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Evaluating the Effects of Different Sowing Dates and Tillage Practices on Faba bean Yield Based on DSSAT Model

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Abstract— *The faba bean is a crucial pulse crop known for its high protein content and its ability to fix nitrogen from the atmosphere. The growth and yield of this crop are influenced by various agronomic practices, such as sowing date and tillage method. To investigate these factors, a two-year field experiment was conducted in the dry and hot environment of Egypt's western desert. The experiment aimed to evaluate the yield and its components of faba bean under four different sowing dates and three tillage practices. To accurately simulate the outcomes, the Decision Support System for Agro-technology Transfer (DSSAT) model was employed. This model allowed for the prediction of seed yield, total above-ground biomass, and harvest index based on the varying sowing dates and tillage practices. It was found that the highest seed yield, reaching 4011 kg ha^{-1} in the first season and 4115 kg ha^{-1} in the second season, was achieved when the plants were sown on October 15th. Additionally, the seed yield peaked at 3690 kg ha^{-1} in the first season and increased to 4074 kg ha^{-1} in the second season when the no-tillage practice was implemented. The other yield components followed a similar trend to the seed yield, responding to the different sowing dates and tillage practices. The DSSAT model proved to be a reliable tool for simulating the seed yield and total above-ground biomass, exhibiting a Nash and Sutcliffe Efficiency (NSE) above 0.80 when compared to the calculated values. However, for the harvest index, the NSE was 0.669 in the first year and 0.772 in the second year. Despite this slight discrepancy, the DSSAT model remains a valuable decision support tool for predicting faba bean yield under various agronomic practices.*

Keywords*— *Sowing date, tillage practices, faba bean, New Valley, DSSAT, dry-hot environment

I. INTRODUCTION

Egypt has a long-standing tradition of both producing and consuming the faba bean (*Vicia faba* L.), which has played a vital role in the Egyptian diet. In fact, it holds the distinction of being the nation's first leguminous food crop (Ouda and Zohry, 2017). However, the production of faba beans in Egypt has encountered numerous challenges over the years. Extensive studies have revealed a concerning decline in the cultivation areas of faba beans, plummeting from 271.5 thousand feddanes (1 feddan = 4200 m^2) in 2000 to 175.4 thousand feddanes in 2019. Consequently, the total production has also suffered, dropping from 252.4 thousand tons in 2000 to 242.07 thousand tons in 2019. This decline has resulted in a significant decrease in self-sufficiency rates, which fell from 31.4% to 67.4% during the same period (Abdelaal and Soliman, 2022). Despite its historical significance, faba bean production in Egypt has faced considerable difficulties due to a shrinking cultivable area and fierce competition from other winter crops.

Heat stress has the potential to significantly reduce crop productivity and undermine global food security, particularly in the context of climate change (Lamaoui et al., 2018; Jagadish et al., 2021). Drought and heat are two major abiotic stresses that lead to significant decreases in the growth and yield of various important crops (Fahad et al., 2017). High temperature is a critical stressor that restricts the growth and productivity of plants (Zhao et al., 2020). Extensive research has been conducted on the vulnerability of faba bean to heat and drought stress. It has been observed that heat stress during the flowering stage can result in a decline in the seed yield and its components of faba bean (Bishop et al., 2016). Moreover, the current rapid climate changes in arid regions have had severe adverse effects on faba bean production, particularly due to drought stress (Abdelhaleim et al., 2022). To mitigate the impact of heat stress on different crops, the adjustment of the sowing date has been identified as a potential strategy. This approach holds promise in alleviating the detrimental effects of heat stress on crop growth and productivity.

The impact of sowing dates on faba bean production in Egypt has been the subject of extensive research due to its significant influence on growth, production, and maturity. Several studies have shed light on this matter, providing valuable insights for farmers. In a study conducted by Tarek et al. (2020), it was concluded that late sowing of faba beans resulted in a shorter maturation period. Additionally, certain genotypes exhibited higher seed yields when sown on November 1st, which was the second sowing date used in the experiment. Another study by Badran and Ahmed (2010) explored the effects of different sowing dates on faba beans, revealing that it impacted the number of days to maturity, growth characteristics, and seed yield. The study also evaluated various sowing methods.

It is crucial for farmers to take into account local conditions, climate, and available resources when determining the optimal sowing date for faba beans in Egypt. For the cultivars Sakha 1 and Giza 461, it was found that seed yield and its attributes increased when sown early on October 31st (Badr et al., 2013; Hegab et al., 2014). Conversely, cultivating faba beans after the first of November led to a decrease in seed and biological yields. The lowest values for these yields were observed when faba beans were cultivated on the first of December in the Nile delta.

Tillage is the process of preparing the soil for planting or seeding by utilizing techniques such as plowing or turning the soil (Claassen et al., 2018). While it has long been a common practice in crop farming, tillage can have detrimental effects on soil health, leading to issues such as nutrient run-off and carbon sequestration (Bhattacharyya et al., 2022). The consequences of regular tillage include the loss of topsoil, reduced yields due to the depletion of organic matter and nutrients, and a decline in soil structure and overall quality (Zikeli et al., 2013). However, experienced organic farmers have found ways to mitigate the negative impacts of tillage by operating equipment with care and maintaining optimal soil conditions (Mader and Barner, 2011). One alternative approach gaining attraction is conservation agriculture, a farming method that emphasizes the preservation of a continuous layer of soil cover, minimal disturbance of the soil, and the utilization of diverse plant species. The primary objectives of conservation agriculture are to enhance biodiversity, improve water and nutrient efficiency, and sustain crop productivity. To achieve these goals, three guiding principles are followed: (1) minimizing soil disturbance, (2) maintaining permanent soil cover through crop residues and/or cover crops, and (3) implementing crop rotations with a variety of plant species, including legumes (FAO, 2010). In Egypt, the implementation of these three principles has resulted in increased productivity of cultivated crops (Harb et al., 2015).

No-till farming is a highly beneficial practice that enhances soil quality by effectively retaining soil moisture, organic matter, and nutrients. It also plays a crucial role in reducing erosion, increasing biodiversity, and promoting the development of robust root systems in crops (Mu˜noz-Romero, 2011). However, it is important to acknowledge the challenges associated with no-till farming, such as the need for specialized equipment and the potential for increased weed growth due to undisturbed soil. Despite these challenges, no-till farming has consistently demonstrated its feasibility and sustainability as an approach to crop production, particularly when implemented with proper management techniques and in specific environments (Su et al., 2021). In fact, no-tillage systems have shown remarkable potential in enhancing soil fertility and quality while minimizing environmental impact in faba bean production. These systems effectively reduce soil N_2O emissions and significantly increase crop productivity (Tedone et al., 2023). Reduced tillage and no-tillage practices are being extensively studied as viable alternatives to conventional faba bean farming. These practices have shown promising results in enhancing soil quality and boosting crop yield (López-Bellido et al., 2003; Amami et al., 2021).

Crop growth models are valuable tools that allow us to integrate our understanding of physiological processes with the ability to formulate and evaluate crop management strategies. One such model, the CROPGRO-Faba bean model, was developed by Boote et al. (2002). This model builds upon the foundation of the CROPGRO-Soybean model (Boote et al., 1998) and has been further refined through extensive growth analysis of two faba bean cultivars i.e., Alameda and Brocal cultivated in Cordoba, Spain. These cultivars were subjected to two seasons of irrigation, both under N-fixing and N-fertilized conditions

(Sau and Mınguez, 2000). The model successfully predicted the total accumulation of dry matter in crops, the mass of pods, and the distribution of resources to different parts of the plant. The model accurately predicted high yields of faba bean, with yields exceeding 6000 kg ha^{-1}, which aligned with the actual data. Sensitivity analyses on the timing of sowing indicated that the best yields were achieved with early winter sowing in Cordoba and late winter sowing in northern Europe. Using an existing mechanistic model like CROPGRO had its benefits as it allowed for the simulation of similar processes across different species (Manschadi et al., 1998 and Bogale 2021).

The primary agronomic factors that significantly impact the growth and yield of faba bean are the sowing date and tillage practices. In order to gain a better understanding of how these factors affect faba bean, this study aims to investigate the response of faba bean's yield and its various components to different sowing dates and tillage practices. The study specifically focuses on faba bean cultivation under hot and dry conditions. To achieve this, a crop growth model called DSSAT was utilized to simulate the yield in two consecutive growing seasons.

II. MATERIALS AND METHODS

Two field experiments were conducted at a private farm located in El-Moneera village, Kharga Oasis, New Valley governorate, situated in the western desert of Egypt (25.62° N, 30.64° E). The objective of these experiments was to assess the impact of sowing dates and different tillage practices, as well as their interaction, on the yield and its components of faba beans (specifically the Giza 716 variety). To provide a visual representation of the experimental period (1st of October to 30th of April) during the growing seasons of 2021/2022 and 2022/2023, Figure 1 displays the recorded average temperatures.

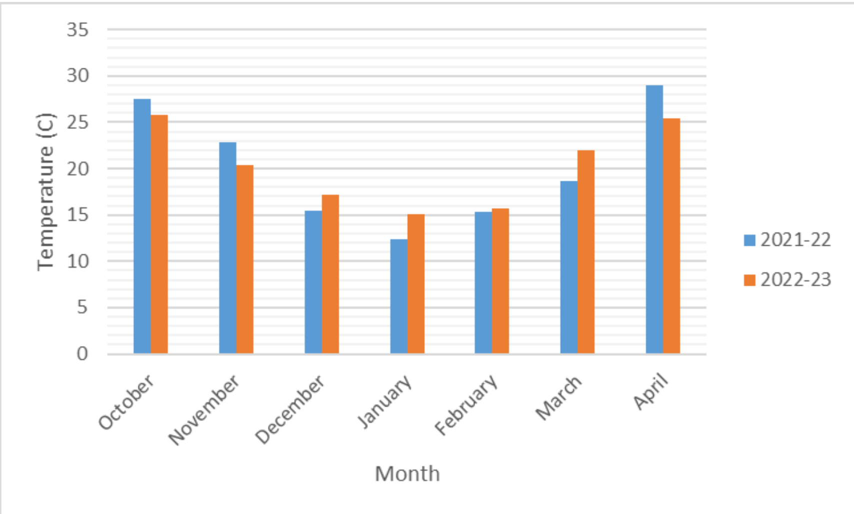

Fig.1: Mean monthly temperature at the study location in 2021-2022 and 2022-2023 seasons

The treatments consisted of four sowing dates: 1st of October, mid-October, 1st of November, and mid-November. Additionally, three tillage treatments were employed: conventional tillage (involving three passes with the removal of maize residues), mulch tillage (which incorporated maize residues into the conventional tillage process), and no-tillage (direct drilling without any prior preparation).

The chemical properties of the soil used in the experiment were analyzed prior to cultivation, and the findings have been presented in Table 1.

Table.1: Some physical and chemical properties of the soil in the experimental site.

Depth (cm)	pH	EC (dS m^{-1})	OM (%)	Soil texture	Available macro-nutrients (mg kg^{-1})			Available micro-nutrients (mg kg^{-1})			
					N	P	K	Fe	Mn	Zn	Cu
0-30	8.2	12.1	0.24	Clay loam	38.5	3.5	454.6	10.2	13.8	1.5	0.44
30-60	8.7	9.0	0.24	Clay loam	30.8	1.0	569.0	13.9	3.8	1.1	0.56

The experiment was designed in a split plot arrangement with three replications. Sowing dates were distributed in the main plots, and tillage treatments were allocated in the subplots. Sub-Plot area was 15 m length × 3 m width, occupying an area of 45 m^2. Plant distances were 0.30 m apart; the distances between rows were 0.60 m. All other agriculture practices of faba bean cultivation were done in accordance with standard recommendations for commercial growers by the Ministry of Agriculture (MALR, 2013).

At harvest, samples of ten plants of each experimental plot were taken to determine plant height (cm), number of seeds/plant, 100-seed weight (g). Seed yield and biological yield (kg ha^{-1}) were determined from each plot.

The analysis of variance (ANOVA) was conducted to determine the effects of treatments on the obtained data as described by Gomez and Gomez (1984). Least significant difference test (LSD) was used to test the differences between means at $P < 0.05$.

The CROPGRO model, which is part of the DSSAT; Decision support system for Agro-technology Transfer, (Jones *et al*. 2003), system, has been adapted to simulate the growth and yield of faba beans. The model is a suite of crop models developed to simulate the growth, development, and yields of several crops, as well as changes in soil water, carbon, and nitrogen. It was calibrated using the data collected from the field experiments of faba bean crop for the years 2021-22 and 2022-23, respectively. Calibration was done using seed yield, total aboveground biomass (referred to as biological yield in other places in this text) and harvest index. Local soil and weather parameters, initial conditions of experiment and management practices were used for running the model

To evaluate the model performance and to compare the simulated grain yield, biomass and harvest index versus the observed data, three statistical measurements were used: the coefficient of determination (R^2), Nash- Sutcliff efficiency (NSE) (Nash and Sutcliffe, 1970), and the root mean square error (RMSE) (Eq. 1,2 and 3).

$$\boldsymbol{R^2} = \frac{[\sum_{i=1}^{n}(\boldsymbol{O_i} - \boldsymbol{\bar{O}})(\boldsymbol{P_i} - \boldsymbol{\bar{P}})]^2}{[\sum_{i=1}^{n}(\boldsymbol{O_i} - \boldsymbol{\bar{O}})^2][\sum_{i=1}^{n}(\boldsymbol{P_i} - \boldsymbol{\bar{P}})^2]} \quad (1)$$

where, Pi are the predicted values, Oi are the observed values, n is the total number of observations, is the mean of the observed data and is the mean of the predicted data. R^2 ranges from 0 to 1, with higher values indicating less error variance

$$\boldsymbol{NSE} = \frac{\sum_{i=1}^{n}(\boldsymbol{O_i} - \boldsymbol{\bar{O}})^2 - \sum_{i=1}^{n}(\boldsymbol{P_i} - \boldsymbol{O_i})^2}{\sum_{i=1}^{n}(\boldsymbol{O_i} - \boldsymbol{\bar{O}})^2} \quad (2)$$

NSE, ranges between $-\infty$ and 1, The value of NSE = 1 corresponds to a perfect match between predicted and observed data

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(O_i - P_i)^2}{n}} \quad (3)$$

where, The RMSE is defined as the square root of the mean squared error. In modeling this is used to measure the geometric difference between observed and modeled data.

III. RESULTS AND DISCUSSION

3.1 The effect of sowing date

Table 2 illustrates the impact of sowing date on faba bean yield and its various components throughout the two seasons under study. In terms of plant height, the most noteworthy results were observed during the first and second seasons, specifically when cultivation took place on October 15th, resulting in heights of 95.6 cm and 97.8 cm, respectively.

Table.2: Effect of sowing date on the faba bean's yield and its component during the 2021-22 and 2022-23 growing seasons.

Sowing date	Plant height (cm)		No. seeds/plant		100-seed weight (g)		Seed yield (kg ha^{-1})		Bio. yield (kg ha^{-1})		Harvest index (%)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
1st Oct.	92.3	88.6	41.2	48.7	79.3	81.6	2970	3678	9171	10233	32.34	35.92
15th Oct.	95.6	97.8	44.3	52.2	84.8	92.1	4012	4115	11644	11534	34.44	35.43
1st Nov.	86.3	88.0	42.4	51.2	82.9	85.0	3514	3648	10694	10822	32.85	33.64
15th Nov.	83.0	83.5	36.2	46.0	71.1	73.7	3166	3079	10558	10017	29.98	30.76
LSD at 0.05	2.77	1.61	1.73	1.49	1.38	1.51	129.6	72.07	283.0	117.2	0.59	0.48

When considering the number of seeds per plant, the highest significant value was achieved through cultivation on October 15th in the first season, with a value of 44.3. Similarly, sowing on October 15th and November

1st yielded values of 52.2 and 51.2, respectively, during the second season. The 100-seed weight also exhibited notable variations, with the highest significant values recorded as 84.8 g in the first season and 92.1 g in the second season, both achieved through sowing on October 15th.

In terms of seed yield, the first season recorded the highest significant value of 4012 kg/ha, while the second season reached 4115 kg/ha, both obtained through sowing on October 15th. Conversely, the lowest yield was observed during the first season with sowing on October 1st, resulting in a value of 2970 kg/ha, and during the second season with sowing on November 15th, resulting in a value of 3079 kg/ha. The biological yield also displayed significant variations, with the highest values recorded as 11644 kg/ha in the first season and 11534 kg/ha in the second season, both achieved through sowing on October 15th.

Lastly, the harvest index exhibited notable differences, with the highest significant values of 34.44% achieved through sowing on October 15th during the first season, and 38.92% achieved through sowing on October 1st during the second season.

These results indicate that sowing faba bean on October 15th consistently resulted in the highest seed yield across both seasons. This suggests that this particular sowing date is optimal for achieving maximum productivity in terms of seed yield. On the other hand, sowing faba beans on October 1st or November 15th led to the lowest yields. This implies that these specific sowing dates may not be suitable for obtaining high seed yields in faba bean cultivation. The difference in seed yield between the two seasons is also worth noting. While the first season had a higher overall yield compared to the second season, both seasons still showed a similar trend with respect to sowing dates. This suggests that sowing date plays a significant role in determining seed yield regardless of seasonal variations.

The choice of sowing date plays a crucial role in determining the ultimate seed yield of faba bean. The importance of selecting an appropriate sowing date cannot be overstated, as it directly influences various physiological processes and growth stages, thereby affecting overall productivity. Optimum sowing dates for faba bean cultivation are influenced by several factors such as photoperiod sensitivity, temperature requirements, and management practices (McDonald et al., 1994; Adisarwanto and Knight, 1997; Yasmin et al., 2020; Manning et al., 2020). Planting at the right time (October 15th) ensures that the crop goes through key developmental stages under favourable environmental conditions, allowing for optimal vegetative and reproductive growth. A well-timed sowing date helps synchronize plant maturity with conducive environmental conditions during flowering, pollination, and pod filling stages, thus maximizing seed yield potential. Failure to choose the correct sowing date can result in reduced flowering period duration, increased susceptibility to pests and diseases, uneven pod set or abortion, impaired grain filling process, and ultimately diminished seed yields. Successful management strategies incorporating precise sowing dates have shown significant improvements in achieving maximum seed yield potential in faba bean crops across various regions (Sharaan et al., 2004; Hasanvand et al., 2015; Megawer et al., 2017; Zeleke and Nendel, 2019).

3.2 The effect of tillage practices

Table 3 illustrates the impact of different tillage practices on faba bean yield and its various components throughout the two seasons under study. The practices examined were conventional tillage, conventional tillage with mulching, and no-tillage. In terms of plant height, the most noteworthy results were observed with the no-tillage practice. During the first season, the plant height reached a significant value of 102.2 cm, while in the second season, it reached 96.8 cm.

Table.3: Effect of tillage practices on the faba bean's yield and its component during the 2021-22 and 2022-23 growing seasons.

Tillage	Plant height (cm)		No. seeds/plant		100-seed weight (g)		Seed yield (kg ha^{-1})		Bio.yield (kg ha^{-1})		Harvest index (%)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Conventional	78.7	82.1	35.0	44.6	74.23	77.3	3226	3155	10156	9913	31.73	31.93
Con.+mulch	87.1	89.5	40.5	49.8	80.85	82.8	3330	3661	10408	10642	31.93	34.36
No tillage	102.2	96.8	47.7	54.2	83.62	89.2	3690	4074	10985	11397	33.55	35.53
LSD at 0.05	2.40	1.39	1.50	1.29	1.20	1.31	112.3	62.4	245.1	101.5	0.51	0.42

When considering the number of seeds per plant, the no-tillage practice also yielded the highest significant values. In the first season, the number of seeds per plant reached 47.7, and in the second season, it increased to 54.2.

Furthermore, the 100-seed weight was found to be significantly higher with the no-tillage practice. In the first season, the weight reached 83.62 g, and in the second season, it increased to 89.2 g.

The seed yield, a crucial measure of productivity, also demonstrated the superiority of the no-tillage practice. In the first season, the seed yield reached a significant value of 3690 kg/ha, and in the second season, it increased to 4074 kg/ha. It is worth noting that the conventional tillage treatment resulted in the lowest yields in both seasons, with values of 3226 and 3155 kg/ha, respectively. Additionally, the biological yield, which encompasses all plant material produced, showed significant increases with the no-tillage practice. In the first season, the biological yield reached 10985 kg/ha, and in the second season, it increased to 11397 kg/ha.

Finally, the harvest index, a measure of the proportion of harvested yield to total biological yield, also favoured the no-tillage practice. In the first season, the harvest index reached a significant value of 33.55%, and 35.53% in the second season.

This data clearly indicates that adopting the no-tillage practice has a positive impact on the seed yield of faba bean. The significant increase in seed yield from the first season to the second season further reinforces this superiority. The fact that the conventional tillage treatment resulted in the lowest yields in both seasons is noteworthy. This suggests that traditional methods of tilling the soil may not be as effective in promoting optimal growth and productivity for faba bean. Recent research studies have provided compelling evidence that the no-tillage treatment of faba bean cultivation consistently yields higher seed productivity compared to conventional tillage (Stringi et al., 2004, Ali et al., 2018; Badagliacca et al., 2018; Volpi et al., 2018; Kimbirauskiene et al., 2023). This technique allows for improved water infiltration, reduced erosion risks, and increased microbial activity in the soil (Reicosky and Saxton, 2007; Blanco-Canqui and Ruis, 2018). By maintaining an undisturbed top layer of soil, no-tillage treatment promotes optimal root development and actively facilitates nutrient uptake by the plants (Triplett Jr and Dick, 2008; Mehra et al., 2020). In contrast, conventional tillage commonly disrupts soil structure and exposes it to erosion risks while also causing loss of organic matter content crucial for future crop production (Madarász et al., 2016; Kuhwald et al., 2017; Rahmati et al., 2020). The higher seed yield obtained through no-tillage treatment signals its potential as an environmentally-friendly and sustainable approach with considerable economic benefits for farmers growing faba bean.

3.3 The effect of sowing date × tillage practices

Table 4 presents the findings on the impact of different sowing dates of faba bean and tillage practices on the yield and its components in two consecutive seasons. The results indicate that the interaction between no-tillage and sowing on October 15th had a significant effect on plant height. In the first season, the highest recorded value was 111.8 cm, while in the second season, it reached 113.4 cm. These findings highlight the importance of considering both the sowing date and tillage practices in order to achieve optimal plant height.

Table.4: Effect of the interaction between sowing dates and tillage practices on the faba bean's yield and its component during the 2021-22 and 2022-23 growing seasons.

Treatment	Plant height (cm)		No. seeds/plant		100-seed weight (g)		Seed yield (kg ha^{-1})		Bio. yield (kg ha^{-1})		Harvest index (%)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
1st Oct.+Con.	79.3	84.4	34.3	42.9	75.1	77.5	2582	3145	8025	8961	32.17	35.10
1st Oct.+Con.and mulch	93.8	88.8	41.9	49.3	79.5	80.9	2941	3784	9333	10270	31.52	36.85
1st Oct.+No tillage	103.7	92.5	47.4	54.0	83.4	86.4	3385	4104	10153	11467	33.33	35.79
15th Oct.+Con.	84.3	84.4	37.4	46.8	77.9	85.3	3872	3319	11297	10279	34.27	32.29
15th Oct.+Con.and mulch	90.8	95.8	42.0	52.1	84.5	92.9	3902	4028	11510	11459	33.90	35.15
15th Oct.+No tillage	111.8	113.4	53.5	57.5	92.1	98.0	4262	4999	12123	12864	35.15	38.86
1st Nov .+Con.	75.6	81.8	36.1	46.7	76.8	77.1	3445	3193	10860	10259	31.69	31.12
1st Nov.+Con.and mulch	85.3	89.6	43.6	52.1	84.4	83.3	3346	3737	10441	10789	32.04	34.64

1st Nov.+No tillage	98.0	92.6	47.4	54.8	87.6	94.5	3750	4014	10780	11419	34.79	35.16
15th Nov.+Con.	75.4	77.9	32.0	41.9	67.1	69.4	3003	2965	10443	10156	28.76	29.19
15th Nov.+Con.and mulch	78.4	83.9	34.5	45.7	75.0	74.0	3131	3095	10348	10054	30.26	30.79
15th Nov.+No tillage	95.3	88.8	42.3	50.4	71.4	77.7	3363	3178	10882	9840	30.90	32.30
LSD at 0.05	4.80	2.79	2.99	2.57	2.39	2.62	224.5	124.8	490.2	203.1	1.02	0.84

Furthermore, the study also examined the number of seeds per plant. Similar to plant height, the interaction between no-tillage and sowing on October 15th resulted in the highest significant value in both seasons. In the first season, the number of seeds per plant reached 53.5, while in the second season, it increased to 57.5. These results emphasize the positive impact of the selected sowing date and tillage practices on the number of seeds produced per plant.

In addition, the study investigated the 100-seed weight. The interaction between no-tillage and sowing on October 15th yielded the highest significant value in both seasons. In the first season, the 100-seed weight was recorded at 92.1 g, while in the second season, it increased to 98.0 g. These findings suggest that the selected sowing date and tillage practices contribute to achieving a higher weight per seed, which can have implications for overall yield.

Moreover, the study examined the seed yield. Once again, the interaction between no-tillage and sowing on October 15th resulted in the highest significant value in both seasons. In the first season, the seed yield reached 4262 kg/ha, while in the second season, it increased to 4999 kg/ha. It is worth noting that the lowest significant values were observed with conventional tillage and sowing on October 1st in both seasons, with values of 2582 kg/ha in the first season and 3145.7 kg/ha in the second season. These findings highlight the importance of considering the sowing date and tillage practices in order to achieve optimal seed yield.

In terms of biological yield, the first season witnessed a significant value of 12,123 kg/ha. This result was attributed to the synergistic effect of implementing no-tillage techniques and sowing on October 15th. Impressively, the same combination of practices also yielded the highest significant value in the second season, reaching an impressive 12,864 kg/ha.

Shifting the focus to the harvest index, the first season showcased a significant value of 35.15%. This outcome was once again attributed to the successful interaction between no-tillage practices and sowing on October 15th. Astonishingly, the same combination of techniques also produced the highest significant value in the second season, reaching an impressive 38.86%.

No-tillage and sowing faba bean on October 15th has been proven to be the most effective method for achieving optimal yield and yield components. This agricultural practice involves eliminating conventional tillage methods, such as ploughing or discing, and directly sowing the beans into untilled soil. By doing so, the natural structure of the soil is preserved, minimizing erosion and conserving moisture content (Fengyun et al., 2011; Komissarov and Klik, 2020; Bekele, 2020; Mondal and Chakraborty, 2022). The specific timing of sowing on October 15th ensures that the faba beans are planted early enough to take advantage of cooler temperatures required for optimum growth. Additionally, this timing allows for an extended growing season during which the plants can accumulate enough biomass, leading to high yields (Catt and Paull, 2017; Manning et al., 2020; Alharbi, and Adhikari, 2020). Overall, adopting no-tillage techniques combined with sowing faba bean on October 15th represents a best-practice approach for maximizing yield and optimizing various growth factors in faba bean cultivation.

3.4 DSSAT model simulation results

The crop and soil parameters of the DSSAT model were iteratively adjusted until close agreement was achieved between the measured and simulated seed yield, total biomass and harvest index. The agreement was measured using different statistical fitting parameters (NSE, R^2 and RMSE). Figure 2 shows the measured and simulated values of these variables and values of statistical fitting parameters. The fitting of the calibration data and model simulation was very good with statistical parameters as indicated; grain yield (NSE = 0.879 and 0.84, R^2 = 0.88 and 0.855, and RMSE = 157.5 and 227.7) total above ground biomass (NSE = 0.839 and 0.829, R^2 = 0.886 and 0.831, and RMSE = 406.2 and 402.2) and harvest index (NSE = 0.669 and 0.772, R^2 = 0.752 and 0.884, and RMSE = 1.07 and 1.28) in the 2021-22 and 2022-23 seasons, respectively (Figure 2).

Data reveals that DSSAT model accurately reflected the sowing dates and tillage practices on the faba bean grain yield, total biomass yield and harvest index. Same trends were reported by Zeleke et al. (2019) when the Aqua Crop model was used to simulate the impact of sowing dates, sowing rates and supplemental irrigation on faba bean growth and yield. Several studies also reported the successful application of the crop growth models to simulate the different management practices on plant growth and yield of faba beans using APSIM (Keating et al., 2003), STICS (Falconnier et al., 2019) and CROPGRO (Hassanein et al., 2007 and Boote et al., 2002)

Same results were obtained by Osman et al. (2014) when using Cropsyst model to simulate the growth and yield of faba bean, they reported that the R^2 values where above 0.9 when the predicted versus measured grain yield and total biomass were compared.

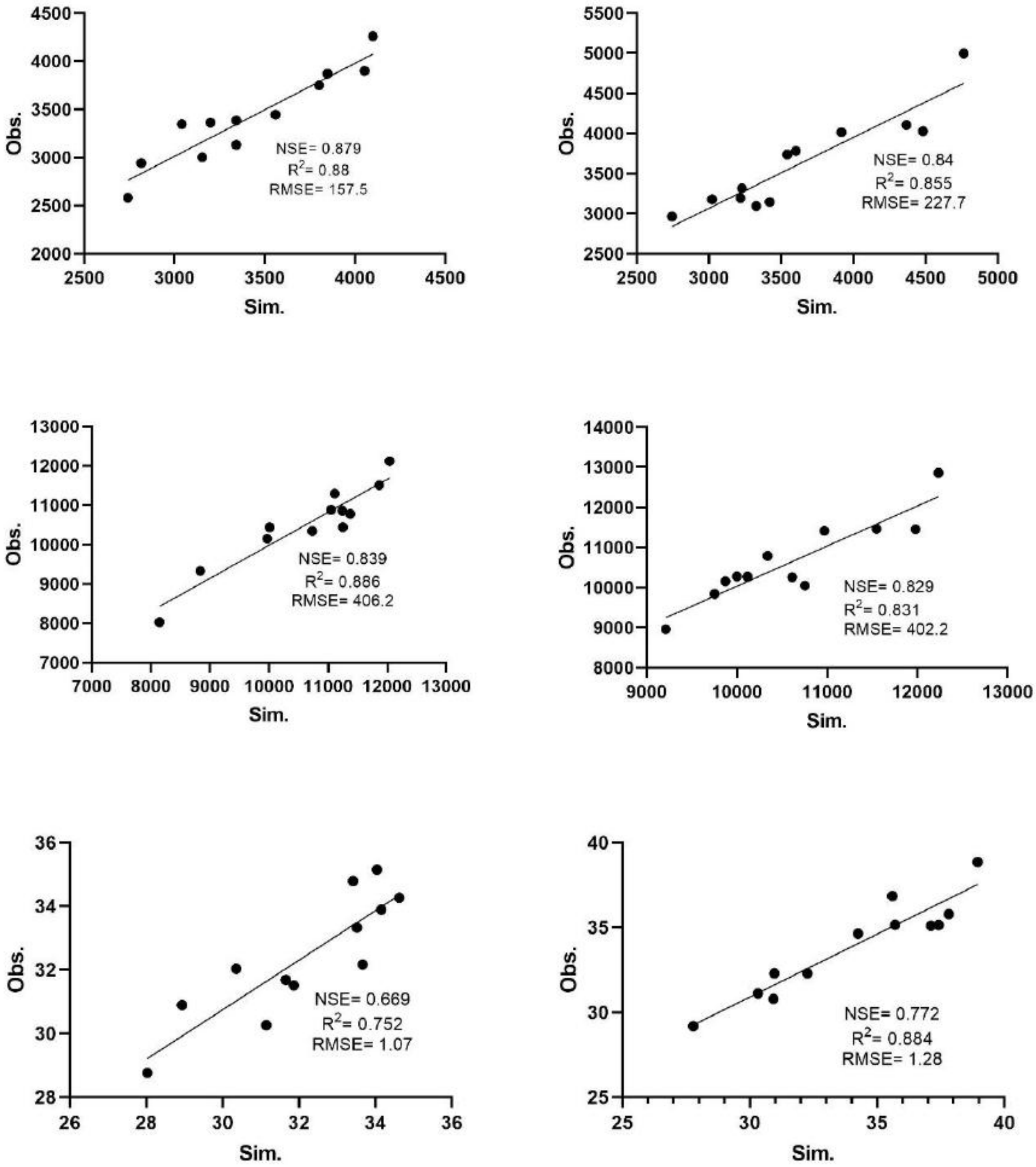

Fig.2: Simulated vs. observed seed yield (upper), total biomass (middle) and harvest index (lower) in the first (left) and second (right) seasons.

IV. CONCLUSION

The study revealed that the timing of sowing and the tillage practices exert a significant influence on the yield of faba bean seeds and their components. Notably, the DSSAT model demonstrated remarkable accuracy in simulating the seed yield, total above-ground biomass, and harvest index. The model achieved an NSE value exceeding 0.80 for both the seed yield and the total biomass, effectively capturing the impact of various sowing dates and tillage practices across two seasons. In the specific context of Kharga, New Valley, the study identified mid-October as the optimal sowing date for faba beans. Deviating from this timeframe, whether by sowing earlier or later, resulted in reduced seed yield. Furthermore, the adoption of a no-tillage practice proved advantageous in enhancing both faba bean yield and soil health. These findings underscore the potential value of the DSSAT model as a valuable decision-making tool for determining faba bean sowing dates and implementing effective tillage management strategies.

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