.33 grain heads$^{-1}$, and did not differ significantly from the plants of 15$^{th}$ of April (2589.33 grain heads$^{-1}$). However, both dates were significantly superior to the planting date of 15$^{th}$ March which gave the lowest average of 2403.00 grain head$^{-1}$. This difference may be attributed to the superiority of the planting date at 1$^{st}$ of April in leaf area (Table 4), and consequently the increase in light interception by the leaves, and then an abundance of materials manufactured in the process of photosynthesis, which enabled the plant to improve its performance in the process of photosynthesis. This was reflected in the increase in the number of grains in the head. These results are in agreement with the results of [11], who found a significant effect of planting dates on the number of grains per head of sorghum crop. The interaction between cultivars and planting dates had no significant effect on the number of grains per head.
Table 5. Effect of cultivars, planting dates and their interaction on number of grain head\(^1\) of sorghum crop for spring season 2017

| Cultivars | Planting dates | Cultivar mean |
|-----------|----------------|---------------|
|           | 15 March | 1 April | 15 April |
| Babel     | 2407.00 | 2813.00 | 2719.00 | 2646.33 |
| Warka     | 2566.00 | 2716.00 | 2695.00 | 2659.00 |
| Rabeh     | 2236.00 | 2482.00 | 2354.00 | 2357.33 |
| Mean planting dates | 2403.00 | 2670.33 | 2589.00 |
| L.S.D 0.05 | 105.3 | | 192.50 |

3.5. Grain weight per head (gm)

The results indicate a significant effect of the cultivars on the weight of the grains per head (Table 6). The Rabeh cultivar had the highest average of 63.41 gm, which did not differ significantly from the Warka variety (62.62 gm). However, both cultivars were significantly superior to Babel cultivar, which gave the lowest average of 53.95 gm. The superiority of the Rabeh cultivar in this trait is due to its significant superiority in leaf area (Table 4), providing a greater amount of processed nutrients for grains, which was positively reflected in the increase in the weight of the grains per head. In this regard, [12] indicated that the weight of the seed is a function of the rate of photosynthesis and the transmission of its products. This result conforms to the results of [13], which found a significant difference between sorghum cultivars in the weight of grains per head.

It is also clear from the results that there is a significant difference between the planting dates in the weight of grains per head. The plants planted on 1\(^{st}\) April recorded the highest average of 62.12 gm and did not differ significantly from the plants planted on 15\(^{th}\) of April (59.72 gm), but they significantly outperformed the cultivated plants on the 15\(^{th}\) of March, which gave the lowest average of 58.14 gm. This confirms the chronological compatibility with regard to heat and light, which was ideal for growth rates and the manufacture of photosynthetic products at the highest rates, which was positively reflected in most of the characteristics of vegetative growth. This led to an increase in the weight of the grains in the head. This is in agreement with the results of [13] who found a significant increase in the grain weight of the head of sorghum plants with different planting dates. The interaction between cultivars and planting dates had no significant effect on the weight of grains per head.

Table 6. Effect of cultivars, planting dates and their interaction on weight of grain head\(^1\) of sorghum crop for spring season 2017

| Cultivars | Planting dates | Cultivar mean |
|-----------|----------------|---------------|
|           | 15 March | 1 April | 15 April |
| Babel     | 52.45 | 54.20 | 55.20 | 53.95 |
| Warka     | 60.39 | 65.84 | 61.64 | 62.62 |
| Rabeh     | 61.59 | 66.31 | 62.32 | 63.41 |
| Mean planting dates | 58.14 | 62.12 | 59.72 |
| L.S.D 0.05 | 3.07 | | 5.34 |
3.6. Grain yield (ton ha\(^{-1}\))

The results showed that there is a significant effect of the cultivars on grain yield per unit area (Table 7). The cultivar Rabeh achieved the highest average of 7.44 ton ha\(^{-1}\), significantly outperforming the two cultivars Babel (6.64 ton ha\(^{-1}\)) and Warka, which recorded the lowest average of 6.21 ton ha\(^{-1}\), which did not differ from each other significantly. The reason for the superiority of the Rabeh cultivar in this trait may be due to its superiority in leaf area and grain weight per head (Tables 4 and 6). In this context, many researchers found a significant difference between sorghum cultivars in grain yield per ha\(^{-1}\) [14] [15].

The results also indicate a significant effect of the planting dates in this trait (Table 7). The second planting date (April 1) recorded the highest average grain yield of 7.55 ton ha\(^{-1}\), significantly superior to the third planting date (April 15) of 6.54 ton ha\(^{-1}\). The planting date at 15\(^{th}\) March recorded the lowest average grain yield of 6.20 ton ha\(^{-1}\). The reason may be attributed to the fact that the increase in the grain yield increases with the increase of one or more of its components. It is noted through (Tables 5 and 6) that this date was significantly superior in the number of grains per head and the weight of grains per head, which was positively reflected in the increase in the grain yield at this date. This result reinforced what was indicated by [16] [17], who found a significant difference between sowing dates of sorghum crop in the character of grain yield.

Table 7. Effect of cultivars, planting dates and their interaction on grain yield (ton ha\(^{-1}\)) of sorghum crop for spring season 2017

| Cultivars | Planting dates | Cultivar mean |
|-----------|----------------|---------------|
|           | 15 March | 1 April | 15 April |          |
| Babel     | 5.86     | 6.96     | 5.80     | 6.21     |
| Warka     | 6.01     | 7.02     | 6.90     | 6.64     |
| Rabeh     | 6.74     | 8.67     | 6.92     | 7.44     |
| Mean planting dates | 6.20 | 7.55 | 6.54 | 0.57        |
| L.S.D 0.05 |          |          |          | 0.74        |

The results showed that there is a significant effect of the interaction between cultivars and planting dates on grain yield. The cultivar Rabeh planted on 1\(^{st}\) April recorded the highest average of 8.67 ton ha\(^{-1}\), significantly superior to the other interaction treatments with a significant increase of 2.87 ton ha\(^{-1}\) over the Babel cultivar planted on 15\(^{th}\) April, which gave the lowest average for a trait was 5.80 ton ha\(^{-1}\).

3.7. Percentage of protein in grain (%)

The results indicate a significant effect of the cultivars on the percentage of protein in grain (Table 8). The cultivar Babel recorded the highest average of 12.21% and differed significantly from the cultivar Warka (9.91%) and the cultivar Rabeh, which recorded the lowest average of 9.58%. The plants of these two cultivars did not differ significantly. The reason for this difference may be attributed to genetic variation between cultivars in the absorption of available nutrients, including nitrogen, which enhanced its transition from leaves to grains, and then increased the protein content in grains. This
result is in line with the results of [18] [19], who found a significant difference between sorghum cultivars in the percentage of protein in the grain.

The results also indicate a significant effect of planting dates, as the plants planted on 1st of April achieved the highest average of 11.49%, which differed significantly from plants grown on 15th of March (10.54%) and plants planted on 15th of April that recorded the lowest average for the trait 9.67%. The reason for this may be attributed to the superiority of plants planted on the second date (1 April) in leaf area (Table 4), which led to an increase in the physiological processes of manufacturing nutrients, including nitrogen, and their transfer from the source (leaf) to the sink (seed). This result is in agreement with the results of [13], who found a significant difference between the planting dates of sorghum crop in the percentage of protein in the grains. The interaction between cultivars and planting dates had no significant effect on this trait.

Table 8. Effect of cultivars, planting dates and their interaction on Percentage of protein in grain (%) of sorghum crop for spring season 2017

| Cultivars | Planting dates | Cultivar mean |
|-----------|----------------|---------------|
|           | 15 March  | 1 April  | 15 April  |               |
| Babel     | 12.11     | 13.22    | 11.31     | 12.21         |
| Warka     | 10.08     | 10.69    | 8.95      | 9.91          |
| Rabeh     | 9.43      | 10.57    | 8.74      | 9.58          |
| Mean planting dates | 10.54 | 11.49 | 9.67 | 0.58 | 0.82 | N.S | 0.05 |

4. Conclusion

We conclude through this study that the date (April 1) was the best under the study conditions, as it was significantly superior in most growth, yield and quality characteristics than the other planting dates (March 15 and April 15). Also, the cultivars differed among themselves with the effect of dates, and the cultivar Rabeh was more distinguished than the other two cultivars Babel and Warka, in most of the studied traits.

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