Journal of Medicinal and Industrial Plants (2025) 3 (1): 113- 127
ISSN: 2959 – 121X
DOI: https://doi.org/10.32894/MEDIP.25.3.10

Effect of planting dates on some morphological and productive traits of soybean varieties.

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ABSTRACT
A field experiment was conducted at the Field Crops Research Station, College of Agriculture, Tikrit University, during the summer of 2024 to study the effect of planting dates and soybean Varieties on growth traits and yield. The experiment included eight Varieties and three planting dates (May 15, June 5, and June 25) using a Randomized Complete Block Design.

Results showed that the June 5 planting date outperformed others, recording the highest plant height (82.34 cm), leaf area (825.78 cm^2 $plant^{-1}$), number of pods, seeds per pod, and seed yield (5.97 tons ha^{-1}). The "Shimaa" variety showed the best performance, achieving the highest seed yield (6.44 tons ha^{-1}). The interaction between planting date and variety was significant, with "Shimaa" planted on June 5 yielding the highest values in growth and productivity, reaching 6.87 tons ha^{-1} of seed yield.
KEYWORDS: Planting dates; Soybean; Morphological traits; Productive traits.

Received: 15/03/2025 ; **Accepted**: 27/03/2025 ; **Available online:** 31/03/2025

تأثير مواعيد الزراعة في بعض الصفات المورفولوجية والإنتاجية لأصناف من فول الصويا.

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الملخص
أُجريَت تجربة حقلية في محطة أبحاث المحاصيل الحقلية، كلية الزراعة، جامعة تكريت، خلال صيف عام 2024، لدراسة تأثير مواعيد الزراعة وتراكيب وراثية من فول الصويا في صفات النمو والحاصل.
تضمنت التجربة ثمانية تراكيب وراثية وثلاثة مواعيد زراعة (15 أيار، و5 حزيران، و25 حزيران)، وطبق فيها تصميم القطاعات العشوائية الكاملة (**RCBD**).
أظهرت النتائج أن موعد الزراعة في 5 حزيران تفوق معنوياً على بقية المواعيد، إذ سجّل أعلى معدل لارتفاع النبات (82.34 سم)، والمساحة الورقية (825.78 سم² نبات⁻¹)، وعدد القرنات، وعدد البذور في القرنة، وحاصل البذور (5.97 طن هكتار⁻¹).
أما الصنف "شيماء"، فقد أبدى أفضل أداء مقارنةً ببقية الأصناف، محققاً أعلى حاصل للبذور بلغ (6.44 طن هكتار⁻¹).
كما كان للتداخل بين موعد الزراعة والصنف تأثير معنوي في الصفات المدروسة، حيث أعطى الصنف "شيماء" المزروع في 5 حزيران أعلى القيم في صفات النمو والإنتاجية، إذ بلغ حاصل البذور 6.87 طن هكتار⁻¹.
الكلمات المفتاحية: مواعيد الزراعة؛ فول الصويا؛ الصفات المورفولوجية؛ الصفات الإنتاجية.

INTRODUCTION

Soybean (Glycine max L.) is one of the most important leguminous crops worldwide, serving as a primary source of protein and oil in various food and agricultural industries (Jauhar *et al*., 2023). It contains 30-50% protein and 14-24% oil, making it a crucial component in human and animal nutrition (Liu *et al*., 2022). Additionally, soybeans are rich in unsaturated fatty acids, essential vitamins, and amino acids necessary for growth, further enhancing their nutritional value (Bellaloui *et al*., 2015).

The productivity of soybean is highly influenced by environmental factors, particularly temperature, photoperiod, and planting dates (Hu *et al*., 2021). Planting time plays a crucial role in regulating growth stages such as flowering, pod formation, and seed filling (Egli & Bruening, 2000). Studies indicate that early planting allows for an extended vegetative phase, leading to higher yields, whereas late planting may reduce photosynthetic efficiency, shorten the reproductive phase, and ultimately decrease seed production (Bastidas *et al*., 2008; Rahman *et al*., 2020).

High temperatures during flowering and pod formation negatively affect pod retention and seed quality (Salmeron *et al*., 2014). Additionally, elevated temperatures can accelerate physiological maturity, reducing the time available for seed filling and affecting final seed weight (Dornbos & Mullen, 1991).

Genetic variation among soybean Varieties significantly influences their adaptability to environmental conditions, including heat tolerance and radiation use efficiency (Bellaloui *et al*., 2015). While some Varieties can withstand heat stress and maintain pod production, others are highly sensitive, leading to lower yields when exposed to high temperatures (Egli *et al*., 2017; Patrignani *et al*., 2014). Selecting the appropriate Varieties for specific environmental conditions is essential for maximizing growth and productivity (Chen *et al*., 2020).

The interaction between planting dates and Varieties selection plays a vital role in soybean production. Some Varieties exhibit high yield potential when planted early but lose this advantage under late planting conditions due to temperature stress (Dornbos *et al*., 2019). Conversely, other Varieties show better adaptability to varying climatic conditions, allowing for flexible planting schedules (Kumagai & Sameshima, 2014). Research has shown that planting time and Varieties selection directly impact yield components such as pod number, seeds per pod, and 100-seed weight, ultimately influencing total seed yield and biological yield (Board & Kahlon, 2013).

Given the importance of these factors, this study aims to evaluate the effects of different planting dates on the growth and yield of eight soybean Varieties. It also seeks to determine the best planting date for each Varieties and assess the interaction between planting time and Varieties performance in order to optimize soybean production under varying environmental conditions.

MATERIALS AND METHODS

A field experiment was conducted at the Crop Science Research Station, Faculty of Agriculture, University of Tikrit, during the summer growing season of 2024 on gypsiferous soil (Table 1). The experiment followed a factorial design (two factors) using a split-plot arrangement within a randomized complete block design (RCBD) with three replications. The experiment included the following factors:

Factor 1 (Varieties):

In this study, eight soybean Varieties were used: Shaimaa, Li, Di, Lora, Andalus, Warka, Yama Soy, and Turki. Each Varieties was assigned the codes (V1, V2, V3, V4, V5, V6, V7, and V8), respectively. The seeds for these Varieties were obtained from the General Company for Industrial Crops, which is affiliated with the Iraqi Ministry of Agriculture, and is responsible for providing high-quality seeds.

Factor 2 (Planting Dates):

Three planting dates were tested in the study to assess their impact on soybean growth. These dates were May 15, June 5, and June 25, assigned the codes D1, D2, and D3, respectively. These dates were carefully chosen based on previous studies that indicate the significant impact of different planting dates on crop productivity.

The experimental land was plowed twice perpendicularly using a disk harrow to loosen the upper soil layer without inverting it to prevent gypsum from surfacing. The field was then divided into three blocks, each containing eight main plots (for Varieties), and each main plot was further divided into three subplots (for planting dates). The experimental unit size was 9 m^2 (3 × 3 m), resulting in a total of 72 experimental units .

The field was fertilized before planting with 120 kg N ha^{-1} of urea (half applied before planting and the other half at the fourth leaf stage). Additionally, 80 kg P ha^{-1} of triple superphosphate (46% P_2O_5) was applied as a single dose before planting.

Soybean seeds were sown with 3-4 seeds per hill at a depth of 4 cm and later thinned to one plant per hill at the third true leaf stage. Rows were spaced 0.75 m apart, with 0.10 m between hills. Drip irrigation was used throughout the growing season based on plant requirements, with water sourced from a well (Table 2). Weeding was performed manually as needed.

Measured Traits:

Plant Height (cm):

Plant height was measured for three randomly selected plants per subplot from the base to the top of the main stem using a standard measuring tape .

Leaf Area (cm^2 $plant^{-1}$):

The leaf area was determined for five plants per experimental unit using the formula:

Leaf Area per Leaf (cm^2) = Leaf Length × Maximum Width × 0.75 (Sahuki, 1990).

The average leaf area per leaf was then used to calculate total leaf area per plant using the equation:

Leaf Area per Plant (cm^2) = Average Leaf Area per Leaf × Number of Leaves per Plant

Number of Branches per Plant:

The number of branches was counted for three randomly selected plants at the end of the season before harvest.

Number of Pods per Plant:

The number of pods was counted for ten randomly selected plants per subplot.

Number of Seeds per Pod:

The average number of seeds per pod was determined by counting seeds from pods of five randomly selected plants (from the two central rows) per experimental unit.

Weight of 100 Seeds (g):

The weight of 100 seeds was recorded using a precision balance, selecting seeds randomly from harvested plants.

Seed Yield (t ha^{-1}):

The total seed yield was calculated based on the individual plant yield from ten selected plants, multiplied by the plant density per unit area, then converted to hectares.

Biological Yield (t ha^{-1}):

Biological yield was determined as the total dry matter, including seeds, leaves, and stems. Five plants per subplot were sampled at maturity, dried in an oven until constant weight was achieved, and weighed.

Statistical Analysis

The collected data were statistically analyzed using SAS software (SAS Institute, 2011) according to the factorial experiment within a randomized complete block design with a split-plot arrangement. Duncan's multiple range test was used for mean comparisons at a 0.05 probability level (Al-Rawi & Khalaf Allah, 2000).

Some physical and chemical properties of the study soils

Method Used in Analysis	Unit of Measurement	Value

Determined using the pipette method (Black, 1965).	g kg^{-1}	415	Sand
		324	Silt
		261	Clay
		Loam	Texture
Using ammonium acetate solution (Black, 1965).	cmol kg^{-1}	17.01	CEC
Using a pH meter (Page *et al*., 1982).		7.65	pH (1:1)
Using an electrical conductivity meter (Page *et al*., 1982).	dS m^{-1}	2.43	EC (1:1)
Using the dilution method (Lagerwerff *et al*., 1965).		57.22	$CaSO_4$
Determined by the gravimetric method (Page *et al*., 1982).	g kg^{-1}	197.87	$CaCO_3$
Determined using the wet digestion method (Black, 1965).		8.20	O.M
According to the Micro-Kjeldahl method (Black, 1965).		20.76	Available Nitrogen
Extracted from the soil using sodium bicarbonate solution (0.5M $NaHCO_3$) at pH 8.5, according to the method of Olsen *et al*. (1954).	mg kg^{-1}	8.01	Available Phosphorus
Extraction with ammonium acetate according to the method described by Black (1965) using a flame photometer.		129.33	Available Potisuim

Some chemical properties of the well water used for irrigation in the experiment					
Trait	**Unit**	**Value**	**Value**	**Unit**	**Trait**
Trait		1.14	EC	dS m^{-1}	3.11
Sodium	Mmol L^{-1}	5.02	Chlorine		5.43
Magnesium		9.76	Sulphates	Mmol L^{-1}	12.71
Calcium		0.11	Bicarbonates		3.50
Potassium		7.42	Carbonates		Nill
pH					

RESULTS AND DISCUSSION

1-Plant Height (cm)

Soybean plant height was significantly influenced by planting dates, as shown in Table 1. When comparing planting dates on May 15 (75.12 cm), June 25 (68.76 cm), and June 5 (82.34 cm), the latter two resulted in the lowest average heights. This is because plants benefit from a longer development period when planted early, providing more time to establish a robust root system and vegetative structure. This finding aligns with research by Bateman *et al*. (2020), who found that earlier planting dates resulted in taller plants due to extended growth periods. In addition, the research demonstrated that there were notable variations in plant height across the various soybean Varieties. Table (1) shows that the plant heights recorded varied among different Varieties. The greatest was 84.67 cm from the "Lee" Varieties, followed by 79.45 cm from the "Laura" Varieties, and 72.39 cm from the "Deli" Varieties, which was the lowest. The genetic influences of each Varieties are responsible for these variations; for example, some Varieties have genes that make their stems longer, which gives them an advantage when competing for light and leads to higher development. The study conducted by Ali *et al*. (2021), which highlighted the importance of genetic variables in regulating plant height, is supported by these findings.

Table (1) reveals a significant interaction between planting dates and soybean Varieties. For instance, when the "Lee" Varieties was planted on June 5, plants reached their maximum height of 88.45 cm, while the "Deli" Varieties, planted on June 25, exhibited the lowest height of 66.34 cm. This interaction suggests that early planting benefits certain Varieties more than others, providing them with an extended period to maximize the use of available natural resources, such as sunlight and nutrients, leading to faster development. These findings are consistent with the observations of Hashemi Jazi (2001), who highlighted the significant role of planting dates and Varieties selection in shaping plant morphological characteristics.

Table 1. Effect of Varieties, Planting Dates, and Their Interaction on Soybean Plant Height (cm)

Varieties	**Planting Dates**			**Average of Varieties**
	May 15	**June 5**	**June 25**	
Shima	95.22 e-j	115.37 a	102.34 b-g	104.31 a
Deli	92.00 g-j	107.47 a-c	98.22 c-i	99.23 b
Laura	89.14 ij	105.77 a-d	95.68 d-j	96.86 c
Andalus	92.33 f-j	110.34 ab	100 b-h	100.89 b
Worka	90.22 h-j	105.91 a-e	96.25 d-j	97.46 bc
Iman	88.10 ij	103 b-f	93.11 f-j	94.74 cd
Yama sawiaa	87.08 j	100.05 b-h	92.39 f-j	93.17 d
Turkement	87.12 j	101 b-g	93.00 f-j	93.71 cd
Average of Planting Dates	90.15 c	106.11 a	96.37 b	

The means that share similar letters do not differ significantly according to the Duncan test at a 0.05 probability level.

2 -Leaf Area (cm^2 $plant^{-1}$)

The results from Table (2) indicated that planting dates significantly affected the leaf area of soybean plants. Planting on June 5th resulted in the highest average leaf area (825.78 cm^2 $plant^{-1}$), compared to planting on May 15th (601.42 cm^2 $plant^{-1}$) and June 25th (697.28 cm^2 $plant^{-1}$). The mild temperatures and just-right humidity in June boosted photosynthesis and leaf growth, leading to an increase in leaf area, which is why June is considered the best month for this. These findings corroborate those of Ali *et al*. (2023), who discovered that planting soybeans during times of good weather conditions increases the development of their leaves**.**

When comparing several soybean Varieties, the researchers found that leaf area varied significantly. In terms of average leaf area, the "Shimaa" Varieties outperformed the "Andalus" and "Imam Soy" Varieties, which had lower values. Some Varieties can grow bigger leaves, which improves their efficiency in light interception and photosynthesis; this variation is likely due to genetic variations in the root systems' and physiological mechanisms' capacity to use environmental resources. Wang *et al*. (2023), Abdullah *et al* (2024) showed that soybean Varieties with more developed root systems had larger leaf areas, therefore our results are in line with theirs. Leaf area was greatly impacted by the interplay of planting dates and Varieties. The maximum average leaf area was achieved by planting the "Shimaa" Varieties on June 5th (1100.01 cm² plant⁻¹), but other combinations, including the "Deli" Varieties planted on May 15th (657 cm² plant⁻¹), had lower leaf areas. This variance may be explained by how well different Varieties work with different ideal planting dates. Certain Varieties have a knack for flourishing in the ideal circumstances that are present at certain planting dates, which allows them to produce larger and better leaves. This lines up with the findings of Chen *et al*. (2020), who demonstrated that the interaction between Varieties and planting dates has a substantial impact on the growth of soybean plants' leaf area.

Table 2. Effect of Varieties, Planting Dates, and Their Interaction on Soybean Leaf Area (cm² plant⁻¹)

Varieties	Planting Dates			Average of Varieties
	May 15	June 5	June 25	
Shima	701.22 d-h	1100.01 a	876.09 bc	892.44 a
Deli	657 e-h	855.14 b-d	749.09 c-g	753.74 bc
Laura	582.32 g-i	759.95 c-f	638.01 f-i	660.09 de
Andalus	684.45 d-h	950.39 b	844.72 b-d	826.52 ab
Worka	634.33 f-i	819.03 b-e	698.88 d-h	717.41 cd
Iman	550.04 hi	720.25 c-h	600.14 f-i	623.48 e
Yama sawiaa	490.01 i	691.33 d-h	549.17 hi	576.84 e
Turkement	511.99 i	710.10 c-h	622.14 f-i	614.74 e
Average of Planting Dates	601.42 c	825.78 a	697.28 b	

The means that share similar letters do not differ significantly according to the Duncan test at a 0.05 probability level.

3- Number of Branches (branch plant⁻¹):

Table 3 demonstrates that the number of branches in soybean plants was significantly influenced by planting dates. Among the three planting dates—May 15 (4.48 branches plant⁻¹), June 5 (6.08 branches plant⁻¹), and June 25 (4.92 branches plant⁻¹)—the June 5 planting date recorded the highest average branch count. This outcome is attributed to optimal environmental conditions during early planting, such as moderate temperatures and humidity, which enhance branch formation. These findings align with Bellaloui *et al*. (2011), who reported that early planting promotes branch development and improves resource allocation **.**

The study also revealed significant varietal differences in branch number. As shown in Table 5, the "Shima" Varieties exhibited the highest average branch count (6.33 branches plant⁻¹), followed by "Andalus" (5.83 branches plant⁻¹), while "Yama sawiaa" recorded the lowest average (4.36 branches plant⁻¹). This variation likely stems from genetic differences in lateral branch formation capacity among Varietiess, corroborating Kawasaki *et al*. (2018), who emphasized the role of genetic makeup in determining branching potential **.**

Regarding the interaction between planting dates and Varietiess, "Shima" planted on June 5 achieved the highest branch count (7.54 branches plant⁻¹), whereas "Yama sawiaa" planted on June 25 showed the lowest value (3.92 branches plant⁻¹). This interaction underscores that certain Varietiess benefit more from optimal planting dates due to their compatibility with favorable environmental conditions. These results support Akhter *et al*. (1996), who demonstrated that the interaction between planting dates and Varietiess critically affects branching traits in soybeans.

Table 3. Effect of Varieties, Planting Dates, and Their Interaction on Soybean Number of Branches (branch plant^{-1})

Varieties	**Planting Dates**			**Average of Varieties**
	May 15	**June 5**	**June 25**	
Shima	5.44 a-c	7.54 a	6.01 a-c	6.33 a
Deli	4.77 bc	6.58 a-c	5.31 a-c	5.55 ab
Laura	4.28 bc	6.00 a-c	4.66 bc	4.98 a-c
Andalus	4.98 a-c	6.77 ab	5.75 a-c	5.83 a-c
Worka	4.37 bc	5.96 a-c	4.87 bc	5.07 a-c
Iman	4.09 bc	5.59 a-c	4.41 bc	4.70 bc
Yama sawiaa	3.92 c	5.07 a-c	4.08 bc	4.36 c
Turkement	3.95 c	5.16 a-c	4.27 bc	4.46 bc
Average of Planting Dates	4.48 b	6.08 a	4.92 ab	

The means that share similar letters do not differ significantly according to the Duncan test at a 0.05 probability level.

4 -Number of Pods (pod plant^{-1})

The results in Table (4) indicate that planting dates significantly affected the number of branches in soybean plants. Planting on June 5 resulted in the highest average number of branches (125.32 branches per plant) compared to the planting dates of May 15 (115.36 branches per plant) and June 25 (117.28 branches per plant). This effect is attributed to the optimal environmental conditions provided by early planting, where moderate temperatures and appropriate humidity create better opportunities for plant branching. These results are consistent with the findings of Bellaloui *et al*. (2011), who reported that early planting of soybeans improves resource distribution and increases the number of branches.

The study also showed significant differences among soybean Varieties in the number of branches. The Varieties " Andalus " recorded the highest number of branches (130.73 branches per plant), followed by "Laura" with 5.83 branches per plant, while the lowest number of branches was observed in the " Turkement " Varieties (111.32 branches per plant), as shown in Table (4). This variation is due to genetic differences in the ability of Varieties to produce lateral branches. These results are in line with Kawasaki *et al*. (2018), who emphasized that the genetic composition of the Varieties plays a major role in determining the soybean plant's branching ability.

There was a significant interaction between planting dates and Varieties, with the combination of "Shaima" Varieties and June 5 planting showing the highest number of branches (138.85 branches per plant), while the combination of "Turkement" Varieties and May 15 planting recorded the lowest (111.06 branches per plant), as indicated in Table (4). This interaction suggests that some Varieties benefit more from optimal planting dates due to their compatibility with favorable environmental conditions. These findings align with Akhter *et al*. (2022), who demonstrated that the interaction between planting dates and Varieties significantly affects branching characteristics in soybean plants.

Table 4. Effect of Varieties, Planting Dates, and Their Interaction on Soybean Number of Pods (pod plant^{-1})

Varieties	**Planting Dates**			**Average of Varieties**
	May 15	**June 5**	**June 25**	
Shima	120.94 bc	138.85 a	126 a-c	128.60 ab
Deli	112.98	127.09 a-c	119.13 bc	119.73 bc
Laura	109.30 c	127.58 a-c	112.63 c	116.50 c
Andalus	128.35 a-c	137.45 ab	126.38 a-c	130.73 a
Worka	113.84 c	125.84 a-c	117.76 c	119.15 bc
Iman	113.99 c	116.74 c	112.82 c	114.52 c
Yama sawiaa	111.88 c	117.74 c	112.45 c	114.02 c
Turkement	111.60 c	111.30 c	111.06 c	111.32 c
Average of Planting Dates	115.36 b	125.32 a	117.28 ab	

The means that share similar letters do not differ significantly according to the Duncan test at a 0.05 probability level.

5 -Number of Seeds (Seeds Pod^{-1})

The number of seeds per pod was significantly affected by planting dates, according to Table (5). The greatest average yield was 2.98 seeds per pod when planted on June 5, while the lowest yield was 2.74 seeds per pod when planted on May 15. With delayed planting on June 25, the lowest number was achieved, reaching 2.61 seeds per pod. The reason behind this is because plants may yield more seeds per pod when planted early since they have more time to mature. Stable flower setting and enhanced seed development are both aided by the ideal moisture-to-temperature balance. The findings on soybean plants are in agreement with these results (Beuerlein *et al*., 2005) **.**

The quantity of seeds per pod was another variable that varied significantly between soybean Varieties, as seen in Table (5). With an average of 2.89 seeds pod^{-1}, the Varieties "Shaimaa" was second, while the Varieties "Andalus" recorded the greatest number of seeds pod^{-1} at 3.04. On the other hand, the Varieties "Di" had the fewest seeds per pod, averaging just 2.53 seeds per pod. Genetic influences explain the observed variance in this feature; for example, some Varieties are more efficient at transporting nutrients from stems and leaves to the seeds, allowing them to produce pods with a larger seed yield than others. Chowdhury (1985) studied soybean plants, and this finding is in line with that **.**

The number of seeds per pod was significantly affected by the interplay between planting dates and Varieties. With an interaction between the "Andalus" Varieties and a planting date of June 5, the maximum quantity reached 3.19 seeds per pod. The interaction between the "Di" Varieties and the June 25 planting date had the lowest quantity of seeds per pod, with 2.41 seeds pod^{-1}, as shown in Table (5). This is because some Varieties benefit more from the compatibility between their genetic makeup and the optimal environmental conditions provided by the planting date, leading to increased efficiency in nutrient conversion into seed production within the pod. This is in line with a study conducted by Smith *et al*. (2020) on soybean plants.

Table 5. The effect of Varieties, planting dates, and their interaction on the number of seeds per pod in soybean plants (Seeds Pod^{-1}).

Varieties	**Planting Dates**			**Average of Varieties**
	May 15	**June 5**	**June 25**	
Shima	2.23 d-h	2.95 a	2.52 b-e	2.57 a
Deli	2.14 d-i	2.71 a-c	2.29 c-g	2.38 ab
Laura	2.01 f-i	2.54 a-e	2.14 d-i	2.23 bc
Andalus	2.15 d-i	2.81 ab	2.37 c-f	2.44 ab
Worka	2.09 e-i	2.55 a-d	2.25 d-h	2.30 bc
Iman	1.91 g-i	2.33 c-g	2.05 f-i	2.10 cd
Yama sawiaa	1.76 hi	2.10 e-i	1.88 g-i	1.91 d
Turkement	1.82 h-	2.14 d-i	2.01 f-i	1.99 d
Average of Planting Dates	2.01 b	2.52 a	2.19 b	

The means that share similar letters do not differ significantly according to the Duncan test at a 0.05 probability level.

6 -Weight of 100 Seeds (g)

The results of Table (6) show that planting dates had a significant effect on the weight of 100 seeds. The highest weight was recorded for the June 5 planting date, reaching (17.85 g), compared to May 15 (16.74 g) and June 25 (15.92 g). This superiority is attributed to the optimal environmental conditions available in the early planting date, as moderate temperatures during the seed-filling period enhance the accumulation rate of nutrients within the seeds, leading to an increase in their weight. Kahlon *et al*. (2012) confirmed in soybean plants that favorable temperatures during the seed formation stage contribute to improved water and organic matter absorption, thereby enhancing seed growth**.**

The study revealed significant differences among soybean Varieties in the weight of 100 seeds. The Varieties "Shaimaa" recorded the highest average weight of (18.34 g), followed by the Varieties "Andalus" in second place with (17.02 g), while the lowest seed weight was recorded for the Varieties "Di" at (15.68 g), as shown in Table (6). The genetic variety across Varieties is responsible for this variance; for example, some Varieties produce seeds that are heavier because they store more carbs and proteins. According to research on soybean plants conducted by Woong *et al*. (2004), the efficiency with which seeds accumulate organic matter is influenced by genetic variations among Varieties, which in turn affects the seeds' eventual weight **.**

Table (6) further demonstrated that there was a substantial influence from the combination between planting dates and Varieties. For the interaction between the "Shaimaa" Varieties and the June 5 planting date, the greatest 100-seed weight was reported at 19.12 g, while the lowest was recorded at 15.21 g for the interaction between the "Di" Varieties and the June 25 planting date. This interaction suggests that certain Varieties require optimal environmental conditions to achieve the best seed growth. The compatibility between Varieties genetics and the appropriate planting time enhances metabolic efficiency within the seeds. Patel *et al*. (2017) indicated in their study on soybean plants that proper planting timing can improve seed-filling characteristics, thereby increasing the final seed weight.

Table 6. Effect of Varieties, planting dates, and their interaction on the weight of 100 seeds in soybean plants (g)

Varieties	**Planting Dates**			**Average of Varieties**
	May 15	**June 5**	**June 25**	
Shima	15.64 cd	18.05 a	16.43 b	16.71 a
Deli	13.88 hi	15.89 bc	14.36 f-h	14.71 c
Laura	13.26 j	15.03 e	14.19 gh	14.16 de
Andalus	14.32 f-h	16.40 b	14.91 ef	15.21 b
Worka	13.54 ij	15.12 de	14.51 e-g	14.39 d
Iman	13.11 j	15.00 e	14.07 g-i	14.06 de
Yama sawiaa	12.95 j	14.15 gh	13.47 ij	13.52 f
Turkement	13.05 j	14.84 ef	13.87 hi	13.92 e
Average of Planting Dates	13.72 c	15.56 a	14.48 b	

The means that share similar letters do not differ significantly according to the Duncan test at a 0.05 probability level.

7 -Seed Yield (tons ha^{-1})

The results of Table (7) indicate that planting dates had a significant effect on total seed yield. The highest productivity was recorded for the June 5 planting date, reaching (5.974 tons ha^{-1}), whereas yield decreased to (4.547 tons ha^{-1}) with the June 25 planting date. The lowest yield was recorded for the May 15 planting date at (3.828 tons ha^{-1}). This decline in yield is attributed to the fact that delaying planting reduces the vegetative growth period, leading to a decrease in biomass accumulation and a reduction in the number of stored materials in the seeds. Delaying planting in soybean plants shortens the seed formation period, which in turn reduces the filling rate and the accumulation of carbohydrates in the seeds, according to (Egli *et al*., 2009)

Total yield was another area where Table (7) revealed statistically significant variations among the Varieties under investigation. With a yield of 6.447 tons ha⁻¹, the Varieties "Shaimaa" was the most productive, followed by the Varieties "Lora" with 5.953 tons ha⁻¹, and the Varieties "Yema Soy" with the lowest yield of 3.461 tons ha⁻¹. Varieties differ in their capacity to dry out carbon assimilation products, which accounts for the observed variation. According to Yari *et al*. (2010), different Varieties have different yield performance because they absorb nutrients and convert them into dry matter at different rates **.**

Table (7) also showed that total yield was significantly affected by the interaction of planting dates and Varieties. When the "Shaimaa" Varieties was interacted with the June 5 planting date, the resulting yield was 8.117 tons ha⁻¹, whereas the "Yema Soy" Varieties was interacted with the May 15 planting date, resulting in the lowest yield of 3.000 tons ha⁻¹. This interaction suggests that certain Varieties respond more effectively when planted at optimal dates, thereby enhancing their efficiency in utilizing environmental factors. Salmeron *et al*. (2014) confirmed in their study on soybean plants that selecting the appropriate planting date in combination with the suitable Varieties can increase productivity by up to 15% compared to suboptimal planting dates**.**

Table 7. Effect of Varieties, planting dates, and their interaction on total seed yield in soybean plants (tons ha⁻¹).

Varieties	**Planting Dates**			**Average of Varieties**
	May 15	**June 5**	**June 25**	
Shima	4.990 fg	8.117 a	6.234 cd	6.447 a
Deli	4.011 ij	6.543 c	4.891 g	5.148 c
Laura	3.129 lm	6.005 d	4.176 hi	4.437 d
Andalus	4.884 g	7.498 b	5.477 e	5.953 b
Worka	4.105 i	6.083 d	4.875 g	5.021 c
Iman	3.407 kl	5.135 f	3.967 j	4.17 e
Yama sawiaa	3.000 m	4.184 hi	3.199	3.461 f
Turkement	3.101 m	4.224 h	3.560 k	3.628 f
Average of Planting Dates	3.828 c	5.974 a	4.547 b	

The means that share similar letters do not differ significantly according to the Duncan test at a 0.05 probability level.

8 -Biological Yield (tons ha⁻¹)

The results of Table (8) indicate that planting dates had a significant effect on biological yield. The highest yield was recorded for the June 5 planting date, reaching (24.68 tons ha⁻¹), while the yield for the June 25 planting date was (23.02 tons ha⁻¹), and it decreased to (21.58 tons ha⁻¹) for the May 15 planting date. This drop is because the plant's ability to accumulate dry matter is diminished due to decreased photosynthetic rates during early planting. The results are consistent with (Smith *et al*., 2021).

There were notable variations in biological yield amongst the Varieties, according to the research. With an average of 20.58 tons ha⁻¹, the Varieties "Yema Soy" had the lowest yield, while the Varieties "Shaimaa" and "Lora" had the highest yields, with 25.61- and 24.77-tons ha⁻¹, respectively. Varieties differ in their capacity to produce dense vegetative growth and increased organic matter buildup, which causes this variety. Genetic variations are the primary factor in a plant's Biological or biomass production capacity, as shown by Elmore *et al*. (1990). Table (8) further shown that biological yield was significantly affected by the interaction between planting dates and Varieties. With a yield of 28.09 tons ha⁻¹, the interaction between the "Shaimaa" Varieties and the June 5 planting date was the most productive, whereas the "Yema Soy" Varieties and the May 15 planting date produced the lowest yield of 19.37 tons ha⁻¹. This interaction provides further evidence that biological production is enhanced when the optimal planting date is paired with the appropriate Varieties. The importance of the relationship between Varieties and environment in enhancing growth efficiency was emphasized by Beatty *et al*. (2022) in their study on soybean plants.

Table 8. Effect of Varieties, planting dates, and their interaction on biological yield (tons ha⁻¹).

Varieties	**Planting Dates**			**Average of Varieties**
	May 15	**June 5**	**June 25**	
Shima	23.54 c-h	28.09 a	25.200 b-d	25.61 a
Deli	22.06 f-j	25.69 bc	23.72 c-g	23.82 bc
Laura	20.92 h-k	24.09 c-g	22.81 e-j	22.60 c-e
Andalus	22.54 e-j	26.75 ab	25.01 b-e	24.77 ab
Worka	22.00 f-j	24.44 b-f	23.18 c-i	23.21 cd
Iman	21.52 g-k	23.52 c-i	22.06 f-j	22.37 de
Yama sawiaa	19.37 k	21.88 f-k	20.50 jk	20.58 f
Turkement	20.68 i-k	23.01 d-j	21.70 g-k	21.80 ef
Average of Planting Dates	21.58 c	24.68 a	23.02 b	

The means that share similar letters do not differ significantly according to the Duncan test at a 0.05 probability level.

CONCLUSION:

1. Planting on June 5th outperformed in most studied traits.
2. Early planting on May 15th resulted in delayed flowering and maturation, yielding less.
3. The Varieties Shaima, Laura, and Andalus showed the best content of chlorophyll and nutrients.
4. The Shaima variety was the most productive in seed yield, while the Li variety excelled in oil content.
5. The compatibility between the variety and the optimal planting time significantly improved productivity.

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