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THE RESPONSE OF *NIGELLA SATIVA* PLANTS TO DIFFERENT NATURAL AND CHEMICAL FERTILIZERS UNDER MEDITERRANEAN CONDITIONS

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Abstract

The paper studied the impact of integrated plant nutrients management strategy (IPNM) on the agricultural return during current Syrian crisis through the application of camel manure and chemical fertilizers on the black cumin quantitatively and qualitatively. The fertilization treatments were denoted as T_2 [N_{120}-P_{30}-K_{30}], T_3 [N_{120}-P_{30}-K_{60}], T_4 [5 t. ha^{-1}camel manure], and T_5 (½ [T_3 + T_4]), respectively. The no-fertilizer treatment (T_1) was considered as control. Soil fertility, irrigation water use efficiency (IWUE), and oil content were considered. Results have showed that organic manure(camel dung)decreased soil pH and OC/ON ratio and increased the availability of nutrients in the soil. What led the black cumin to respond by significantly increasing the following productive parameters: plant height, roots depth, number of primary and secondary branches,..etc. The treatment T_5 recorded the highest IWUE values (5.2 and 6.2 kg.ha^{-1}.mm^{-1}) and the best oil content (33.3% and 34.2%) in the two seasons, respectively. Furthermore, the applied IPNM strategy had remarkably increased fertilization efficiency and economical feasibility (profit/ total costs) in the order of T_5>T_4>T_3>T_2 compared to T_1.

Key words*: *IPNM, camel manure, black cumin, oil content, fertilization efficiency.

INTRODUCTION

Medicinal plants are a unique type of natural product requiring special consideration due to their potential impact on people's health. Therefore, improving the productivity and quality of various medicinal and aromatic plants like black cumin in Syria was an ultimate goal in the latter decade. Aromatic plants containing volatile and fixed oils belongs to this family (Ranunculaceae) [16]. And they are currently an important source of the income of Syria for local consumption and export. Black cumin is water and fertilizer demanding crop, whereas, the availability of water during growth season is very crucial to hasten flower emergence, seed set, and seed yield [15, 7]. A lack of fertilizer applications may lead to yield reduction, though moderate fertilization is important to get optimum yield. The varieties of the black cumin sometimes select the fertilization efficiency. For example, the Exotic variety produced maximum grain yield (3.43 g. $plant^{-1}$ and 2.30 t. ha^{-1}) at (N_{120}-P_{40}-K_{60} kg. ha^{-1}) level of fertilizers compared to the other black cumin's varieties like BARI $kalozira^{-1}$, Faridpur local and Natore local in Bangladesh [4]. Black cumin gives a significant response to the fertilizer application on the most of the productive parameters (plant height, number of primary branches, number of secondary branches, chlorophyll content,..etc. However, the highest yield obtained was reported from the use of both organic and inorganic sources of nutrients in an integrated manner [2, 35]. However, [39] showed that the interaction of N and P with a rate 60/40 kg. ha^{-1} NP significantly ($p<0.01$) influenced different growth and yield parameters except for 1,000 seed weight of black cumin. Furthermore, [30] have proven that the combined application of 7.5 t. ha^{-1} cattle manure and 100 kg. ha^{-1} NPSB fertilizer can promote the economically feasibility of black cumin in study area (Guder, Ethiopia). The harsh financial circumstances have been forcing Syrian farmers to choose the most available economic fertilizers for their crops. A thing which has led them to add organic manures and inorganic fertilizers but without any scientific concept. When looking at this idea scientifically, the combined use of organic compost along with chemical fertilizer has been widely recognized as an effective IPNM strategy for the sustainability of agricultural production systems in several world regions [5, 17].

The adoption of an appropriate IPNM strategy doesn't only enhance crop production and increases the economic returns to farmers but also maintains soil fertility and supports environmental preservation [28]. [18] have proven that Organic Carbon (OC) / Organic Nitrogen (ON) ratio in camel manure is less than that one in goat manure.

Recently, some researchers have proven that there is a huge benefit caused by the usage of camel dung considering it as promising organic manure compared to the other cattle dung [1].

It does not only contain a huge amount of ON compared to the amount of OC but can be consider it as a source of renewable energy [29]. Furthermore, [11] have recommended camel manure compared to goat, swine, sheep, and poultry manures, whereas, the OC/ON ratio ranged in the following order: cattle (59)> goat (32) = swine (31)> sheep (25)> camel (21)> poultry (14). Thus, camel manure would be more desirable of these natural fertilizers because of its small OC/ON ratio. What would increase soil organic matter that would have a powerful effect on its development, fertility, and available moisture [3].

On the grounds of the previous information, there was urgent need to conduct innovative methods can minimize agricultural inputs like chemical fertilizer. For this purpose, it is essential to use camel dung after treating it as a manure in plant production, especially in low organic matter agricultural soils. In this context, this study aimed to reveal the combined effect of applying camel manure and chemical fertilizers to the soil at different levels on seed yield and some quality parameters of black cumin.

MATERIALS AND METHODS

The experiment was conducted at Scientific Agricultural Research Center, SARC at Salamiyah district (35° 00' N, 37 02' E and 480.8 m altitude), Hama Governorate, Syria. It specializes in breeding, reproducing animals and producing crops.

Salamiyah forms about 37.1% of available arable land of Hama governorate; the average annual precipitation and evaporation from February to Jun were 177.3 mm and 545.5 mm, during successive 2020-2021 growth seasons respectively.

Therefore, irrigation is essential for good quality optimal crop yield. At 0-20 cm soil depth characteristics of the experimental fields were clay loam: high in clay (42%), low in silt (20%) and a pH of 7.31, organic matter (2.31%), total N (0.13%) and organic carbon (1.34%). Available phosphorus content of the soil was 11.2 mg/kg while potassium was 560 mg/kg. Available soil water holding capacity was 98.7 mm for 0-60 cm depth. Furthermore, hand Beerkan infiltration methods have been used and their results in the same type of soil were compared with SPAW software results [33], for accurate timing of irrigation through defining the water that can be added to reach the field capacity in each soil layer until 60 cm depth during growing of the similar plants to black cumin concerning the root depth [6, 26].

The soil is well-drained yellow and very poor in organic matter. Thus, it is very suitable to plant this type of medical plants (*Nigella sativa* L.), [22, 36].

The results of a chemical analysis of camel dung show that it's rich in carbon and nitrogen, among other beneficial nutrients such as Mg, K, and Na, etc. Moreover, when we compared this manure with other animals' manure in SARC, we noticed that it contains the lowest levels of carbon. On the other hand, nitrogen levels were higher than those in goat manure. Thus, the ratio of organic carbon and organic nitrogen (OC/ON) was 17.5 as given in Table 1. These results were in the same line with those obtained by [18].

Table 1. Chemical properties of camel dung.

pH (1:2.5 H_2O)	OC (%)	Total nitrogen (%)	Avail-P (mg/kg)	CEC (meq 100^{-1} g^{-1})	EC (dS m^{-1})	OM (%)
7.2	11.22	0.64	29.3	69.1	0.14	23.3

Source: The results of soil analysis at Homs Research Center's lab, GCSAR, Syria.

Daily climate data were collected from Feb 9 until Jun 30 during 2020-2021 successive growth seasons. Furthermore, the ET_0 had been calculated by using two programs (ET_0 Calculator and New_LocClim 1.10 software).

Experimental treatments, planting, cultural practices, and drip irrigation system design

The study was conducted using complete randomized block design (CRBD) with four replications. Experimental treatments were T_1 (control, without fertilizer), T_2 [N_{120} P_{30} K_{30} (kg. ha^{-1})], T_3 [N_{120} P_{30} K_{60} (kg. ha^{-1})], T_4 [camel manure (5 t. ha^{-1})], and T_5 (½ [T_3 + T_4]), whereas, the soil was very rich in potassium and the rest amounts of chemical balance like N and P were added according to the best results and the recommendations in the same place for the same crop (*Nigella sativa* L.), [21]. The experimental area consisted of a total of 20 plots. The area of each plot was 6 m^2 (2*3 m), and the total area was 231 m^2 (21*11 m). To prevent the interaction between irrigation treatments, 1.5 m space between the experimental plots and 1 m between the complete blocks were left. Besides, two rows in each plot were left out of the assessment due to the edge's effect, and the remaining area formed the harvest plots, (Fig. 1).

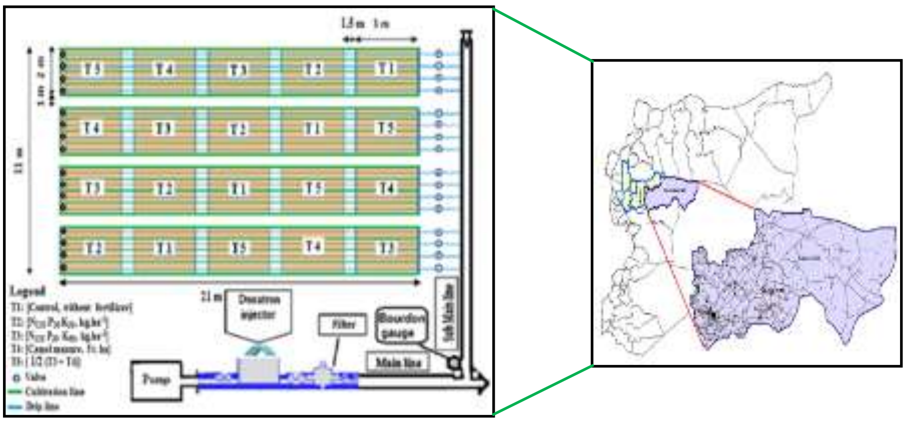

Fig. 1. Layout of site of study area at Salamiyah in Hama governorate deriving from it the scheme clarifying the design of trial (the plots of the different fertilizers treatments).

Source: The results of scientific research which was listed into the research plan of Natural Resources Researches administration, 2017-2021, GCSAR. Syria.

Fig. 1 expresses that there are 4 drip lines for 5 cultivation lines in each plot. Each line was equipped with external drippers (GR, 8 L. h^{-1}). The distance between two lines was 0.5 m. Based on technical advice received from soil lab staff, K (Potassium oxide, K_2O) wasn't needed while the nitrogen fertilizers (N, 120 kg. ha^{-1}), phosphorous (P, 30 kg. ha^{-1}) were needed. The N and P have been added in the form of Urea [CO $(NH_2)_2$, 46% N] and Triple

Super Phosphate TSP [46% P_2O_5], respectively. Half of the total chemical nutrients amount (fertilizers) and all of natural nutrients amount were given during the preparation of soil. The remaining amount was given with irrigation as equal amounts during the period of irrigation by dividing into the number of irrigations. Local variety of black cumin was used as plant material and its seeds were planted with a planting density of 4 kg. ha^{-1}. Farming operations such as reseeding, weeding and irrigation were followed continuously. Moreover, pesticides were used once in the two seasons.

Irrigation water, evapotranspiration, and productivity

The volume of irrigation water requirement for each treatment was calculated according to the squared area:

$$I = ET_c * Sd \quad ....(1)$$

where:

ETc is crop evapotranspiration (mm), Sd is irrigation water ratio (Sd = 50% according to [12].

$$WUE = Y / (I+P_e) \quad ....(2)\ [25]$$

where:

WUE is water use efficiency (kg. ha^{-1}. mm^{-1}), I is irrigation water amount (mm), P_e is effective rainfall (mm) = 0.6 P (precipitation, mm) if P<75%, P_e = 0.8 P if P>75 mm. $month^{-1}$, Y is seed yield obtained from the treatments (kg. ha^{-1}).

The reproductive and vegetative parameters

Data were collected from the inner rows of each plot to avoid the border effect. The following seed yield and yield contributing parameters were observed.

Ten randomly selected plants from each plot were used for counting the following parameters:

The number of branches per plant, plant height, root depth, length of capsule, capsule diameter, number of seeds per capsule, number of capsules per plant, fresh seed yield per plant, dry seed yield per plant, 1,000 seed weight, seed yield, dry matter and harvest index: Harvest index was calculated as follow:

$$HI = [Y / (Ps+Y)] * 100 \quad ....(3)\ [12]$$

where:

HI is harvest index (%), Y is an economical seed yield (kg. ha^{-1}), Ps is straw yield (kg. ha^{-1}).

Black cumin quality analysis

Fertilization efficiency (Fe):

$$Fe\ (\%) = [(Y-Y_0)/Y_0]*100 \quad ....(4)\ [10, 24]$$

where:

Fe is increasing productivity caused by the usage of fertilizer (%), Y is seed or fixed oil yield obtained from the fertilization treatments, Y_0 is seed or fixed oil yield obtained from the untreated treatment (control).

Fixed oil content:

Fixed oil yield per hectare was calculated based on seed oil content and seed yield obtained per hectare and expressed in kilograms per hectare:

$$\text{Fixed oil yield} = \text{Oil content} \times \text{Seed yield} \quad ....(5)$$

where:

the fixed oil yield (kg. ha^{-1}) and oil content (%) which was determined using the method of oil extraction described by [9].

$$Oil = [(W_2-W_1) / S] * 100 \quad ....(6)\ [37]$$

where:

Oil is oil content (%), W_1 is weight of the empty flask (g), W_2 is weight of the flask and the extracted oil (g), S is weight of the sample (g).

Statistical analysis and economical study

We had employed the univariate analysis of variance using a statistical package for social science (SPSS software) to analyze the collected data. The difference between treatment means was compared by Duncan's Multiple Range Test (DMRT) at 0.05 statistical significance level. Furthermore,

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economical study (statistical approach) was performed through deducing the ratio between the profit and the total costs for each treatment.

RESULTS AND DISCUSSIONS

The traced effect of the fertilizer on the soil and the phenological black cumin phases

Soil analysis results before planting showed the soil is clay loam in texture and it was found to be moderately alkaline with a pH of 8.4 as an average in the two first and second depths. The application of different fertilizers through T_2, T_3, T_4, and T_5 has led to a slight decrease in pH level after harvesting from 8.5 (season 1) and 8.7 (season 2) in T_1 and to 6.95 (1) and 7.20 (2) in T_5, which was different from the initial soil sample pH level during two seasons, respectively as given in Table 2.

Consequently, the application of organic manure had led to get a moderate surface soil pH compared to soil receiving only chemical fertilizers. These results were in line with those obtained by [23, 30]. It is therefore advisable to apply organic fertilizer (camel manure, CM) to experimental site to reduce the high pH level. Similar data were reported by [31]. Organic carbon before planting was 1.065% as an average in the two first depths and increased noticeably after adding the fertilizers particularly the mixed fertilizers in treatment T_5. That can be explained through the role the mixed fertilizers had acted in maintaining the organic matter status of the soil. Furthermore, the change in both of the total N and P after harvest revealed that incorporation of CM and chemical fertilizer could improve the fertility status of the soil. Improving in the soil nutrient contents with the application of pelleted cow manure (PCM) might be a result of buildup in the organic carbon [34], solubilization of different organic nitrogenous compounds into a simple and available form, and conversion of unavailable P into available form at the time of decomposition of manure. The application of organic and inorganic fertilizers is widely known to ameliorate soil N and P statuses [27]. What explains why the soil of treatments T_4 and T_5 that received CM only or CM and chemical fertilizers have had higher N and P contents after harvest. Whereas the total soil N content reached 0.28 %, and the traced amount of the available (P) achieved 17.1 mg/kg as a maximum. Similar data were reported by [19]. The status of soil fertility had been reflected by black cumin plants obviously when tracking the number of days to get emergence, flowering and phenological maturity. The results have showed that days to 50% emergence of black cumin seeds was not significantly ($p<0.05$) influenced by the different fertilization treatments (T_2, T_3, T_4, and T_5) compared to the treatment (T_1). That stage had spent about 15-17 days after sowing at all treatments, these results were in agreement with those obtained by [39, 4]. This might be due to the reason that seed used its own nutrients and left unused fertilizer applied to the soil before the root emerged [38]. While there were obvious differences between the mentioned treatments to get the flowering and phenological maturity phases. The usage of organic fertilizer itself in treatment T_4 prolonged the appearance of flowers compared to the other treatments (T_2, T_3 and T_1). That might be because the camel dung enhanced the soil pH and its temperature to be more suitable to support the vegetative unit first and to create the flowers second. That was also confirmed by treatment T_5 compared to the rest of the treatments. Similar data were reported by [8, 32].

Whereas, after 76 days (season 1) and 75 days (season 2) and 73 d (1) and 72 d (2), the flowers appeared in both of treatments T_1 and T_2 in the two seasons, respectively. The same spent about 89 d (1) and 82 d (2) in the treatment T_3 and about 90 d (1) and 94 d (2) in the treatment T_4 and 94 d (1) and 93 d (2) in the treatment T_5. That delay in the fertilization treatments can be explained by excessive nitrogen and phosphorus what resulted in prolonged vegetative growth of the plant. These results were in line with those obtained by [39, 30]. In the same context, the phenological maturity initialed in T_1 and T_2 (after approximately 90 d (1)- 91 d (2), and T_3 103 d (1) - 104 d (2), then T_4 105 d (1) - 106 d

(2) and lastly in T_5 107 d (1) - 110 d (2) in the two seasons, respectively. These results were agreed with those obtained by [20].

Table 2. Selected physio-chemical properties of soil after harvesting the black cumin during the two seasons 2020-2021, which had been analyzed in the labs of Homs, Hama and Damascus researches centers, GCSAR.

Fertilization Treatments	Depth (cm)	pH (1:5)	EC (1:5) (dS m^{-1})	OM (%)	OC (%)	TN (%)	Av.P (mg/kg)
First season-2020							
T_1 (control, without fertilizer)	0-30	8.5	0.41	1.81	1.05	0.16	10.2
	30-60	8.3	0.51	1.47	0.85	0.09	6.02
T_2 [N_{120} P_{30} K_{30} (kg. ha^{-1})]	0-30	8.6	0.57	2.25	1.31	0.17	12.1
	30-60	8.9	0.67	2.34	1.36	0.16	12.5
T_3 [N_{120} P_{30} K_{60} (kg. ha^{-1})]	0-30	8.22	0.71	2.51	1.46	0.2	13.3
	30-60	8.1	0.79	2.39	1.39	0.14	14.2
T_4 [camel manure (5 t. ha^{-1})]	0-30	7.31	0.89	4.2	2.44	0.25	14.9
	30-60	7.7	0.82	5.6	3.26	0.24	14.8
T_5 (½ [T_3 + T_4])	0-30	6.95	0.92	5.2	3.02	0.24	16.1
	30-60	7.10	0.99	5.8	3.37	0.22	16.9
Second season-2021							
T_1 (control, without fertilizer)	0-30	8.7	0.34	1.61	0.94	0.17	14.7
	30-60	8.61	0.44	1.33	0.77	0.07	7.2
T_2 [N_{120} P_{30} K_{30} (kg. ha	0-30	8.80	0.5	2.41	1.40	0.19	12.3
	30-60	8.87	0.61	2.5	1.45	0.15	12.1
T_3 [N_{120} P_{30} K_{60} (kg. ha^{-}	0-30	7.01	0.73	2.42	1.41	0.19	13.4
	30-60	7.53	0.87	2.36	1.37	0.16	14.1
T_4 [camel manure (5 t. ha-1)]	0-30	7.41	0.88	4.55	2.64	0.27	14.8
	30-60	7.35	0.87	5.81	3.37	0.28	14.1
T_5 (½ [T_3 +T_4])	0-30	7.20	0.93	5.7	3.31	0.25	16.7
	30-60	7.31	0.95	6.2	3.61	0.24	17.1

Source: The results of soil analysis at Homs Research Center's lab for the first season while the same parameters were analyzed at Damascus and Homs Research Centers' labs for the second season, GCSAR, Syria.

Impact of the applied different fertilizers on the black cumin vegetative growth parameters.

There were significant differences for the studied plant attributes (plant height, branches number [only primary and secondary], dry matter, roots depth and harvest index) between treatments (T_5 and T_4) and treatments (T_3, T_2 and T_1) as presented in Table 3. While, there were no significant differences in tertiary branches number, roots depth, dry matter and harvest index at the chemical treatments (T_2 and T_3) in the two seasons. The treatment T_4 had the highest harvest index, while the treatment T_1 had the smallest. It may be due to the residual positive effect in soil after adding the fertilizers carefully.

The significant distinction of T_4 and T_5 compared with the rest of the treatments can be explained by the unprecedented effect of the usage of camel dung which improved soil's OC/ON ratio and simultaneously it regulated the relation between water, air, and plant in this type of yellow soil. This organic fertilizer made soil more dynamic and effective than the usage of recommended chemical ones only for this type of plant [31]. Furthermore, nitrogen and phosphorus have an enhancing effect on the vegetative growth of plants by increasing cell division, elongation, and the varietal variability to absorb the nutrients from the soil. That has also been confirmed through the finding of [13] who reported that organic manure and inorganic fertilizer supply most of the essential nutrients at growth stage resulting in increase of growth variables including plant height, roots depth and branches number,..etc. [14] also reported the highest plant height (78 cm) from the integrated application of 7.5 t ha^{-1} camel manure and seeds inoculation by Azotobacter and Azospirillium. They have ensured the importance of the integrated application of organic and inorganic fertilizers particularly the camel dung to obtain good growth parameters as in our study (Table 3). Furthermore, the study has also showed that there were also significant differences between the number and diameter of capsule as well as seeds number per capsule especially after the application of the IPNM in T_4 and T_5 but no tangible differences regarding the 1,000 seeds weight between the two treatments T_2 and T_3 and the treatment T_1 (control). Similar data were reported by [4]. Thus, it can be said that the difference was semi significant between the chemical fertilization treatments and the treatment (control) while was an extraordinarily significant after the application of the organic fertilization.

Table 3. The main effects of IPNM strategy application on growth parameters and yield components of black cumin during the two seasons 2020- 2021 at Salamiyah Research Center, GCSAR, Syria.

Fertilization Treatments	Plant height (cm)	Primary branches number	Secondary branches number	Tertiary branches number	Dry matter per plant (g)	Roots depth (cm)	Harvest Index (HI) (%)	Diameter of capsule (cm)	Empty capsules per plant	Capsules per plant	Seeds per capsule	1,000 seeds weight (g)
First season-2020												
T_1	12.5e	4.9dc	5.8e	1.2b	0.6e	9.4d	39.9c	0.5e	3.1a	4.e	75.2de	2.0d
T_2	25.1d	5.4dc	7.4dc	2.7ba	1.7dc	18.0cb	57.5ba	0.9d	2.2b	10.1d	77.4d	2.5cb
T_3	36.2cb	5.4c	9.1c	3.26a	1.9c	18.4cb	56.0ba	0.9c	2.0c	14.8c	88.3cb	2.7b
T_4	37.4b	6.1ba	12.4b	3.4a	3.0ba	19.2b	58.3a	1.0ba	0.4d	18.7b	88.6b	2.9b
T_5	43.3a	6.3a	14.5a	3.33a	3.4a	23.8a	55.4ba	1.2a	0.2d	23.3a	92.1a	3.2a
CV (%)	7.3	6.63	10.1	13.4	0.67	11.1	7.1	3.11	1.7	6.9	5.7	3.1
$LSD._{0.05}$	**	**	**	**	**	**	**	**	**	**	**	*
Second season-2021												
T_1	14.3e	4.8d	6.1ed	1.2cb	0.77e	10.9e	43.1d	0.6e	4.5a	5.1e	70.2dc	2.3dc
T_2	23.7d	5.6cb	6.4d	1.7b	1.8d	17.4d	46.0cb	0.8d	1.4b	7.0d	71.5c	2.4c
T_3	35.0c	5.4cb	8.9c	1.8b	3.1cb	22.2c	48.8cb	1.0c	1.2c	18.5cb	80.6b	2.4c
T_4	42.2b	5.9b	10.6b	4.4a	3.6ba	23.3b	52.5a	1.1b	0.3d	20.1b	87.98a	2.9b
T_5	47.2a	6.5a	13.8a	4.8a	4.2a	27.2a	49.1b	1.3a	0.5d	28.4a	88.4a	3.6a
CV (%)	9.8	7.1	9.4	11.5	0.88	9.88	8.2	2.88	2.1	8.4	5.3	2.8
$LSD._{0.05}$	**	**	**	**	**	**	**	**	**	**	**	*

Means followed by different letter (s) within a parameter differed significantly by DMRT at $P \leq 5$ %.
Source: The results of the 2nd step of the scientific research which had been listed into the plan of Natural Resources Researches Administration, General Commission for Scientific Agricultural Research (GCSAR), Syria.

Economic feasibility of IPNM strategy on black cumin.

This study assured the importance of fertilization management to increase black cumin yield components. That was obvious in T_4 and T_5, whereas seeds yield has increased to reach (1,234.6 kg. ha^{-1} - 1,631.5 kg. ha^{-1}) and (1,879.2 kg. ha^{-1} - 1,904.1 kg. ha^{-1}) in T_4 and T_5 in the two seasons, respectively. What led also to improve IWUE to reach 5.2 kg. ha^{-1}. mm^{-1} and 6.2 kg. ha^{-1}. mm^{-1} at the two treatments respectively. Moreover, the applied management enhanced oil content to achieve the highest values (31.2% - 33.3%) and (31.7% - 34.2%) in T_4 and T_5 in the two seasons, (Table 4). That could be explained not only because of high nitrogen concentration but also due to better physiological equilibrium of NPK in the two added amounts according to N_{120}-P_{30}-K_{30} and N_{120}-P_{30}-K_{60} first as well as the integrated management of the camel dung with the chemical fertilizer existing in the treatment T_3, second. Furthermore, it could explain the difference between the treatments (T_3 and T_2) effects on the yield and yield components through the best physiological equilibrium of NPK which has been expressed by the treatment T_3 more than the treatment T_2 despite they have the same quantity of nitrogen. Moreover, we cannot ignore the regulated water supplies through drip irrigation system, which can provide the required water at the suitable time. The thing might make nutrients uptake easier. Although it had been given about 50 % of the potential evapotranspiration (ET_P), irrigation water amounts were 239.34 mm and 222.2 mm through two seasons, respectively. A thing that expresses the huge gap between the precipitation and evaporation in the study area. The results of study also indicated that IPNM treatments significantly increased the fertilization efficiency (Fe) in the order of T_5> T_4> T_3>T_2 compared to the treatment T_1 (control, without fertilizer).

The T_5 treatment has achieved the highest fertilization efficiency (151% and 399%) regarding the black cumin seed yield and the fixed oil yield, respectively. The lowest values of Fe (31% and 64%) were at the treatment (T_2) according to both of yields of seed and fixed oil respectively (Fig. 2). These results are also in agreement with those of [32] who concluded that the IPNM strategy based on organic manures positively affected the yields of seed and oil too.

Results of economic feasibility and statistical analyses have indicated that the fertilization management on black cumin was successful and beneficial in the dry environments. However, the best profit could be achieved only after the application of IPNM strategy with organic manures such as the camel dung. The (profit/total costs) ratio values were at (T_5 and T_4) higher than the rest of the fertilization treatments (T_2, T_3 and T_1).

The treatments with organic manures whether the treatment T_4 or the treatment T_5 excelled all the treatments achieving 260.3%-267.5% and 345.8%-339.02% in both seasons respectively as given in Table 4. While this ratio didn't differ much between the chemical fertilization treatments and the control.

Table 4. The economical study of black cumin crop clarifying oil content, oil yield and IWUE during 2020-2021 growth seasons (DMRT at P ≤ 5 %).

Fertilization Treatments	Seed yield (kg. ha^{-1})	Oil content (%)	Oil yield (kg. ha^{-1})	IWUE (kg. ha^{-1}. mm^{-1})	Seed product value ($. ha^{-1})	Oil product value ($. ha-1)	Fertilizer costs ($. ha^{-1})	Harvest costs ($. ha^{-1})	Total costs ($. ha^{-1})	Profit to total cost (Seed yield) (%)	Oil extraction costs ($. ha^{-1})	Profit to total cost (Oil yield) (%)
First season-2020												
T_1	700.5e	18.2e	127.5e	2.2d	1883.5e	12967e	0	123.0	708.0	166.03	3267.8	226.2
T_2	1082.8d	25.7dc	278.3d	3.4cb	2767d	24515d	285.8	132.0	1134.8	187.5	6178.3	235.2
T_3	1128.6c	27.8c	313.75c	3.6b	3036c	27638c	310.6	132.4	1310	169.6	6965.3	233.9
T_4	1234.6b	31.2ba	385.2b	3.9b	3321b	33932b	65	155.9	1032.9	260.25	8551.4	254.0
T_5	1631.5a	33.3a	543.3a	5.2a	4389a	47859a	187.7	189.7	1330.4	267.5	12061.3	257.4
CV (%)	402	3.7	47	1.8	6090	7777	-	-	-	-	-	-
Second season-2021												
T_1	634.3 e	16.3ed	103.4e	2.1cd	1706e	9109e	0	110.0	709.5	140.45	2357.5	197.0
T_2	808.0 d	17.9d	144.6d	2.6c	2174d	12738d	291	124.0	862.3	152.12	3296.8	206.3
T_3	1204.8c	20.2c	243.4c	3.9b	3241c	21441c	311.3	158.1	1047.7	209.34	5549.5	225.0
T_4	1879.2b	31.7ba	595.7b	6.1a	5055ba	52475ba	70	173.7	1134	345.77	13582	255.8
T_5	1904.1a	34.2a	651.2a	6.2a	5122a	57364a	188.8	190.8	1166.7	339.02	14847	258.2
CV (%)	377	4.3	66	2.3	5498	7659	-	-	-	-	-	-
$LSD_{0.05}$	**	**	**	**	**	**	-	-	-	-	-	-

Source: The results of the 2nd step of the scientific research which had been listed into the plan of Natural Resources Researches Administration, General Commission for Scientific Agricultural Research (GCSAR), Syria.

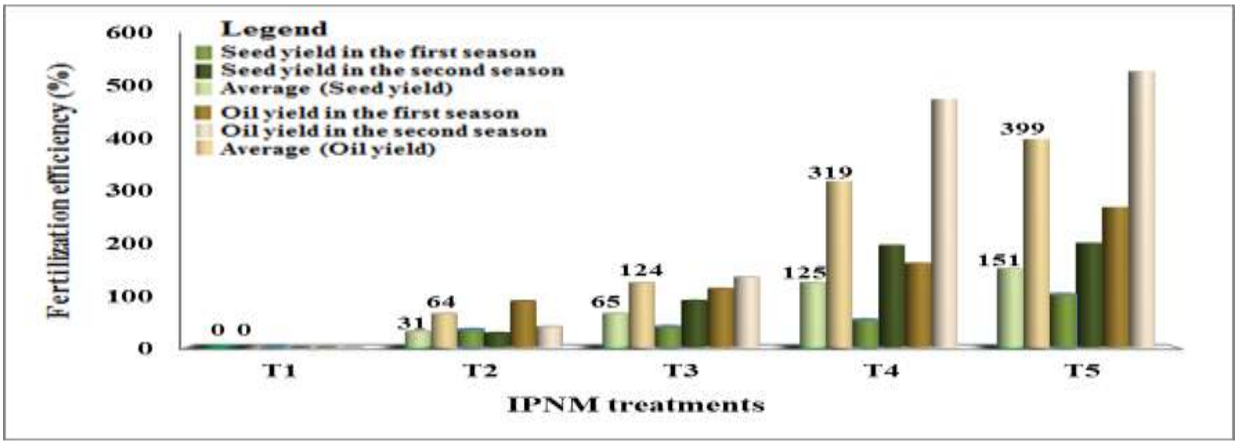

Fig. 2. The fertilization efficiency (Fe) of black cumin during the two seasons and as an average which was calculated by the increase in seed yield and the increase in oil yield.

Source: The results of the 2nd step of the scientific research which had been listed into the plan of Natural Resources Researches Administration, General Commission for Scientific Agricultural Research (GCSAR), Syria.

By considering the costs of oil extraction, the ratio (profit/total costs) would change but still the treatment T_5 has the first rank between the other treatments. Thus, we found that it could consider black cumin an economical crop in the dry environment first, as well as fertilizing it with an organic manure such as camel dung would make it the one of the richest crops locally, second.

CONCLUSIONS

This research interprets an important part of the integrated plant nutrients management strategy (IPNM) through studying the effect of several types of recommended chemical and organic fertilizers on Nigella sativa crop quantitatively and qualitatively.

Generally, the usage of fertilizer made black cumin productivity better. However, organic fertilizer (camel dung) added a bulk footprint on soil and plant. The camel dung has enhanced the soil fertility through moderating soil pH, increasing plant nutrients, and raising bio-activation energy through increasing the soil temperature and the ability of its enzymes. What led black cumin to give vegetative growth better than the one who grows under only chemical fertilizers effect or that untreated one with fertilizer. This was also reflected by increasing the black cumin seed yield and the rest of other yield components later.

We cannot deny the role of balanced chemical fertilizers in improving the black cumin production and yield, but the economic feasibility and environmental security issue remain the final arbiter. The results of this experiment have showed that the black cumin respond to organic fertilizer much, whereas the treatments (T_5 and T_4) have achieved the highest economic feasibility (profit/total costs) compared to the rest of the other treatments regarding the seed yield first and the oil yield, second.

To confirm our research results more, we suggest following and testing the application of other organic fertilizers whether caused by animal source like cows, sheep, goat, poultry or any source else on this crop. That will certainly save money and keep the environment clean too.

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