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GOAT PEA (*SECURIGERA SECURIDACA* L.) SEED YIELD AND PHYTOCHEMICALS IMPROVEMENT THROUGH CROP MANAGEMENT PRACTICES

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SUMMARY

The presented trial carried out at the District Baqubah, Diyala Governorate, Iraq, assessed the effects of three planting dates (15 October, 05, and 25 November 2018) and four levels of organic fertilizer (0, 150, 250, and 350 kg ha^{-1}) on the seed yield and chemical composition of the goat pea (*Securigera securidaca* L.). The experiment in a randomized complete block design with a factorial arrangement had three replications. The results showed that the 15 October planting was significantly superior in the percentage and yield of oil and the total content of phenols and glycosides, which amounted to 3.86%, 14.17 kg ha^{-1}, 1.23 mg g^{-1}, and 29.44 mg g^{-1}, respectively. The organic fertilizer treatment, 350 kg ha^{-1}, proved superior and provided the highest oil yield (14.48 kg ha^{-1}), while organic fertilizer, 250 kg ha^{-1}, was higher in the oil content (3.90%) and phenols (1.21 mg g^{-1}). The interaction between 15 October planting and organic fertilizer, 250 kg ha^{-1}, revealed a significant increase in oil percentage and the total content of phenols and glycosides, which amounted to 4.01%, 1.24 mg g^{-1}, and 29.68 mg g^{-1}, respectively. However, the interaction of the 15 October planting with organic fertilizer, 350 kg ha^{-1}, was superior in the oil yield (15.23 kg ha^{-1}).

Keywords: Goat pea (*Securigera securidaca* L.), planting time, organic fertilizer levels, seed and oil yield, phenols and glycosides

Key findings: The goat pea 15 October planting with organic fertilizer, 250 kg ha^{-1}, emerged superior in terms of significant enhancement in oil percentage, oil yield, and total content of phenols and glycosides.

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INTRODUCTION

Investments in the cultivation of medicinal plants possess vitality in providing strategic resources for the pharmaceutical industry. The goat pea (*Securigera securidaca* L.) is a very eminent medicinal plant belonging to the family Leguminosae. It is a herbaceous plant that grows in winter and spreads widely in the humid environments of Europe, Australia, and Asia. The goat pea seeds contain the highest percentage of cardiac glycosides used in the preparation of diabetes and antioxidant compounds (Ali *et al*., 1998). The goat pea seeds contain cardiac glycosides that significantly reduce blood sugar due to their influence in increasing insulin levels (Tofighi *et al*., 2017).

Goat pea seeds also contain biologically active compounds, such as, phenols, flavonoids, saponins, and tannins (Rajaei *et al*., 2015; Jamshidzadeh *et al*., 2018). Planting time greatly influences and manages plant production for quantity and quality. Sowing time also provides an ideal opportunity to invest in appropriate environmental conditions, such as, temperatures, lighting periods, and other environmental factors affecting plant growth and development. Environmental conditions possess a vital role in stimulating enzymes and metabolic pathways for synthesizing carbohydrates and distributing them within the reproductive parts of plants.

According to Jevdjovic and Radojka (2007), the early planting dates of fenugreek (*Trigonella foenum-graecum* L.) led to an increase in the number of fruits, seed weight, plant yield, and active compounds of the seeds. In calcareous and saline soils, one of the constraints for medicinal plant cultivation is the lack of necessary nutrients to meet the needs of growing plants, requiring organic fertilizers' application. Organic fertilizers are complex compounds made from plant and animal materials, and these resources consist mainly of humic and fulvic acids and hemomin.

Organic fertilizer is imperative in increasing plant production by maintaining soil fertility and processing by supplying the major and minor nutrients necessary for plant growth. It also provides suitable environmental conditions for plant growth, such as, improving soil structure, reducing its apparent density, increasing water retention, and improving porosity, which helps plant roots grow properly, providing suitable environmental conditions for the activity of the microorganisms and supplying them carbon and energy it needs during the process of metallization and reducing the pollution of heavy elements (Abu-Rayan, 2010). Chafi and Bensoltane (2009) showed that humic fertilizers contribute to the recovery of the bacterial activity of *Rhizobium* in the roots of plants of the legume family. In addition to its physiological effect in plants, are stimulating enzymatic and biological reactions, cell division, and elongation.

Early planting of fenugreek crops and fertilizing with organic fertilizer caused a significant increase in the number of fruits per plant, seed yield, and contents of biologically active compounds (Majid *et al*., 2019). Therefore, the presented study planned to determine the effects of planting time and organic fertilizer (humic acid) on seed yield, oil content, and chemical composition of goat peas. This study aimed to know planting dates and organic fertilizers' effects on seed yield and chemical compounds in plant seeds.

MATERIALS AND METHODS

The presented research proceeded during the winter of 2018–2019 at the District Baqubah, Diyala Governorate, Iraq. The experiment was in a randomized complete block design with a factorial arrangement and had three replications. The study included two factors, i.e., the first was the three planting dates (15 October, 05, and 25 November), while the second was the organic fertilizer applied with four levels (0, 150, 250, 350 kg ha^{-1}). The organic fertilizer (Care Ball Supermix) is in granular form, which was added at a depth of 30 cm from the soil surface, according to the manufacturer's recommendation (Table 1). Mixing the organic fertilizer with the soil ensued before planting. The chemical composition of the organic fertilizer is also shown in Table 1. The goat pea seeds came

Table 1. The chemical components of the organic fertilizer (Careball Supermix).

The material	Ratio (%)
Total organic material	40
Free amino acid	5
Seaweed	3
Humic acid	30
Fulvic acid	10

Table 2. The physical and chemical properties of the soil before planting goat pea seeds in the Central Laboratory.

Measurements	Value	Unit of measurement
Organic matter	0.57	g kg^{-1}
CO_3	0.30	%
Ec	2.12	ds m^{-1}
Ph	6.21	-
N	10.6	Ppm
P	35.1	Ppm
K	187.3	Ppm
Clay	45.2	g kg^{-1}
Silt	25.92	g kg^{-1}
Sand	28.88	g kg^{-1}
Texture of soil	Clay	
HCO_3	85	mEq L^{-1}
SO_3	0.4	%

from the National Center for Agricultural Research and Extension, Hashemite Kingdom of Jordan. The tested seed's vitality was 95%. Soil samples collected randomly from the experimental field at a depth of 15–30 cm before planting underwent analysis for their physical and chemical properties in the Central Laboratory, College of Science, University of Baghdad, Iraq (Table 2).

Crop husbandry

The plowing and leveling of the experimental soil used two orthogonal plowings, then divided into experimental units with dimensions of 4 m × 3.5 m. The experimental section included six rows with 50 cm spacing among the rows and plants and one-meter spacing between the experimental units and the replications. The experiment soil received fertilization with phosphate fertilizer at the rate of 100 kg ha^{-1}, which was added after plowing and before planting the seeds. Planting goat pea seeds occurred by holes method in rows. Nitrogen fertilizer application at the rate of 80 kg ha^{-1} was in two doses: the first after one week of germination, while the second N dose after one month of the first batch. Crop irrigation processes were carried on when needed. The goat pea crop harvesting was on 25 May 2019, after getting physiological maturity and when the pods became light brown.

Data recorded

Yield-related traits

Ten plants, randomly selected in each experimental unit, had their data recorded on the following yield-related traits, i.e., number of pods per plant, 500-seed weight (g), and seed yield per plant (g).

Chemical composition of seed

Oil percentage

The estimates of the percentage of fixed oil in the seeds after extraction used the standard method (A.O.A.C., 1984) of taking 10 g of dried and ground seeds using Soxhlet. The oil percentage estimation had the following equation:

$$\text{Percentage of oil} = \text{Oil weight} / \text{Seed sample weight} \times 100$$

Total glycoside content (mg.g^{-1})

A 20 g of goat peas' dried and ground seeds proceeded immersion in 80% methanol at a rate of 3 × 300 ml for 48 h, filtering and concentrating the extract using a vacuum, with the cardiac glycoside content of said isolate determined using the method of Solich *et al*. (1992) by taking 10% of the extract and mixing the total extract of the seeds with 0.16 ml freshly prepared Baljet reagent. After an hour, the mixture dilution with 10 ml of distilled water ensued. The absorbance measurement at 495 nm used a spectrophotometer for UV/VIS. Then, taking 10 ml of different concentrations (12.5–100 ppm) prepared a standard curve, according to Tofighi (1992). The total glycosides in the samples were expressed as securidaside (mg/g) in dried seed extract.

Total phenolic content (mg g^{-1})

Using 1 g of dried and ground seeds with 20 ml of ethanol at a concentration of 80% for 24 h and preparing the Folin-ciocalteu reagent determined phenolic compounds (Slinkard and Singleton, 1977; Jeffery *et al*., 1989). After its dilution (1 ml reagent: 4 ml distilled water), the mixture of 1 ml of it to 50 microliters of the above extract gained shaking for 3 min. Afterward, adding 1 ml of Na_2CO_3 solution at 10% concentration continued before leaving for an hour in the dark. The absorbance measurement of phenolic compounds with a spectrophotometer was at a wavelength of 760 nm. The total phenolic compounds estimated as gallic acid equivalent followed the method of Masum-Akond *et al*. (2010).

Statistical analysis

Analysis of all recorded data employed the SAS statistical program (2001), with the averages compared according to Duncan's Multiple Range (DMR) test at a 5% probability level (Al-Rawi and Khalaf-Allah, 1980).

RESULTS

Yield-related traits

Pods per plant

Planting dates revealed a significant effect by showing varied values for pods per plant (Table 3). The 15 October 2018 planting was significantly superior and gave the highest average of pods per plant (79.7 pods), compared with the lowest average obtained with the late planting made on 25 November 2018 (75.0 pods). In the same table, organic fertilizer treatments also showed significant differences for pods per plant, with organic fertilizer, 350 kg ha^{-1}, emerging superior in the number of pods per plant by giving the highest average (82.6 pods), compared with the control treatment (with no fertilizer) which amounted to 70.3 pods per plant. As for the interaction between the planting dates and the organic fertilizer, the combination of 10 October planting with organic fertilizer, 350 kg ha^{-1}, proved superior, with the highest rate of pods per plant in goat pea (86.0 pods), compared with the 25 November planting with no organic fertilizer (68.0 pods).

500-seed weight (g)

For 500-seed weight, the planting dates also showed significant differences, revealing the 15 October planting as significantly superior (4.26 g) compared with the lowest average due to late planting made on 25 November (4.01 g) (Table 3). The various levels of organic fertilizer also showed significant differences for 500-seed weight, with the organic fertilizer,

Table 3. Effect of planting dates and organic fertilizer on the pods per plant, 500-seed weight, and seed yield of goat pea.

Planting dates	Organic fertilizer (kg ha^{-1})				Means
	0	150	250	350	
	Pods per plant				
15 Oct	72.0 E	78.0 D	86.0 A	83.0 AB	79.7 A
5 Nov	71.0 E	76.0 D	82.0 B	84.0 AB	78.2 B
25 Nov	68.0 F	73.0 E	78.0 CD	81.0 BC	75.0 C
Means	70.3 C	75.6 B	82.0 A	82.6 A	
	500-seed weight (g)				
15 Oct	4.02 G	4.18 E	4.57 A	4.28 D	4.26 A
5 Nov	3.90 I	4.07 F	4.45 B	4.17 E	4.14 B
25 Nov	3.77 J	3.94 H	4.04 GF	4.32 C	4.01 C
Means	3.89 D	4.06 C	4.35A	4.25 B	
	Seed yield per plant (g)				
15 Oct	5.35 E	5.83 D	6.43 A	6.20 B	5.95 A
5 Nov	5.09 F	5.41 E	5.83 D	6.01 C	5.58 B
25 Nov	4.73 G	5.31 E	5.40 E	5.71 D	5.28 C
Means	5.05 D	5.51 C	5.88 B	5.97 A	

250 kg ha^{-1}, showing superior in 500-seed weight (4.35 g) versus the control treatment (3.89 g). In the interaction of planting time and various doses of organic fertilizer, the early planting of 15 October with the organic fertilizer at the rate of 250 kg ha-^{1} occurred superior with the highest 500-seed weight (4.57 g), compared with the late planting on 25 November with no organic fertilizer as the lowest seed weight (3.77 g).

Seeds yield per plant

Planting dates significantly impacted production in goat peas and showed varied values for seed yield per plant (Table 3). The 15 October, being an early planting date, was highly influential by giving the highest average seed yield per plant (5.95 g) compared with the lowest average obtained with late planting made on 25 November (5.28 g). For seed yield per plant, various doses of organic fertilizer exhibited significant differences, displaying the organic fertilizer at the rate of 350 kg ha^{-1} as superior in the seed yield per plant with the highest average (5.97 g) compared with the control with no organic fertilizer (5.05 g). On the interaction between the planting dates and the organic fertilizer, the planting made on 15 October, in combination with the 250 kg ha^{-1}, revealed the highest rate in the seed yield per plant (6.43 g) versus the lowest seed yield per plant obtained with late planting made on 25 November with no organic fertilizer (4.73 g).

Chemical composition

Oil percentage

For oil percentage in goat pea seeds, the planting dates revealed significant differences, with the early planting on 15 October found superior with the highest rate of oil content (3.86%) compared with the lowest value secured from late planting on 25 November 25 (3.72%) (Table 4). Varied doses of organic fertilizer also revealed a significant effect on the oil percentage in goat pea seeds, with the 250 kg ha^{-1} as superior, giving the highest average oil percentage (3.90%) versus with no organic fertilizer obtaining the lowest at 3.60%. As for the interaction between both experimental factors, the 15 October early planting with organic fertilizer, 250 kg ha^{-1}, surfaced as superior, excelling over all other interactions with the highest oil percentage (4.01%) compared with the late planting made on 25 November with no organic fertilizer, recording the lowest oil content (3.53%).

Table 4. Effect of planting dates and organic fertilizer on the percentage and yield of oil, the total content of phenols, and glycosides in the goat pea seeds.

Planting dates	Organic fertilizer (kg ha^{-1})				Means
	0	150	250	350	
			Oil percentage		
15 Oct	3.69 F	3.85 CD	4.01 A	3.90 BC	3.86 A
5 Nov	3.59 G	3.75 EF	3.97 AB	3.8 DE	3.77 B
25 Nov	3.53 G	3.7 SF	3.74 EF	3.91 BC	3.72 C
Means	3.60 C	3.76 B	3.90 A	3.87A	
			Oil yield (kg ha^{-1})		
15 Oct	12.33 F	14.02 CD	15.11 A	15.23 A	14.17 A
5 Nov	11.42 G	12.67 E	14.46 B	14.27 BC	13.20 B
25 Nov	10.43 H	12.27 F	12.62 E	13.95 D	12.31 C
Means	11.39 D	12.98 C	14.06 B	14.48 A	
			Total phenols (mg g^{-1})		
15 Oct	1.22 D	1.23 B	1.24 A	1.23 C	A1.23
5 Nov	1.19 H	1.20 F	1.21 E	1.19 G	B1.20
25 Nov	1.16 L	1.17 J	1.18 I	1.17 K	C1.17
Means	D1.19	B1.20	A1.21	1.19 C	
			Total glycosides (mg g^{-1})		
15 Oct	29.05 A-D	29.47 ABC	29.68 A	29.57 AB	A29.44
5 Nov	28.32 A-E	28.75 A-E	29.09 A-D	28.83 E	B28.75
25 Nov	27.51 E	27.94 ED	28.14 B-E	28.04 CDE	C27.91
Means	A28.29	A28.72	A28.97	28.81 A	

Oil yield

For oil yield, significant differences resulted in early and late planting dates. The early planting on 15 October appeared superior, with the highest oil yield (14.17 kg ha^{-1}) compared with the lowest value obtained for late planting made on 25 November (12.31 kg ha^{-1}) (Table 4). Various doses of organic fertilizer also showed significant differences in oil yield. The organic fertilizer, 350 kg ha^{-1}, was excellent, giving the highest average oil yield (14.48 kg ha^{-1}) relative to the lowest average obtained in the control treatment (with no organic fertilizer) at 11.39 kg ha^{-1}. On the interaction between the planting date and the organic fertilizer, the early planting (15 October), in combination with 250 kg ha^{-1}, was notable by exhibiting the highest oil yield (15.23 kg ha^{-1}) compared with the minimum oil yield revealed from late planting (25 November) with no fertilizer (10.43 kg.ha^{-1}).

Phenol content

The planting dates also indicated relevant differences in phenol content in goat pea seeds (Table 4, Figure 1). The early planting of 15 October led by showing the highest content of phenols in the seeds (1.23 mg g^{-1}), compared with the lowest value obtained on 25 November (1.17 mg g^{-1}). The organic fertilizer with various doses showed a significant impact on phenol content, with the 250 kg ha^{-1} occurring superior with the highest average of total phenols (1.21 mg g^{-1}) compared with the lowest average obtained in the control treatment (1.19 mg g^{-1}) (Table 4, Figure 3). The interaction of planting dates and organic fertilizer doses signified most excellent the early planting on 15 October with organic fertilizer, 250 kg ha^{-1}. It showed the highest rate of total phenol content (1.24 mg g^{-1}) compared with the lowest value of the said trait obtained with late planting on 25 November with no organic fertilizer (1.16 mg g^{-1}).

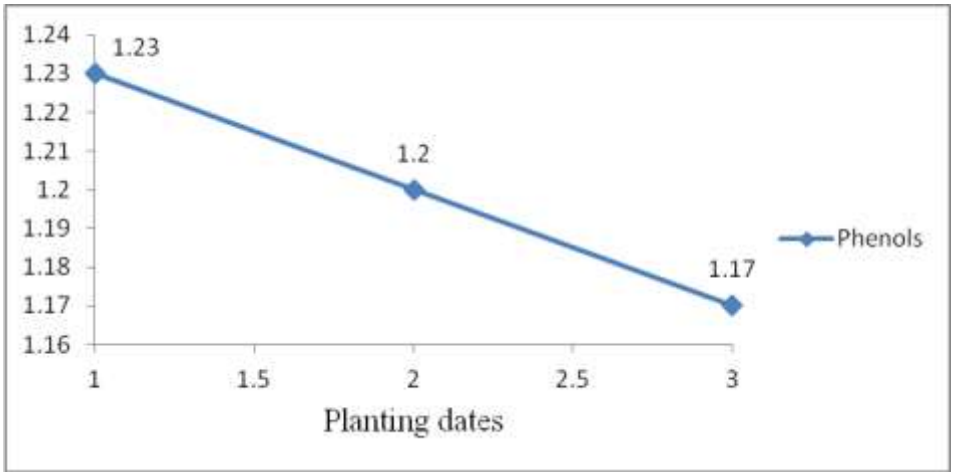

Figure 1. Effect of planting dates on total content of phenols (mg g^{-1}) in goat pea seeds.

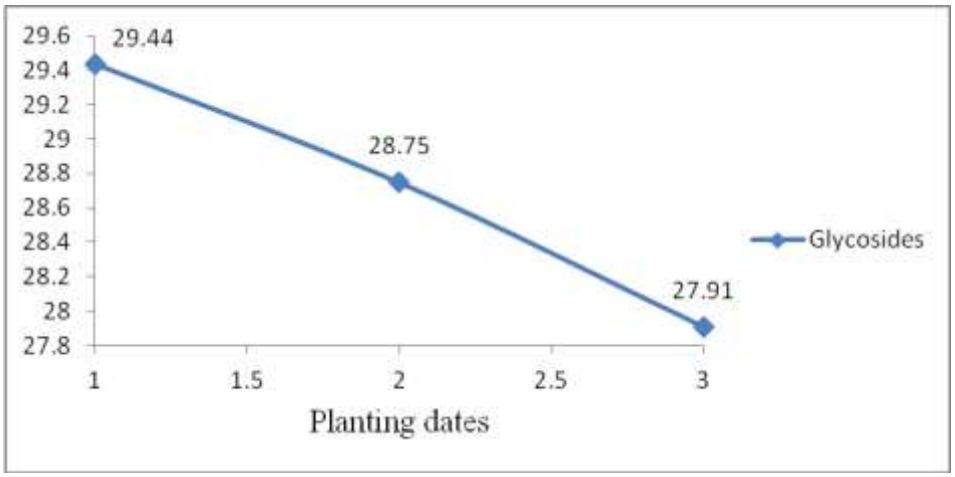

Figure 2. Effect of planting dates on total content of glycosides (mg g^{-1}) in goat pea seeds.

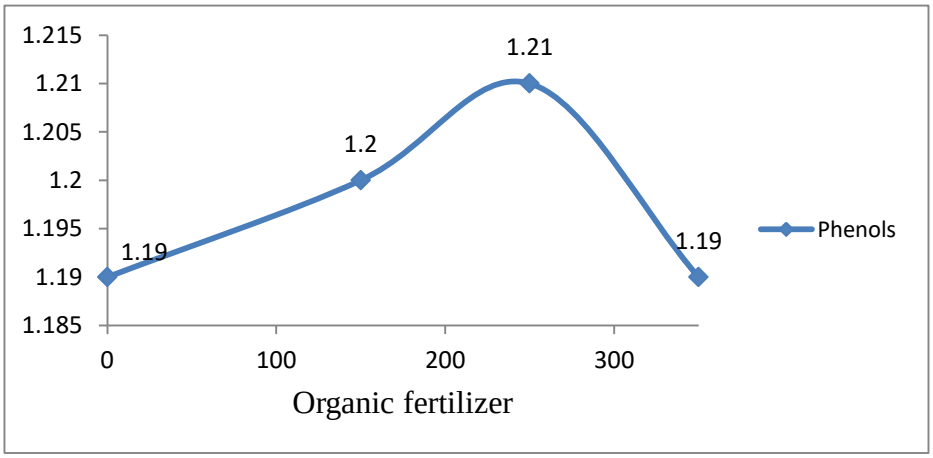

Figure 3. Effect of organic fertilizer on the total content of phenols (mg g^{-1}) in goat pea seeds.

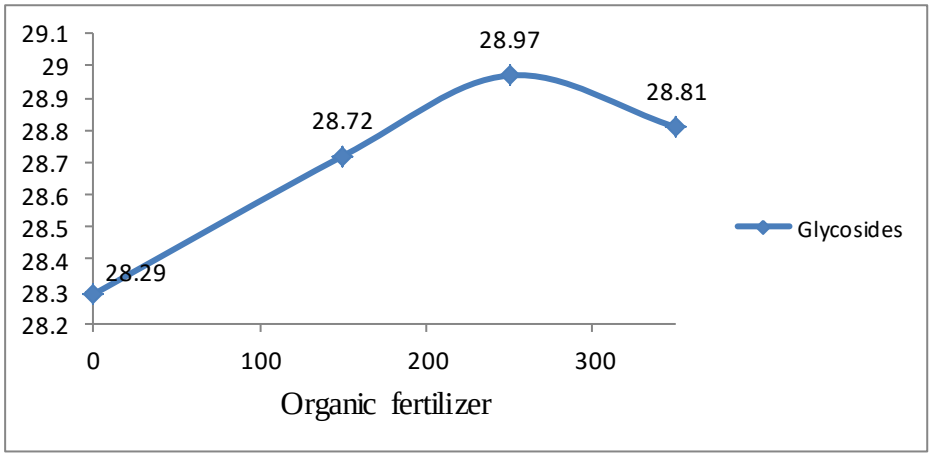

Figure 4. Effect of organic fertilizer on the total content of glycosides (mg g^{-1}) in goat pea seeds.

Glycoside content

For glycoside content in goat pea seeds, the planting dates provided significant differences (Table 4, Figure 2), with the early planting (15 October) found superior, recording the highest rate of glycoside content (29.44 mg g^{-1}), compared with the lowest value enunciated by late planting on 25 November (27.91 mg g^{-1}). However, the organic fertilizer showed no significant effect on the total glycoside content in the seeds (Table 4, Figure 4). On the interaction between the planting dates and the organic fertilizer, the early planting (15 October) with the organic fertilizer, 250 kg ha^{-1}, was superior, giving the highest rate of total glycoside content in the goat pea seeds (29.68 mg g^{-1}) versus the late planting of 25 November with no organic fertilizer, recording the lowest glycoside content (27.51 mg g^{-1}).

DISCUSSION

The results revealed that early planting provided an extended growth period and available primary compounds obtained from the photosynthesis process transferred to plant parts, reducing the competition between the vegetative parts and their reflection in the emergence of flowers, seed formation, and increase in the yield of the goat pea (*Securigera securidaca* L.). Moreover, early planting has an impact on the growth capacity of roots and the efficiency of the absorption of water and nutrients in Fenugreek (*Trigonella foenum-graecum* L.) (Majid *et al*., 2019) and their reflection in yield indicators, including the number of pods and seed yield per plant in flax (*Linum usitatissimum* L.) (Samira *et al*., 2018).

The early planting accompanying suitable conditions for vegetative growth improved the vital activity of physiological processes, including photosynthesis and producing more carbohydrates and their transfer to the formation of oil in seeds (Shaker, 2011; Ruqayya *et al*., 2013**)**. Similar findings also came from Ebrahimghochi *et al*. (2018) in studying the effects of early planting on the fenugreek plant, which led to a significant increase in vegetative growth, yield traits, and seed oil content. In the presented results, the early planting also showed a positive impact on the chemical composition of goat pea seeds, indicating enhanced values for total phenols and glycoside content in seeds. It may be due to the effect of the early planting that improved the efficiency of photosynthesis and the production of the first metabolic compounds in cumin (*Cuminum cyminum* L.) (AL-Mohammadi, 2009). Hence, it improved the growth and yield-related traits and the glycoside content in the stevia (*Stevia rebaudiana* Bertoni) (Aladakatti *et al*., 2012). Producing and accumulating more carbohydrate and amino acid compounds

stimulated the biosynthetic pathway toward phenolic compounds' synthesis.

Adding organic fertilizer to the soil and its content of humic compounds, organics, and amino acids, also significantly enhanced the plant production in goat peas, which contributed to providing the necessary nutrients for the plants and increasing the growth of the vegetative area and its reflection on the physiological activities and seed production. The carbohydrate compounds also contributed more to forming fruits and producing seeds in saffron flowering plants (Jahan and Jahani, 2007)**,** in addition to their similar effect on hormones and their vital role in cell division and elongation in stevia (*Stevia rebaudiana* L.) **(**Kakhki *et al*., 2019), and improving the efficiency of photosynthesis, thus producing and accumulating carbohydrates and transferring them to the reproductive parts, resulting in seed yield increase and its components in plants (Nardi *et al*., 2002). These results were consistent with the past findings, which revealed that organic fertilizer had a significant effect on increasing the number of fruits and seed yield of fenugreek (*Trigonella foenum - graecum* L.) (Emad-El-Deen *et al*., 2021).

Existing results further detailed the significant increase in oil percentage and total oil yield due to the application of organic fertilizer, which may refer to its vital role in biological activities and improving carbohydrate contents (Tan, 2004), which are also essential compounds for oil synthesis in seeds in Dill plant (*Anethum graveolens* L.) (AL-Mohammadi and AL-Jubouri, 2017). Similarly, Fatma and Helaly (2017) mentioned that adding organic fertilizers increased the proportion of seed yield and its oil content in the fenugreek crop. Additionally, the vital role of organic fertilizer in improving the total phenols includes its activity in physiological processes and stimulating the growth regulators and enzymes in crop plants (Mikkelsen, 2005), which contribute to carbohydrates accumulation, thus stimulating the Shikimic acid pathway toward synthesizing phenols (AL-Mohammadi and AL-Jubouri, 2019; Abdel-Amin and Abbas, 2019). Majid *et al*. (2019) further confirmed that adding organic fertilizers to fenugreek fields significantly increased seed production and its active substances.

CONCLUSIONS

The presented investigation suggests that early planting of goat pea seed had a significant positive impact on increasing the seed yield, oil content, and the total content of phenols and glycosides in the seeds. Also, the organic fertilizer at the rate of 350 kg ha^{-1} was excellent by giving the highest oil yield. Similarly, the organic fertilizer, 250 kg ha^{-1}, increased the oil and the total content of phenols in the goat pea seeds. For the medicinal importance of the *S. securigera* plant, more studies need their undertaking on feeding the plant and adding it at different stages of its life.

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