Online ISSN: 2588-3526

Journal of Wildlife and Biodiversity

Volume 7 (Special Issue): 300-311 (2023) (http://www.wildlife-biodiversity.com/)

Research Article

Impact of different levels of nitrogen and spraying with Ethephon on physiological parameters and yield of rape (*Brassica napus* L.)

Sundus Kamil Jabbar Alhilfi*, Lamiaa Mahmood Salman Alfreeh

Department of Field Crop, College of Agriculture, University of Basrah, Basrah, Iraq

*Email: sundus.jabar@uobasrah.edu.iq

Received: 01 September 2023 / Revised: 30 October 2023 / Accepted: 21 November 2023/ Published online: 28 November 2023.

How to cite: Jabbar Alhilfi, S.K., Salman Alfreeh, L.M.(2023). Impact of different levels of nitrogen and spraying with Ethephon on physiological parameters and yield of rape (*Brassica napus* L.), Journal of Wildlife and Biodiversity, 7 (Special Issue), 300-311. **DOI**: https://doi.org/10.5281/zenodo.10212427

Abstract

A field experiment was performed at the Karma Ali site, affiliated with the Agricultural Research Station of the College of Agriculture, University of Basra, located in Basra Governorate. An experiment was conducted in the winter of 2021-2022 to examine the impact of four nitrogen fertilizer concentrations (N0, N1, N2, and N3) and three concentrations of Ethephon (750 and 1500 microliters L-1) on the growth characteristics and yield of rape (Brassica napus L. Var. Pactol). The nitrogen levels tested were as follows: 0, 100, 200, and 300 kg N ha--1. It was designed using randomized complete blocks (RCBD) in three replications using the factorial experimental method. For both seasons, the N3 fertilizer level substantially improved the following parameters: net photosynthesis, crop growth rate, leaf area, and leaf area index. In the second season, as for seed yield, the N3 level exceeded (3.24 tons ha-1), and it did not. In the first season, the N3 level (2.71 tons ha-1) differs significantly from the N2 level (2.60 tons ha-1). The findings also indicated that foliar spray treatments containing varying concentrations of Ethephon had a significant impact on the majority of the traits examined, as evidenced by the higher average E2 concentration for the majority of the traits. Yield and development over two seasons. The interaction between nitrogen and Ethephon was high in most traits except leaf area, leaf area index, and net photosynthesis for the first season. The combination N2×E2 recorded the highest average for seed yield (2.91 tons ha-1) in the first season.

Keywords: rape, nitrogen levels, foliar spraying, Ethephon

Introduction

As one of the important oil crops, Rape crop, *Brassica napus* L. is one of the world's essential fundamental sources of vegetable oils. Global productivity was estimated at 71.15 million tons. Following legumes and oil palm, it is produced in the third position. The cultivated area globally is about 37.77 million hectares, and the total is 1.89 tons ha^{-1} (Steensland, 2022). In comparison to other oil products, rape oil has a low proportion of saturated fatty acids (6%) and a high proportion of unsaturated fatty acids (oleic acid comprises approximately 80% and linoleic acid comprises around 20%), rendering it a high-quality consumable oil (Bocianowski et al., 2012). Its seeds are also considered a source of natural phenols and flavonoids, among the most important antioxidants, and many biologically active compounds, including polyphenols, flavanol derivatives, and vitamin E. (Ilyas & Shahzad, 2018). One of the most critical determinants in attaining high productivity is the effective management of plant nutrients. Nitrogen is an essential element for plant development due to its relatively high quantity requirement compared to other elements. A lack of nitrogen in the soil leads to a decrease in yield per unit area and a decrease in the quality of seeds resulting from the crop (Al-Naimi et al., 2005).

Additionally, Nitrogen is associated with the synthesis of amino acids, proteins, chlorophyll, and protoplasts, and this has a direct impact on plant growth and production characteristics through optimal use of photosynthesis (M. Kumar et al., 2017; Singh et al., 2014). When various levels of nitrogen fertilization were applied to rape crops in this field (AL-Janabi & Ali, 2014; Al-Jumeily, 2007; Ali et al., 2018), increased growth was observed, which contributed to an increase in yield components and yield per unit area. Recently, studies have been conducted in regions of the world that show that growth regulators, both encouraging and inhibitory, significantly influence plant physiological processes by managing the balance between respiration and photosynthesis. Growth retardants typically function by modifying or stimulating a specific physiological process when applied at an optimal concentration and during the suitable growth stage of the plant. Ethen, for instance, plays a critical role in regulating the source-sink relationship by distributing metabolic products among various plant parts and enhancing the plant's capacity to utilize these products for yield and component production (Devi et al., 2011). (Mahmoud, 2016) noted that the highest seed yield of 2175 kg ha-1 was determined by spraying ethephon at a concentration of 100 mg L-1 due to its significant influence on several yield components, including the number of pods per plant and the number of seeds per pod.

Here, we aim to calculate the impacts of nitrogen application and varying concentrations of foliar sprays containing growth regulators (e.g., ethephon) on the developying and yield of rape crops in the Basra Governorate of Iraq.

Materials and methods

A field experiment was performed at the College of Agriculture – University of Basra / Karma Ali site, situated approximately 10 kilometers from the governorate capital of Basra, during the winter seasons 2021-2022 and 2022-2023. It is performed in soil with a clay loam, PH (7.28) and EC (7.30). Its content of N (1.002 mg kg^{-1}), P (5.80 mg kg^{-1}), and K (1.17 mg kg^{-1}), to determine the effect of levels of nitrogen fertilizer (0, 100, 200, and 300 kg N ha $^{-1}$) is symbolized by N0, N1, N2, and N3, and spraying with ethephon (0, 750 and 1500 microliters L^{-1}) and symbols E0, E1 and E2 in some physiological parameter and yield characteristics of rape crop. Using a randomized complete block design (R.C.B.D.), the treatments were allocated under the factorial experiments. The soil was prepared for cultivation with three replications by: plowing, smoothing, and leveling it. Subsequently, the land was partitioned into experimental units, each measuring 1.5 x 2.5 meters and comprising five lines. The length of the line was 2.5 m. It was planted with a 30 cm spacing between each line's dimensions. 20 centimetres separated the plants; planting happened on 10/23/2021. Three applications of nitrogen fertilizer were timed accordingly: one week after the emergence of the plants, during the elongation stage, and at the onset of the blossoming stage. Under the guidance provided by the Iraqi Ministry of Agriculture (Ministry of Agriculture, 2000), a rate of 100 kg ha-1 was fertilized with 45% triple calcium super phosphate P2O5 fertilizer. It is important to use the authorized variety of Brassica napus L.Var. pactol. Ethephon was sprayed at the end of the stage of formation of true leaves and the beginning of the stage of formation of lateral buds. Spraying was done in the morning using a 16-litre backpack sprayer, and a diffuser (Al-Zahi) was used to reduce surface tension and increase absorption efficiency. The approved variety (Brassica napus L.Var. Pactol) was grown. Ethephon was sprayed at the end of the stage of formation of true leaves and the beginning of the stage of formation of lateral buds. Spraying was done in the morning using a 16-litre backpack sprayer, and a diffuser was used to reduce surface tension and increase absorption efficiency.

Traits studied

Physiological parameter

A random area of 60 x 60 cm2 was selected from each experimental unit during the period between elongation and flowering, corresponding to the rapid growth period defined by the growth analysis curve (Sigmoid) and (Hunt, 1982). From this area, physiological characteristics were calculated.

leaves area LA (cm2)

The disc method evaluated it at the flowering stage (Morrison et al., 1992), using a hollow metal cylinder of known inner diameter to cut a fixed number of small discs for a set of leaves.
The paper disks and leaf remain were dried separately at 80°C for 48 hours, and then the paper disks and leaf remain were weighed using the area-to-weight ratio (ROY et al., 1981).

$$\text{LA} = (\text{Disk space x (weight of disks } + \text{ weight of remaining cards))} / \text{ Weight of tablets}$$

Excluding the leaf petiole, the yellowed leaves are more than 50% of their blade.

Leaf Area Index LAI

It was calculated by dividing the total leaf area of the plants by the ground area inhabited by the plant (60×60 cm2) (Hunt, 1982).

Crop growth rate C.G.R. (g m^{-2} day^{-1})

It was obtained from the following law (Hunt, 1982):

C.G.R. = (1/A)× (W2-W1)/(T2-T1)

A = land area

T1=number of days to the elongation phase

W1 = dry weight in the elongation stage

T2=number of days to flowering

W2 = dry weight at flowering stage

5- Net Assimilation Rate N.A.R. (gm m^{-1} day^{-1})

It was calculated from the following law (Hunt, 1982):

N.A. R= (W2-W1/T2-T1) × (log LA2-Log LA1/LA2-LA1)

LA1 = leaf area (elongation)

T1=number of days to elongation

W1 = dry weight in the elongation stage

LA2 = leaf area (flowering)

T2=number of days to flowering

W2 = dry weight at flowering stage

Yield trite

Seed yield (ton ha^{-1}): The value was calculated by converting the weight of the seeds per harvested area of each experimental unit to tonnes per hectare.

The data were subjected to statistical analysis utilizing the GenStat software. To compare the arithmetic means of the coefficients under investigation, the least significant difference test was applied (Abdulrazak et al., 2018).

Results

Leaves erea

Table 1. The effect of nitrogen and ethephon on leaf area(cm^2) for the two seasons.

Seasons	Ethephon conc.	nitrogen				Average ethephon
		0N	N1	N2	N3	
The first season	E0	3955.49	4651.64	5085.04	5673.55	4841.43
	E1	4108.56	4746.10	5018.36	5659.50	4883.13
	E2	4311.26	4987.80	5583.18	5620.84	5125.77
	Average nitrogen	4125.10	4795.18	5228.86	5651.30	
	L S D $(p\leq 0.05)$	nitrogen350.900 =		Interaction = ns		ethephon165.30 =
the second season	Ethephon conc.	nitrogen				Average ethephon
		0N	N1	N2	N3	
	E0	3665.39	4293.79	4488.29	5564.10	4502.89
	E1	3865.75	4595.63	4937.99	5778.66	4794.51
	E2	4022.96	4882.21	5397.89	5717.28	5005.08
	Average nitrogen	3851.37	4590.54	4941.39	5686.68	
	L S D $(p\leq 0.05)$	nitrogen = 143.5		Interaction = 237.0		ethephon = 135.3

Table 1 indicates that the N3 level was better, recording the highest averages of 5651.29 and 5686.68 cm2 for the two consecutive seasons. In contrast, for the two consecutive seasons, the comparison treatment (N0) yielded the lowest average values for this particular attribute, measuring 4125.10 and 3851.37 cm2, respectively. This can be attributed to the function of nitrogen, which is to enhance meristematic activity and consequently augment leaf surface area by stimulating cell division. Furthermore, nitrogen contributes to chlorophyll accumulation by penetrating the leaf structure, thereby augmenting the photosynthesis efficiency and facilitating the vegetative growth of the plant. This is consistent with what (Aminpanah, 2013; Hassan, 2023; R. Kumar et al., 2002). The effect of ethephon was significant on this trait, as the maximum average concentration of E2 was observed for this characteristic, amounting to 5125.76 and

5005.08 cm2 for the two consecutive seasons, and the non-spraying treatment recorded the lowest average, amounting to 4841.43 and 4502.89 cm2 for the two seasons respectively. This could potentially be explained by the effect of ethephon spraying on cell division prior to flowering, resulting in increased leaf area and leaf expansion that reaches its peak before gradually diminishing in subsequent phases (Jirali, 2001). This is similar to what found by (Mir, 2002; Mir et al., 2010; Saxsena et al., 2007). The initial season did not observe a significant interaction between ethephon and nitrogen. However, during the subsequent season, the combination E1 X N3 yielded the highest average trait value of 5778.66 cm2. This value was not substantially different from the average of 5717.28 obtained with the combination E2 N3. Finally, the combination E0 X N0 recorded the lowest average for the characteristic, amounting to 3665.39 cm2.

L A I

Table 2. The effect of nitrogen and ethephon on leaf area index for the two seasons.

Seasons	Ethephon conc.	nitrogen				Average ethephon
		0N	N1	N2	N3	
The first season	E0	6.59	7.75	8.48	9.46	8.07
	E1	6.85	7.91	8.63	9.43	8.14
	E2	7.19	8.31	9.31	9.37	8.54
	Average nitrogen	6.88	7.99	8.71	9.42	
	L S D ($p \leq 0.05$)	nitrogen = 0.36		Interaction = ns		Ethephon = 0.27
the second season	Ethephon conc.	nitrogen				Average ethephon
		0N	N1	N2	N3	
	E0	6.11	7.16	7.48	9.27	7.50
	E1	6.44	7.66	8.23	9.63	7.99
	E2	6.70	8.14	9.00	9.53	8.34
	Average nitrogen	6.42	7.65	8.24	9.48	
	L S D ($p \leq 0.05$)	Nitrogen= 0.23		Interaction 0.39=		Ethephon 0.22=

Table 2 demonstrates that the N3 level was superior for the two seasons and recorded the highest leaf area index of 9.42 and 9.48, respectively. By contrast, the N0 treatment revealed the lowest average for the two seasons, amounting to 6.88 and 6.42, respectively. The observed outcome can lead to the increased leaf area that persisted during the two seasons in which this nitrogen concentration was added (Table 1). Table 1 lists the significant impact of adding ethephon. The average concentration of E2 was the highest for the leaf area indicator, which is characteristic of both seasons, reaching 8.54 and 8.3. However, the E0 concentration gave the lowest average for the two seasons, reaching 8.07 and 7.50, respectively. This superiority may lead to the moral superiority of ethephon spraying in the leaf area index characteristic. (Table 1). The initial season showed no significant interaction between ethephon and nitrogen. On the other hand, in the second season, the interaction between ethephon concentrations and nitrogen levels had a significant impact. Additionally, the highest average is determined for the combination N3XE1 for the leaf area index character, reaching 9.63, and differs slightly from the combination E0XN3 and combination E2XN3, with averages reaching 9.27. 9.53 sequentially. This can be explained on the basis of what was discussed in the influence of factors individually.

CGR

Table 3. The impact of nitrogen and ethephon on Crop growth rate(g m^{-2} day^{-1})for the two seasons.

Seasons	Ethephon conc.	nitrogen				Average ethephon
		0N	N1	N2	N3	
The first season	E0	7.73	9.36	10.49	13.59	10.29
	E1	8.09	9.92	10.93	14.77	10.93
	E2	8.40	9.98	11.96	16.46	11.70
	Average nitrogen	8.07	9.76	11.13	14.94	
	L S D $(p\leq 0.05)$	nitrogen0.246 =		Interaction = 0.455		Ethephon0.267 =
the second season	Ethephon conc.	nitrogen				Average ethephon
		0N	N1	N2	N3	
	E0	9.926	12.134	13.712	16.887	13.165
	E1	10.018	13.037	14.300	17.219	13.643
	E2	10.538	13.943	15.310	17.510	14.325
	Average nitrogen	10.160	13.038	14.441	17.205	
	L S D $(p\leq 0.05)$	nitrogen =0.3784		Interaction = 0.3784		Ethephon = 0.3625

It is a significant indicator of production efficiency, and the growth rate of a crop is the primary determinant of crop productivity. As shown in Table 2, the addition of nitrogen substantially impacted the crop growth rate, as the N3 level recorded the highest average for two consecutive seasons at 14.94 and 17.205 g m-2 day-1, respectively. The non-addition treatment achieved the lowest average values of 8.07 g m-2 day-1 and 10.160 g m-2 day-1, respectively, throughout the two seaso The increase in growth rate resulted in elevated concentrations of nitrogen and chlorophyll, thereby stimulating a surge in photosynthesis and consequently increasing the leaf area. It led to the availability of more assimilated products, which was found in (Table 1), showing an increase in leaf area with increasing nitrogen addition. This is similar to what (Cheema et al., 2010) found, as they found an increase in the crop growth rate with increasing nitrogen addition. According to the findings, the significant effect of ethephon on the crop growth rate is clear, as the E2 concentration showed the highest average for the crop growth rate for the two seasons, reaching 11.70 and 14.325 g m-2 day-1, respectively, while the E0 concentration gave the lowest average, amounting to 10.29 and 13.165 g m-2. 2 days - 1 for the two consecutive seasons. The rise in the crop's growth rate, accompanied by an increase in ethephon, can be ascribed to its function of impeding auxin transfer to the regions where the apices are located, thereby increasing the number of secondary branches (Morgan & Gausman, 1966). This, in turn, results in a greater quantity of leaves and, consequently, a larger leaf area. It is worth noting that the growth rate depends on the leaf area index (Pahwa & Ghai, 2015; Prabhu, 2000), and that adding growth obstacles reduces the capacity of the stem as a source of nutrients due to reducing its growth, and this allows the provision of photosynthesis products to a greater extent. To contribute to stimulating the growth and development of lateral shoots, thus increasing dry matter and weight and thus increasing the crop growth rate (Atiya, 1996). The interaction between ethephon and nitrogen had a significant impact, and the combination E2XN3 recorded the highest average crop growth rate, reaching 16.46 and 17.510 g m-2 day. -1. For the two seasons, the combination E0XN3 showed the lowest average for this trait, amounting to 7.73 and 9.926 g m-2 day-1.

N.E.R.

Table 4. The impact of nitrogen and ethephon on Net stimulation rate (g/m^2.day) for the two seasons.

Seasons	Ethephon conc.	nitrogen				Average ethephon
		0N	N1	N2	N3	
The first seaso	E0	1.07	1.19	1.23	1.51	1.25
	E1	1.03	1.34	1.25	1.70	1.33
	E2	1.14	1.27	1.47	1.92	1.45
	Average nitrogen	1.08	1.27	1.32	1.71	
	L S D ($p \leq 0.05$)	nitrogen = 0.116		Interaction = ns		Ethephon = 0.090
the second season	Ethephon conc.	nitrogen				Average ethephon
		0N	N1	N2	N3	
	E0	1.55	1.66	1.72	1.76	1.67
	E1	1.54	1.74	1.84	1.81	1.73
	E2	1.75	1.83	1.76	1.93	1.82

	Average nitrogen	1.61	1.74	1.77	1.84	
	L S D $_{(p\leq 0.05)}$	nitrogen = 0.041		Interaction 0.068=	Ethephon 0.039=	

The substantial impact of nitrogen fertilizer addition was demonstrated in Table 4. The N3 treatment yielded the highest mean value for this characteristic, measuring 1.71 and 1.84 g m-2 day-1 for the two growing seasons, respectively. In contrast, the N0 treatment yielded the lowest yearly averages for both seasons, 1.25 and 1.67, respectively. The potential explanation for this phenomenon could be attributed to the substantial impact of nitrogen on growth parameters, namely leaf area index and leaf area (Table 4), which resulted in an increase in plant cover and enhanced solar radiation absorption, thereby augmenting the efficiency of photosynthesis. The table additionally indicates that the application of ethephon spray has a notable impact on the net photosynthesis characteristic. Specifically, for both seasons, the E2 concentration yielded the highest average net photosynthesis characteristic of 1.45 and 1.82 g m-2 day-1, whereas the E0 concentration produced the lowest average at 1.25 and 1.67 g m-2. Day 1 for the two consecutive seasons. One possible explanation for this phenomenon is the function of ethephon, which inhibits the breakdown of chlorophyll. This, in turn, enables the primary plant tissues to absorb light more efficiently, thereby enhancing the efficacy of photosynthesis. A significant increase in chlorophyll in rape leaves was observed when using ethephon (Grewal et al., 1993). In contrast to the first season, where the interaction between nitrogen and ethephon had no significant impact, that season witnessed a substantial effect from the interaction combination of E2XN3 and E1N0 produced the lowest average crop growth rate of 1.54 gm m-2 day-1, whereas the E2XN3 combination produced the highest average crop growth rate of 1.93 gm m-2 day-1.

Yield Kg ha^{-1}

Table 5. The effect of ethephon and nitrogen on Yield (Kg ha^{-1}) for the two seasons.

Seasons	Ethephon conc.	nitrogen				Average ethephon
		0N	N1	N2	N3	
The first season	E0	1.44	1.80	2.28	2.44	1.99
	E1	1.83	1.99	2.62	2.85	2.32
	E2	2.02	2.58	2.91	2.85	2.59
	Average nitrogen	1.76	2.12	2.60	2.71	
	L S D $_{(p\leq 0.05)}$	nitrogen = 0.130		Interaction = 0.266		Ethephon = 0.227
the second	Ethephon conc.	nitrogen				Average ethephon
		0N	N1	N2	N3	

	E0	1.59	1.94	2.16	2.63	2.08
	E1	1.67	2.50	2.82	3.53	2.63
	E2	1.90	2.84	3.29	3.58	2.90
	Average nitrogen	1.72	2.43	2.76	3.24	
	L S D $(p\leq 0.05)$	nitrogen =0.194		Interaction = 0.339	=Ethephon 0.232	

The findings presented in Table 4 illustrate the substantial impact of nitrogen levels. Specifically, the N3 treatment produced the greatest yield of 2.71 kg ha-1 for the initial season. In contrast, the N2 treatment yield of 2.60 tonnes ha-1 did not differ substantially. However, it differed significantly from all treatments, averaging 3.24 in the second season. On the other hand, the treatment recorded Comparison: (N0) has a lower average of 1.76 and 1.90 tons ha-1 for the two consecutive seasons. The observed results, regarded as critical indicators for determining crop productivity (growth rate and net photosynthesis), can be attributable to the N3 level's superiority in both seasons. This agrees with the findings of (Ali et al., 2018; Khorshidi et al., 2019; Razzaq et al., 2022), whose research confirmed that nitrogen supplementation resulted in a higher seed yield.

During the two seasons, the E2 level produced the greatest average seed yield of 2.59 and 2.90 tonnes ha-1, respectively, whereas the E0 level produced the lowest average of 1.89 and 2.08 tonnes ha-1. This is consistent with the findings reported by (Mahmoud, 2016). The highest average for this trait was documented in the first season for the combination N2 × E2, which totaled 2.91 tonnes ha-1. The combination of N2 and E3 yielded the highest average yield of 3.58 tonnes ha-1 in the second season. This average yield was not significantly different from that of the N3 and E1 interventions, averaging 3.53 tonnes ha-1. Conversely, for the two seasons, the combination of N0 and E0 produced the lowest average yields of 1.44 and 1.59 tonnes ha-1, respectively.

References

Abdulrazak, A. A., Shakor, Z. M., & Rohani, S. (2018). Optimizing Biebrich Scarlet removal from water by magnetic zeolite 13X using response surface method. *Journal of Environmental Chemical Engineering*, *6*(5), 6175–6183. https://doi.org/10.1016/j.jece.2018.09.043

AL-Janabi, M. A. A., & Ali, H. R. (2014). Effect of Different Levels of Nitrogen Fertilizer and Row Spacing on some Yield Traits and It's Components of Rape Seed (Brassica napus L.). *J. Trikit Agr. Sci*, *14*(2), 139–149.

Al-Jumeily, A. M. H. (2007). Effect of Planting Dates, Nitrogene Levels and Spacing Between Plants on seed yield and yield Components of oil seed Rape (Brassica napus L.). *ANBAR JOURNAL OF AGRICULTURAL SCIENCES*, *5*(1).

Al-Naimi, F. A., Garrett, K. A., & Bockus, W. W. (2005). Competition, facilitation, and niche differentiation in two foliar pathogens. *Oecologia*, *143*, 449–457.

Ali, A., Munsif, F., & Alam, J. E. (2018). Impact of nitrogen on phonology and yield of rapeseed under varies plant population. *International Journal of Environmental Sciences & Natural Resources*, *9*(4), 106–109.

Aminpanah, H. (2013). Effect of nitrogen rate on seed yield, protein and oil content of two canola (Brassica napus L.) cultivars. *Acta Agriculturae Slovenica*, *101*(2), 183–190.

Atiya, H. J. (1996). The effect of the growth retardant Caltar and Cycocel on the growth and yield of sunflower. *Iraqi Agricultural Sciences Journal*, *1*, 99–106.

Bocianowski, J., Mikołajczyk, K., & Bartkowiak-Broda, I. (2012). Determination of fatty acid composition in seed oil of rapeseed (Brassica napus L.) by mutated alleles of the FAD3 desaturase genes. *Journal of Applied Genetics*, *53*, 27–30.

Cheema, M. A., Saleem, M. F., Muhammad, N., Wahid, M. A., & Baber, B. H. (2010). Impact of rate and timing of nitrogen application on yield and quality of canola (Brassica napus L.). *Pakistan Journal of Botany*, *42*(3), 1723–1731.

Devi, K. N., Vyas, A. K., Singh, M. S., & Singh, N. G. (2011). Effect of bioregulators on growth, yield and chemical constituents of soybean (Glycine max). *Journal of Agricultural Science*, *3*(4), 151.

Grewal, H. S., Kolar, J. S., Cheema, S. S., & Singh, G. P. (1993). Studies on the use of growth regulators in relation to nitrogen for enhancing sink capacity and yield of gobhi sarson (Brassica napus). *Indian Journal of Plant Physiology*.

Hassan, Z. A. A. R. (2023). The role of planting dates and nitrogen fertilization in the growth, yield and quality of the Indian mustard crop, Brassica juncea L., grown in two locations in Basra Governorate. In *Sustainability* (Vol. 15, Issue 7). College of Agriculture, B.

Hunt, R. (1982). *Plant growth curves. The functional approach to plant growth analysis.* Edward Arnold Ltd.

Ilyas, N., & Shahzad, A. (2018). Physicochemical and Antimicrobial properties of canola (Brassica napus L.) seed oil. *Pak. J. Pharm. Sci*, *31*(5), 2005–2009.

Jirali, D. I. (2001). *Physiological investigation in turmeric (Curcuma longa L.)*. Ph. D. Thesis, University of Agricultural Sciences, Dharwad.

Khorshidi, M. S., Nikoo, M. R., Sadegh, M., & Nematollahi, B. (2019). A multi-objective risk-based game theoretic approach to reservoir operation policy in potential future drought condition. *Water Resources Management*, *33*, 1999–2014.

Kumar, M., Singh, P. K., Yadav, K. G., Chaurasiya, A., & Yadav, A. (2017). Effect of nitrogen and sulphur nutrition on growth and yield of Indian mustard (Brassica juncea L.) in western UP. *Journal of Pharmacognosy and Phytochemistry*, *6*(6S), 445–448.

Kumar, R., Singh, D., & Singh, H. (2002). Effect of nitrogen and sowing dates on productivity of Brassica species. *Indian Journal of Agronomy*, *47*(3), 411–417.

Mahmoud, R. S. (2016). Effect of Spraying Gibberellin and Ethephon on the Yield and it Component of rapseed. *Euphrates Journal of Agriculture Science*, *8*(3).

Ministry of Agriculture. (2000). Guidance leaflet on the cultivation of rape, General Authority for Agricultural Cooperation and Extension. In *International Journal of Agricultural Extension*.

Mir, M. R. (2002). *Physiological significance of ethrel, 2_chioroethyl phosphonic acid and nitrogen in relation to growth and metabolism of mustard under irrigated and non_irrigated conditions*.

Mir, M. R., Khan, N. A., Bhat, M. A., Lone, N. A., Rather, G. H., Razivi, S. M., Bhat, K. A., Singh, S., &

Payne, W. A. (2010). Effect of ethrel spray and nitrogen on growth, photosynthesis, carboxylation efficiency and water use efficiency of mustard (Brassica juncea L.). *Intl. J. Curr. Res*, *6*(45.52).

Morgan, P. W., & Gausman, H. W. (1966). Effects of ethylene on auxin transport. *Plant Physiology*, *41*(1), 45–52.

Morrison, M. J., Stewart, D. W., & McVetty, P. B. E. (1992). Maximum area, expansion rate and duration of summer rape leaves. *Canadian Journal of Plant Science*, *72*(1), 117–126.

Pahwa, K., & Ghai, N. (2015). Effect of ethylene on physiological and biochemical parameters in different crop plants-A review. *Journal of Applied and Natural Science*, *7*(2), 1064–1069.

Prabhu, D. (2000). *Influence of Plant Growth Regulators and Micronutrients in Blackgram (Vigna Mungo (L.) Hopper)*. University of Agricultural Sciences, GKVK.

Razzaq, Z. A. A., Alabdulla, S. A., & Mohssen, K. H. (2022). Yield and quality of the Indian mustard (Brassica juncea L.) under the effect of planting dates and nitrogen fertilizer levels in southern Iraq. *NeuroQuantology*, *20*(8), 7556–7562.

ROY, P., Maiti, S., & BN, C. (1981). *GROWTH ANALYSIS AND FERTILIZER RESPONSE OF" VARUNA" INDIAN MUSTARD*.

Saxsena, D. C., Abbas, S., & Sairam, R. K. (2007). Effect of ethrel on reproductive efficiency in chickpea. *Indian Journal of Plant Physiology*, *12*(2), 162–167.

Singh, M. P., Singh, R. K., & Chandra, S. (2014). Ionic liquids confined in porous matrices: Physicochemical properties and applications. *Progress in Materials Science*, *64*, 73–120.

Steensland, A. (2022). 2022 Global Agricultural Productivity Report: Troublesome trends and system shocks. *Global Agricultural Productivity Report*.