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PHYSIOLOGICAL STUDIES ON STINGING NETTLE (*URTICA DIOICA* L.) PLANT

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ABSTRACT: The experiment was carried out during two successive winter seasons of 2022/2023 and 2023/2024 at the Agricultural Research Center Farm, Gemmayzeh, Gharbia Governorate, Egypt. The investigation was to study the impact of three-hole distances (20, 25 and 30 cm), NPK fertilizer application rates 100 N: 50 P: 50 K, 200 N: 100 P: 100 K and 300 N: 150 P: 150 K (kg/fed as ammonium sulfate, calcium super phosphate and potassium sulfate fertilizers, respectively) and their interactions on the growth parameters and chemical constituents of stinging nettle (*Urtica dioica* L.) plants. The results indicated that the application of nettle plants thrives in tight growing environments with smaller quantities. The best results of plant height, fixed oil content in seeds, seed weight, carbohydrate content in leaves and potassium percentage, the highest fresh and dry weights of plant, carbohydrate content in seeds and phenolic content in leaves were obtained from 25 cm spacing + 100, 50 and 50 kg NPK fertilizers/fed. The biggest number of branches resulted from 20 cm spacing and 200, 100 and 100 kg NPK fertilizers/fed. Moreover, the treatment of 25 cm with 200, 100 and 100 kg NPK/fed gave the highest chlorophyll a, b and carotenoids contents in fresh leaves. While the wider spacing (30 cm) and the highest fertilizers (300:150:150 kg NPK/fed) gave the highest (chl. a/chl. b) ratio. However, the highest nitrogen percentage resulted from the interaction treatment of 30 cm with 100, 50 and 50 kg NPK/fed and the highest phosphorus percentage from the treatment of 25 cm with 300, 150 and 150 kg NPK/fed. during the two seasons. In brief, the study observed that inter-hole spacing significantly impacts *Urtica dioica* L. growth and yield. The optimal spacing is 25 cm, balancing resource use and competition. Middle NPK fertilization enhances productivity and metabolite accumulation. Combining 25 cm spacing with middle NPK fertilization improves vegetative growth and biomass. However, high rate fertilization can harm plant performance.

Keywords: Stinging nettle, *Urtica dioica* L., inter-hill distances, chemical fertilizers, NPK, fixed oil, chlorophyll

INTRODUCTION

Stinging nettle (*Urtica dioica* L.) is a flowering plant from the *Urticaceae* family, which is found in neglected areas such as roadsides and riverbanks and is used as water-soluble fertilizer (Maričić *et al.*, 2021). The stinging nettle plant is a nuisance to humans and animals because it causes severe itching, so people do not care to grow it as a plant. Roots, rhizomes, and leaves are important sources of medicine (Hayden, 2006), and stinging nettle leaf extract is used in the manufacture of shampoos and other personal care products. Stinging nettle leaf chlorophyll is also processed into a coloring agent (natural green) used in food processing (Bown, 1995). Its extract, rich in nutrients such as nitrogen and potassium, enhances plant growth and can also repel insects when used as a foliar spray (Rivera *et al.*, 2012). Viotti *et al.* (2022) demonstrated the benefits of growing (*Urtica dioica* L.) as a sustainable crop with low fertilizer and pesticide use. Its introduction across Europe could improve regional biodiversity and meet the demand for plant fiber resources. It is a health food that is associated with the medicinal plant and fiber

(Rutto *et al.*, 2013). Nettle serves as an excellent source of vitamin A as well as calcium, iron, and protein (also called a link of essential nutrients, minerals, and vitamins) that are particularly useful in a vegetarian diet. Tarasevičienė *et al.* (2023) substantiated in their studies that stinging nettle is a widely distributed herbaceous plant which, similar to most edible and medicinal plants, has numerous applications. The study aims to fill a research gap in the study of nettle cultivation and environmental requirements, despite its importance in medical and economic fields. It will investigate the specific agricultural conditions, planting distances, and fertilizer needs for nettle growth and yield, aiming to provide valuable insights into the cultivation and environmental aspects of nettle. The levels of chemicals and antioxidants in stinging nettle vary based on several factors such as the cultivation area, soil type, and harvesting time. Leaves contain high levels of fats and carotenoids. This plant finds its application in both the pharmaceutical and food industries, enabling the efficient extraction of bioactive components (Biesiada *et al.*, 2009). Đurović *et al.* (2017) investigated the medicinal properties of stinging nettle, revealing its main chemical constituents, including polyphenols, phenolic acids, fatty acids, carotenoids, proteins, minerals, and trace elements from extensive chemical analysis of its leaves. The plant is a highly nutritious green leafy vegetable packed with minerals, vitamins, and pigments. It is often called a "wonder green leafy vegetable" for its health benefits.

Regarding the effect of inter-hole, Berimavandi *et al.* (2011) discovered that 60 plants/m^2 produced the most floral dry matter and essential oil per unit area, while 20 plants/m^2 produced the greatest values of *Calendula officinalis* L. plants. Salim *et al.* (2014) studied the effect of plant spacing (20, 30 and 40 cm) on growth, yield and oil content of peppermint and Japanese mint plants. They found that 20 cm spacing improved growth parameters, while larger spacings increased branching without changing oil content. Rajput *et al.* (2018) showed that a planting distance of 60 × 45 cm significantly increased plant height, number of leaves, number of branches and yield of okra (*Abelmoschus esculentus* L.) plants. Amare and Gebremedhin (2020) discovered that planting close to the junction (20 cm and 20 cm) produced 35 yields, but planting 60 cm away from the intersection boosted yield by 50% of tomato. Tamboli *et al.* (2020) stated that the best results were found in fennel plants by sowing at 50 cm spacing, which led to the highest growth and yield. The highest oil yield came from sowing at 35 cm. Additionally, sowing at 50 cm resulted in the most branches, while the treatment of 25 cm spacing produced the tallest plants and most umbels. Wu *et al.* (2020) indicated that the higher density specifically increased fresh and dry yields, chlorophyll content and photosynthesis rate in perilas eedlings. Sefaoğlu and Özer (2022) studied safflower as an oilseed crop. They tested three row spacings and three planting levels to see their effects on plant growth and seed yield. Results indicated that smaller spacing and higher planting rates led to better growth and yield. According to research by Bangoria *et al.* (2024), a closer planting spacing of 30 × 30 cm produced greater yields, whereas a wider planting distance of 45 × 45 cm produced higher growth parameters, yield, and quality of broccoli (*Brassica oleracea* var. *italica* Plenck).

Regarding the effect of NPK application (sub plot), Rutto *et al.* (2012) demonstrated that stinging nettle growth was positively correlated with N supply up to 60 g/m^2 during the reproductive phase (summer) and 75 g/m^2 during the vegetative phase, while there was a slight decline in growth and dry matter yield at the highest level of K (12 g/m^2) at all N levels (15, 45, and 75 g/m^2). Radman *et al.* (2015) pointed out that moderate nitrogen application (100 kg N/ha) improved the chemical composition of stinging nettle. This herb is also abundant in minerals such as potassium, calcium, iron, ascorbic acid, and phenols that improve its antioxidant capacity. Radman *et al.* (2016) studied the effect of nitrogen fertilization on the quality of stinging nettle. They found that using 200 kg of nitrogen per hectare increased the yield significantly. However, this increase was at the cost of reducing the dry matter and mineral contents compared to unfertilized plants. In addition, Sultana and Sheikh (2022) disclosed that nitrogen, which constitutes only up to 7% of the entire plant's dry matter, significantly influences the yield of wheat crops. It has been shown that nitrogen fertilization at a rate of 150 kg N/ha increases leaf yield, as well as increases chlorophyll and carotenoids in leaves.

Regarding the effect of interaction of inter-hole spacing and NPK application rates, Khalid (2018) studied the impact of nitrogen and plant density on parsley crop productivity. The study found that the 200 kg N/ha × 8 plants/m² treatment yielded the highest fresh and dry weights, fruit yield, essential oil composition, and NPK content. Mazumder *et al.* (2019) studied how NPK fertilizer application and planting location affect the growth of onion plants. They found that plant height was optimum when plant spacing was 20 × 10 cm^2 and 160 kg N/ha, 70 kg P/ha, and 100 kg K/ha were applied. The study by Amare *et al.* (2020) showed that the onion seed yield per hectare was highest when the row and plant spacing was 10 × 30 cm^2, with 115 P_2O_5 and 114 N kg/ha, resulting in a seed yield per area of 561.7 g. Kaur *et al.* (2020) showed that combining 100% nitrogen with 60 × 45 cm² spacing increased plant height, spread, and foliage formation. However, the highest cream yield and net yield were obtained by applying 100% N on an area of 45 × 30 cm². Plant spacing is very important in determining yield and quality. Rabia *et al.* (2021) found that a spacing of 23 cm and the application of 150 kg N/ha increased seed yield, seed length, sprout, and fiber quality in cotton. Shreya *et al.* (2023) studied the effects of row spacing and nitrogen changes on wheat (*Triticum aestivum*) growth and yield. Row spacing 15 cm recorded significantly higher yield attributes and grain yield of wheat which was at par with 20 cm row spacing but significantly better than 25 cm row spacing, while application of 160 kg N/ha recorded significantly higher yield attributes and grain yield but at par with 140 kg N/ha. Shelema and Hruy (2024) found that 69 kg N/ha and 5 cm spacing increased commercial onion yield to 40.01 tons/hectare, and Omari *et al*. (2023) conducted a study to investigate the effects of different nitrogen applications and planting locations on onion growth. The results showed that the highest biomass (all parts of a plant) was obtained when the nitrogen dosage was 150 kg/ha, especially when the plant spacing was 7.5 × 15 cm^2.

There is little information about stinging nettle planting in a circular pattern, including the optimal planting density and the amount of nitrogen, phosphorus, and potassium fertilizer required. So, this study was conducted to fill this knowledge gap. Modern agriculture is increasingly concentrating on conserving resources and reducing environmental impact to promote sustainable food production. Consequently, this study aimed to assess the effects of various nutrient levels and planting distances on growth parameters and the nutritional composition of stinging nettle leaves and seeds.

MATERIALS AND METHODS

In early December, the plants were transferred to the research site at the Gemmayzeh Research Station, part of the Agricultural Research Center, El Gharbia Governorate, Egypt. This study was conducted during the winter seasons, 2022/2023 and 2023/2024.

Field preparation:

The fields were plowed with two cross plows to remove old crop residues. The field was divided into 12 rows across two reeds, every row had 60 cm width, and the area was further divided into experimental plots. Each experimental plot had three rows with length of 1.2 m and the area of plot was 2.16 m².

Sowing:

Nettle seeds were purchased from local markets (nettle seed vitality of 90–95%) and cultivated in nursery in mid-October each season. The field of nursery was prepared for cultivation, including plowing, fertilizing, weed control, and irrigation. When the seedlings reached the transplanting stage (seedlings 10–15 cm tall, with 4–6 healthy true leaves and display a healthy green color), they were moved to the trial field in early December.

Experimental Design:

The experiment was conducted using a split-plot design system with three replicates, which had two factors. The main plot was plant distance levels, and the sub-plot was NPK fertilization levels.

Plant distance treatments (main plot):

The plant distances designed to three levels (20, 25, and 30 cm) in a row, each hole contains 2 plants. The number of holes per plot were (18, 15 and 12 holes/plot) which contains (36, 30 and 24 plants/plot) for the plant distance treatments (20, 25, and 30 cm), respectively.

Fertilization treatments (sub-plot):

The fertilization treatments were calcium super phosphate fertilizer (16-22% P_2O_5), with the rates of (50, 100 and 150 kg/fed) was mixed with experimental soil before planting, ammonium sulfate fertilizer (20.6% N) with the rates of (100, 200 and 300 kg/fed)was added twice: the first time, two weeks after transplanting, and the second one, one month after the first time, and potassium sulfate fertilizer (48% K_2O) with the rates of (50, 100 and 150 kg/fed) was added at the beginning of flowering. So, the NPK fertilizers treatments were 100:50:50 kg/fed, 200:100:100 kg/fed and 300:150:150 kg/fed, respectively.

The interaction treatments used in the study were as follows:

1. 20 cm distance between holes + NPK fertilizer application (100:50:50 kg/fed).
2. 20 cm distance between holes + NPK fertilizer application (200:100:100 kg/fed).
3. 20 cm distance between holes + NPK fertilizer application (300:150:150 kg/fed).
4. 25 cm distance between holes + NPK fertilizer application (100:50:50 kg/fed).
5. 25 cm distance between holes + NPK fertilizer application (200:100:100 kg/fed).
6. 25 cm distance between holes + NPK fertilizer application (300:150:150 kg/fed).
7. 30 cm distance between holes + NPK fertilizer application (100:50:50 kg/fed).
8. 30 cm distance between holes + NPK fertilizer application (200:100:100 kg/fed).
9. 30 cm distance between holes + NPK fertilizer application (300:150:150 kg/fed).

Vegetative growth parameters:

The plant growth parameters evaluated in this study included various parameters such as plant height (cm), number of branches per plant, fresh and dry weights/plant(g) and seed weight/plot(g).

Fixed oil percentage:

Fixed oil was extracted from the seeds using the organic solvent petroleum ether in the Soxhlet apparatus according to extraction method specified by A.O.A.C. (1990).

Chemical contents:

Total carbohydrate content in leaves and seeds was evaluated according to the method developed by Dubois *et al.* (1956).

Phenolic compounds in leaves were measured according to the method described by Koleva (2015) and Gadkari *et al*. (2014).

Chlorophyll a and b contents, carotenoids content and chl. a/chl. b ratio were determined by method described by Knight and Mitchell (1983).

Nitrogen content in leaves was determined according to the method of Knight and Mitchell (1983), while phosphorus and potassium contents were evaluated using the methods developed by Van Schouwenburg and Walinge (1967) and Hesse (1971), respectively.

The chemical and physical properties of the experimental soil are shown in Table (1) According to Hesse (1971).

Table 1. The initial characteristics of the experimental soil under study (average of both seasons).

Mechanical analysis								
Sand (%)	Silt (%)	Clay (%)	Saturation (SP; %)	Field capacity (FC; %)	Wilting point (WP; %)	ρs (mg/m^3)	ρb (mg/m^3)	Soil texture
11.69	37.17	51.14	68.00	36.23	18.12	2.62	1.12	Clayey

Chemical analysis														
pH	E C mmohs/cm	OM (%)	Soluble cations (meq/l)				Soluble anions (meq/l)				Available (ppm)			
			Mg^{++}	Ca^{++}	K^+	Na^+	Cl^-	HCO_3^-	SO_4^{--}	$CaCO_3$	N	P	K	
7.85	0.55	0.74	0.90	1.70	0.80	2.48	3.29	0.23	1.89	2.91	42.74	11.18	275	

Statistical analysis:

The data obtained were statistically analyzed using ANOVA, and L.S.D. values were calculated to test differences between the treatments' means according to Steel and Torrie (1982).

RESULTS

1. Vegetative growth:

The data in Table (2) showed the effect of distance between holes, NPK values and the interaction between them on the growth parameters of stinging nettle plants (*Urtica dioica* L.). The results indicated that the treatments of 20 and 25 cm distances gave the tallest plant without significant differences between them. The data in branches number stated that there were no significant differences between distance treatments in the 1st season, and the biggest number of branches obtained from the treatment of 25 cm distance in both seasons. The same treatment (25 cm distance) gave the highest fresh and dry weights of plant and significant differences compared with other treatments, during the two seasons which gave 368.02 and 382.58 g for fresh weight/plant and 41.07 and 42.70 g for dry weight/plant during 1st and 2nd seasons, respectively.

Table (2) also indicated that the NPK levels showed significant effects on plant height. The tallest plants resulted from the treatment of NPK 1. There were no significant differences between NPK treatments on number of branches in the first season. The highest numbers obtained from NPK 2 treatment in both seasons, with significant effect in the second season. The treatment of NPK 1 (100:50:50 kg/fed) gave the heaviest fresh and dry weights/plant with significant differences between other NPK levels, which achieved 432.95 and 447.78 g for fresh weight/plant and 48.32 and 49.97 g for dry weight/plant, during both seasons, respectively, while the lightest fresh and dry weights/plant obtained from NPK 3 (300:150:150 kg/fed) treatment, in both seasons.

Regarding the effect of interaction treatments between hole distances and NPK fertilizer rates, the data in Table (2) stated that, the interaction treatment of 20 cm distance + 100:50:50 kg/fed NPK gave the highest and significant plant height in the two seasons. The highest and significant number of branches obtained from the interaction treatment 20 cm distance + 200:100:100 kg/fed NPK in both seasons. While the highest fresh and dry weights/plant resulted from the interaction treatment of 25 cm + 100:50:50 kg/fed NPK which recorded 519.20 and 536.42 g for fresh weight/plant and 57.94 and 59.86 g, for dry weight/plant, in 1st and 2nd seasons, respectively. The lowest weights obtained from the treatment of 25 cm + 300:150:150 kg/fed NPK.

2. Seeds weight/plot and fixed oil percentage:

The presented data in Table (3) discuss the effects of inter-hole distances and varying levels of NPK fertilization on the weight of seeds (g/plot) and fixed oil content (%).

Table 2. Impact of varying inter-hole distances, NPK fertilizer application rates and interaction between them on plant height (cm), the number of branches, fresh and dry weights/plant (g) of stinging nettle (*Urtica dioica* L.) plants in the two seasons of 2022/2023 and 2023/2024.

Treatments		Plant height (cm)		N. branches		F. weight/plant (g)		D. weight/plant (g)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
		Main-plot: inter-hole distances							
20 cm		76.52 a	78.07 a	9.19 a	9.89 b	344.68 b	354.01 ab	38.47 b	39.51 ab
25 cm		77.22 a	77.59 a	9.63 a	10.59 a	368.02 a	382.58 a	41.07 a	42.70 a
30 cm		70.33 b	71.07 b	9.44 a	10.00 b	319.66 c	331.58 b	35.67 c	37.00 b
LSD at 5%		3.73	2.70	NS	0.56	14.57	34.99	1.63	3.90
		Sub-plot: NPK fertilization							
NPK 1		81.11 a	81.70 a	9.48 a	9.67 b	432.95 a	447.78 a	48.32 a	49.97 a
NPK 2		76.96 b	77.30 b	9.37 a	10.19 a	351.41 b	362.67 b	39.22 b	40.47 b
NPK 3		66 c	67.74 c	9.41 a	10.63 a	247.10 c	257.73 c	27.68 c	28.76 c
LSD at 5%		3.23	4.12	NS	0.47	17.94	41.70	2.00	4.65
Inter-hole distances	**NPK fertilization**	**Main-plot × sup-plot**							
	NPK 1	82.89 a	83.78 a	9.56 ab	10.67 ab	424.77 b	436.94 b	47.40 b	48.76 b
20 cm	**NPK 2**	77.33 ab	77.56 c-e	10.88 a	11.11 a	421.97 b	439.86 b	47.09 b	49.09 b
	NPK 3	69.33 c	72.89 e	9.11 ab	10.00 b-d	257.31de	270.94 d	28.72 de	30.24 d
	NPK 1	82.22 a	82.33 ab	10.00 ab	10.44 a-c	519.20 a	536.42 a	57.94 a	59.86 a
25 cm	**NPK 2**	76.89 ab	76.44 c-e	8.89 b	9.56 cd	279.73d	284.60 d	31.22 d	31.76 d
	NPK 3	72.56 bc	74.00 de	9.66 ab	9.67 cd	235.11 e	241.01d	26.24 e	26.90 d
	NPK 1	78.22 ab	79.00 bc	8.66 b	10.33 a-c	354.89 c	369.97 c	39.61c	41.29 c
30 cm	**NPK 2**	76.66 ab	77.89 b-d	8.55 b	10.33 a-c	352.52 c	363.54 c	39.34 c	40.57 c
	NPK 3	56.46 d	56.33 f	9.44 ab	9.33 d	251.57 e	261.22 d	28.08 e	29.15 d
LSD at 5%		6.46	4.68	1.91	0.97	25.23	60.60	2.82	6.76

NPK 1: 100:50:50 kg NPK/fed; NPK 2: 200:100:100 kg NPK/fed; NPK 3: 300:150:150 kg NPK/fed

Table 3. Impact of varying inter-hole distances, NPK fertilizer application rates and interaction between them on weight of seeds/plot (g) and fixed oil (%) of stinging nettle (*Urtica dioica* L.) plants in the two seasons of 2022/2023 and 2023/2024.

Treatments		Weight of seeds/plant (g) 1st season	Weight of seeds/plant (g) 2nd season	Fixed oil (%) 1st season	Fixed oil (%) 2nd season
		Main-plot: inter-hole distances			
20 cm		30.56 a	32.38 a	16.49 a	17.24 a
25 cm		24.35 b	25.73 b	15.94 b	16.69 b
30 cm		21.81 c	23.36 c	16.09 b	16.84 b
LSD at 5%		1.10	1.33	0.37	0.39
		Sub-plot: NPK fertilization			
NPK 1		31.58 a	33.40 a	18.81 a	19.56 a
NPK 2		25.10 b	26.47 b	16.81 b	17.56 b
NPK 3		20.04 c	21.59 c	12.90 c	13.65 c
LSD at 5%		3.16	2.31	2.10	0.08
Inter-hole distances	**NPK fertilization**	**Main-plot × sup-plot**			
20 cm	**NPK 1**	38.14 a	40.63 a	21.85 a	22.60 a
	NPK 2	30.71 b	32.20 b	17.15 b	17.90 b
	NPK 3	30.64 b	32.13 b	17.11 b	17.86 b
25 cm	**NPK 1**	25.96 c	27.44 c	17.43 b	18.18 b
	NPK 2	23.53 d	24.69 d	17.03 b	17.78 b
	NPK 3	22.82 de	24.31 d	16.29 c	17.04 c
30 cm	**NPK 1**	21.05 e	22.54 de	10.51 e	11.26 e
	NPK 2	18.86 f	20.36 ef	14.38 d	15.13 d
	NPK 3	18.42 f	20.09 f	13.80 d	14.55 d
LSD at 5%		1.90	2.30	1.90	2.30

NPK 1: 100:50:50 kg NPK/fed; NPK 2: 200:100:100 kg NPK/fed; NPK 3: 300:150:150 kg NPK/fed

The oil content outcome of all treatments in both seasons was largely close. The data revealed that, the treatment of 20 cm gave the highest weight of seeds/plot (30.56 and 32.38 g/plot) and fixed oil % (16.49 and 17.24%), in the two seasons, respectively. This result suggests that closer plant spacing might promote denser growth and higher resource efficiency, benefiting seed yield and oil accumulation. In contrast, the 25 and 30 cm spacings demonstrated reductions in both parameters, with the 30 cm spacing yielding the lowest seed weight and oil content in seasons of 2022/2023 and 2023/2024.

Also, the effect of NPK treatments on growth parameters indicated that the seed weight (g/plot) and oil content (%) also showed a clear reliance on the NPK fertilizer amounts. In this regard the treatment of 100:50:50 kg/fed (NPK 1) gave the highest values for both key figures with significant differences compared with the other levels, which achieved a seed weight of 31.58 and 33.40 g, as well as a fixed oil content of 18.81 and 19.56%, during both seasons, respectively. This suggests that middle rates of nutrients optimize physiological and metabolic processes techniques for seed and oil production. Conversely, the highest NPK rate (300:150:150 kg/fed, NPK 3) significantly reduced performance, to the lowest values of seed weight/plot and fixed oil content. These results signify possible nutrient toxicity or imbalance affecting plant metabolism.

Regarding the effect of the interaction between main and sub plots, the highest seed weight and oil content were recorded by 20 cm distance + 100:50:50 kg/fed NPK, which gave 38.14 and 40.63 g in seed weight/plot and 21.85 and 22.60% in fatty oil. The superior treatment is followed by treatments that are close to it in both characteristics in values such as 20 cm distance + 200:100:100 kg/fed NPK, 20 cm distance + 300:150:150 kg/fed NPK and 25 cm distance + 100:50:50 kg/fed. This distance, which is a moderate gap, could increase both yield and oil productivity through effective management of inter-plant competition and resource allocation. Notably, the largest distance of 30 cm did not follow this pattern, suggesting that exceeding an optimal distance may result in a reduction in yield benefits. These results suggest that a spacing of 25 cm is likely to create the most favorable conditions for maximizing seed production and oil yield in comparable agronomic environments.

3. Total carbohydrates in leaves and seeds, and phenols (%):

The data recorded in Table (4), assessed how different distances between holes and NPK fertilizer levels affected the carbohydrate and phenolic contents in stinging nettle over two growing seasons, 2022 and 2023. The distance between holes significantly affects the carbohydrate content in leaves and seeds. The treatment of 25 cm had the highest carbohydrate levels, with leaves containing 19.93 and 20.37% and seeds 14.91 and 15.35% in the first and second seasons, respectively. In contrast, 30 cm treatment consistently showed the lowest carbohydrate values in both leaves and seeds. Leaf phenolic content was higher in the treatment of 25 cm followed by 30 cm with no significant differences between them.

Regarding the effect of NPK application, it significantly affected the carbohydrate and phenolic contents in plants. Using NPK 2 (200:100:100 kg/fed) led to higher carbohydrate levels in leaves (18.64 and 19.08%), while NPK 3 (300:150:150 kg/fed) produced the highest carbohydrate levels in seeds (15.01 and 15.45%) in both seasons, respectively. The highest phenolic content came from NPK 1 as well were 0.264 and 0.275%, while NPK 3 had the lowest values (0.247 and 0.258%) during 1st and 2nd seasons, respectively.

The study examined how the distance between plants and the use of NPK fertilizer affect growth. It found that a distance of 20 cm with NPK 1 fertilizer led to the highest carbohydrate content in leaves, reaching 22.89 and 23.33% in two seasons. A distance of 25 cm with the same fertilizer resulted in

Table 4. Impact of varying inter-hole distances, NPK fertilizer application rates and interaction between them on total carbohydrates of leaves, total carbohydrates of seeds and phenols (%) of stinging nettle (*Urtica dioica* L.) plants in the two seasons of 2022/2023 and 2023/2024.

Treatments		Total carbohydrate of leaves (%)		Total carbohydrate of seeds (%)		Total phenols (%)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season
		Main-plot: inter-hole distances					
20 cm		18.30 b	18.74 b	12.85 b	13.29 b	0.232 b	0.243 b
25 cm		19.93 a	20.37 a	14.91 a	15.35 a	0.261 a	0.272 a
30 cm		15.88 c	16.32 c	10.46 c	10.89 c	0.260 a	0.272 a
LSD at 5%		0.33	0.33	0.22	0.22	0.01	0.01
		Sub-plot: NPK fertilization					
NPK 1		18.00 b	18.44 b	15.01 a	15.45 a	0.264 a	0.275 a
NPK 2		18.64 a	19.08 a	13.79 b	14.22 b	0.243 c	0.254 c
NPK 3		17.47 c	17.91 c	9.42 c	9.86 c	0.247 b	0.258 b
LSD at 5%		1.25	1.10	1.18	0.06	1.63	5.53
Inter-hole distances	**NPK fertilization**	**Main-plot × sup-plot**					
	NPK 1	22.89 a	23.33 a	12.77 e	13.21 e	0.233 a	0.244 a
20 cm	**NPK 2**	15.70 e	16.14 e	11.33 f	11.77 f	0.267 a	0.278 a
	NPK 3	17.16 d	17.60 d	7.28 g	7.72 g	0.282 a	0.293 a
	NPK 1	18.35 c	18.79 c	16.70 a	17.14 a	0.307 a	0.318 a
25 cm	**NPK 2**	18.54 c	18.98 c	14.37 c	14.81 c	0.239 a	0.250 a
	NPK 3	14.79 f	15.23 f	13.67 d	14.11 d	0.237 a	0.248 a
	NPK 1	20.87 b	21.31 b	15.57 b	16.01 b	0.253 a	0.264 a
30 cm	**NPK 2**	18.16 c	18.60 c	15.67 b	16.11 b	0.222 a	0.233 a
	NPK 3	15.88 e	16.32 e	7.31 g	7.75 g	0.222 a	0.233 a
LSD at 5%		0.58	0.58	0.38	0.38	NS	NS

NPK 1: 100:50:50 kg NPK/fed; NPK 2: 200:100:100 kg NPK/fed; NPK 3: 300:150:150 kg NPK/fed

the highest seed carbohydrate content at 16.70 and 17.14%. These results suggest that optimal nutrient uptake and energy accumulation occur at smallest spacings and little fertilization rates. In contrast, a distance of 30 cm with NPK 3 produced the lowest carbohydrate levels in both leaves and seed. In terms of phenolic content, all treatments showed a comparable increase in phenolic levels. There were non-significant effects of the interaction treatments on total phenols in both seasons. The best phenolic content was observed with 25 cm and NPK 1, showing 0.307 and 0.318 in both seasons. The study showed that optimal spacing (25 cm) and lighter NPK fertilization (100:50:50 kg/fed) increase the carbohydrate and phenolic content in leaves and seeds significantly, this shows how important it is to combine these treatments to optimize plant productivity and quality.

4. Chlorophyll and carotenoids content (mg/g fresh weight):

Table (5) examines the effects of inter-hole distances and NPK fertilizer levels on key physiological parameters such as chlorophyll a, chlorophyll b, total carotenoids and chl. a/chl. b ratio in two seasons (2022/2023 and 2023/2024). Regarding the effect of inter-holespacing, the distances between mounds had a significant influence on chlorophyll a, chlorophyll b, carotenoid contents, and the ratio of chlorophyll a / b in nettle plants during the two growing seasons. The distance of 25 cm gave the highest values

Table 5. Impact of varying inter-hole distances, NPK fertilizer application rates and interaction between them on chlorophyll a, b, carotenoids (mg/g F.W.) and the chl. a/chl. b ratio of stinging nettle (*Urtica dioica* L.) plants in the two seasons of 2022/2023 and 2023/2024.

Treatments		Chlorophyll a		Chlorophyll b		Total Carotenes		Chl. a/chl. b ratio	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
		Main-plot: inter-hole distances							
20 cm		15.75 a	15.56 b	9.89 b	9.50 b	8.40 b	7.92 b	1.62 a	1.66 b
25 cm		15.96 a	16.70 a	11.55 a	10.93 a	8.73 a	8.55 a	1.48 b	1.58 b
30 cm		15.09 b	14.89 c	9.06 b	8.40 c	8.02 c	7.73 b	1.69 a	1.77 a
LSD at 5%		0.50	0.37	0.85	0.58	0.14	0.49	0.10	0.07
		Sub-plot: NPK fertilization							
NPK 1		16.55 a	18.21 a	12.67 a	11.73 a	9.03 a	9.39 a	1.38 b	1.62 b
NPK 2		15.27 b	14.59 b	9.05 b	8.51 b	8.27 b	7.48 b	1.69 a	1.72 a
NPK 3		14.98 c	14.35 c	8.78 c	8.59 b	7.86 c	7.32 b	1.72 a	1.68 ab
LSD at 5%		0.11	0.09	0.22	0.66	0.05	0.33	0.04	0.08
Inter-hole distances	NPK fertilization	Main-plot × sup-plot							
20 cm	NPK 1	15.15 cde	14.34 ef	9.14 de	8.30 cd	7.90 e	7.68 de	1.67 bc	1.74 bc
	NPK 2	15.38 cde	14.65 de	9.43 cd	8.63 cd	8.27 d	6.80 f	1.63 bc	1.70 bc
	NPK 3	16.38 b	17.70 b	11.09 b	11.56 b	9.03 b	9.28 b	1.57 bc	1.53 d
25 cm	NPK 1	15.27 cde	14.96 de	9.40 cd	8.96 c	8.45 cd	7.02 ef	1.63 bc	1.67 bc
	NPK 2	17.35 a	19.98 a	16.29 a	14.78 a	9.52 a	10.35 a	1.74 ab	1.68 bc
	NPK 3	15.60 bcd	15.17 d	8.98 de	9.05 c	8.22 d	8.27 cd	1.08 d	1.40 e
30 cm	NPK 1	14.52 e	13.76 f	7.81 e	8.52 cd	7.22 f	7.28 ef	1.88 a	1.62 cd
	NPK 2	14.83 de	13.95 f	8.74 de	7.84 d	8.32 cd	7.38 ef	1.70 b	1.78 b
	NPK 3	15.91 bc	16.96 c	10.62 bc	8.84 c	8.54 c	8.54 bc	1.50 c	1.92 a
LSD at 5%		0.86	0.64	1.47	1.00	0.25	0.85	0.18	0.13

NPK 1: 100:50:50 kg NPK/fed; NPK 2: 200:100:100 kg NPK/fed; NPK 3: 300:150:150 kg NPK/fed

for chlorophyll a, chlorophyll b and total carotenoids. In contrast, the 30 cm distance resulted in the lowest contents of them. The treatment of 30 cm distance gave the highest ratio between chl. a and chl. b. Which the least ratio of (chl. a/chl. b) showed with the shortest distance treatment (20 cm) during both seasons.

The chlorophyll and carotenoid contents were strongly influenced by the NPK fertilizer amounts. The 100:50:50 kg/fed treatment (NPK 1) recorded the highest levels of chl. a, chl. b and carotenoids, in both seasons. In contrast, NPK 3 treatment (300:150:150 kg/fed) resulted in the lowest contents, which is likely due to nutrient toxicity or metabolic imbalances that inhibit pigment production. Interestingly, the chl. a/chl. b ratio was highest under NPK 3 in the first season, and NPK 2 in the second one, indicating that excess nutrients may favor chlorophyll a synthesis over chlorophyll b.

Regarding the effect of the interaction treatments, nuanced effects on photosynthetic pigment dynamics were revealed. The combination of 25 cm spacing with NPK 2 recorded the highest chl. a, b and carotenoid contents, which the lowest contents showed with the interaction treatment (30 cm + NPK 1), during 1st and 2nd seasons. The highest chl. a/chl. b ratio obtained from the interaction treatment (30 cm + NPK 3) in 1st season, and (30 cm + NPK 3) in 2nd one.

5. Nitrogen, phosphorus and potassium percentages:

Regarding the effect of inter-hole spacing (main plot), the inter-hole distances notably changed nitrogen, phosphorus and potassium percentages in stinging nettle plants over both growing seasons as mentioned in Table (6). The 25 cm spacing had, across the two seasons, the highest N (0.867 and 0.878%), P (0.434 and 0.445%). Meanwhile, the highest percentage of potassium obtained from 20 cm spacing treatment. These findings reveal in the two seasons. On the other hand, the 20 cm spacing had the lowest N (0.716 and 0.727%) and P (0.352 and 0.363%), while K% was lowest in 30 cm (2.726 and 2.729).

Regarding the effect of NPK application (sub plot) in Table (6), the NPK fertilizers rates had a major influence on plant nutrient levels. The NPK 1 treatment showed the smallest nutrient contents of N (0.685 and 0.696%) and P (0.361 and 0.372%), while NPK 2 treatment gave the highest N (0.849 and 0.860%) and P (0.472 and 0.483%) percentages. Potassium percentage had the highest values with NPK 1 treatment, while the lowest K% resulted from NPK 3 treatment, during the first and second seasons, respectively.

Concerning the effect of interaction treatments of distances between holes and NPK fertilizer rates, recorded in Table (6), all the interaction treatments effects were non-significant on percentages of N, P and K. The highest N% obtained from the treatment of 30 cm with NPK 1. The highest P% resulted

Table 6. Impact of varying inter-hole distances, NPK fertilizer application rates and interaction between them on N, P and K percentages of stinging nettle (*Urtica dioica* L.) plants in the two seasons of 2022/2023 and 2023/2024.

Treatments		Nitrogen (%)		Phosphorus (%)		Potassium (%)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season
Main-plot: inter-hole distances							
20 cm		0.716 c	0.727 c	0.352 c	0.363 c	3.414 a	3.422 a
25 cm		0.867 a	0.878 a	0.434 a	0.445 a	2.952 b	2.955 b
30 cm		0.735 b	0.744 b	0.408 b	0.419 b	2.726 c	2.729 c
LSD at 5%		0.003	0.003	0.004	0.004	0.005	0.001
Sub-plot: NPK fertilization							
NPK 1		0.685 c	0.696 c	0.361 b	0.372 b	3.6277 a	3.635 a
NPK 2		0.849 a	0.860 a	0.472 a	0.483a	3.019 b	3.022 b
NPK 3		0.782 b	0.793 b	0.360 b	0.371 b	2.446 c	2.449 c
LSD at 5%		0.005	0.005	0.008	0.008	0.010	1.937
Inter-hole distances	**NPK fertilization**	**Main-plot × sup-plot**					
20 cm	**NPK 1**	0.745 a	0.756 a	0.334 a	0.345 a	4.512 a	4.529 a
	NPK 2	1.054 a	1.065 a	0.299 a	0.310 a	3.446 a	3.449 a
	NPK 3	0.721 a	0.732 a	0.364 a	0.375 a	3.246 a	3.249 a
25 cm	**NPK 1**	0.645 a	0.656 a	0.324 a	0.335 a	3.126 a	3.129 a
	NPK 2	0.759 a	0.770 a	0.399 a	0.410 a	3.086 a	3.089 a
	NPK 3	0.826 a	0.837 a	0.561 a	0.572 a	2.646 a	2.649 a
30 cm	**NPK 1**	1.077 a	1.088 a	0.532 a	0.543 a	2.526 a	2.529 a
	NPK 2	0.535 a	0.546 a	0.384 a	0.395 a	2.406 a	2.409 a
	NPK 3	0.589 a	0.600 a	0.387 a	0.398 a	2.286 a	2.289 a
LSD at 5%		1.637	1.637	1.964	1.964	2.719	2.437

NPK 1: 100:50:50 kg NPK/fed; NPK 2: 200:100:100 kg NPK/fed; NPK 3: 300:150:150 kg NPK/fed

from 25 cm + NPK 3 treatment. While the interaction treatment of 20 cm with NPK 1 gave the highest percentage of potassium. These results go parallel in the second season as mentioned in the first one.

DISCUSSION

A spacing of 25 cm worked better than both closer (20 cm) and wider (30 cm) spacing on *Urtica dioica* L. (stinging nettle). A moderate spacing like 25 cm likely provides the right balance of sunlight, space for roots, and air flow, which helps the plants grow well. On the other hand, closer spacing (20 cm) led to fewer branches because the plants had to compete more for resources like light and nutrients. Wider spacing (30 cm) reduced competition but also resulted in less biomass likely because the plants didn't fully use the available resources. Inter-hole spacing greatly affected carbohydrate levels in leaves and seeds, with 25 cm spacing yielding the highest content, enhancing photosynthesis through better canopy structure and light interception, leading to enhanced photosynthetic efficiency and carbohydrate accumulation. Wider spacing (30 cm) led to the lowest carbohydrate levels in leaves and seeds, likely due to decreased canopy density and light efficiency. Conversely, phenol content was highest at 25 cm and 30 cm spacings, while closer (20 cm) spacing reduced phenols due to increased competition. Excessive fertilization combined with wider or closer spacing leads to nutrient imbalances or inefficiencies, which may hinder plant productivity. The 30 cm spacing resulted in lower N, P and K%, indicating decreased nutrient uptake efficiency due to less overlap in root zones and canopy coverage. In contrast, 20 cm spacing showed the lowest N% but highest K%, suggesting potassium prioritization in dense conditions.

The plots with very high and low plant spacing were efficient in giving higher seed yield per plot. This might be due to less competition for growth essentialities under low plant spacing; therefore, it can favor vigorous growth and the highest yield. Whereas, when the plant spacing is closer, the total seed yield per plot will be higher, since low seed yield per plant is compensated by higher plant spacing per unit area. The current study result was in accord with the studies by (Jilani *et al*., 2010) and (Ali *et al.*, 2008) who reported significantly higher seed yield per plot from onion plants grown under closer spacing, increased fertilizer applications and from plants grown under wider spacing with optimum fertilizer application. These results match the findings of Berimavandi *et al.* (2011) on *Calenula officinalis* L. plants, Salim *et al.* (2014) on Spearmint and Japanese mint, Amare and Gebremedhin (2020) on tomato, Bangoria *et al.* (2024) in their study on broccoli grown at different spacings. Islam *et al.* (2014) found that decreasing row spacing from 25.4 cm to 12.7 cm increased spinach yield, but no benefits were found at spacing under 5.1 cm. The findings align closely with earlier studies, Ahmed (2017) studied the effect of NPK fertilizer and biofertilizer on growth and essential oil composition of celery and dill plants. Using biofertilizer (CPP) with 50% NPK significantly boosted plant height, weight, chlorophyll, carotenoids, and vitamin C across both seasons. This method also enhanced the presence of key essential oil compounds. Kamboj *et al.* (2017) highlighted the importance of appropriate row spacing for optimal onion growth and seed yield. Caliskan and Caliskan (2018) noted significant variations in seed yield and traits among safflower cultivars, with the best results at 45 × 5 cm spacing. Gerami *et al.* (2018) on oregano's fresh and dry herb yields, finding that higher density significantly boosts herb yields. While, Rajput *et al.* (2018) reported similar trends in okra. Kenawey (2019) discovered that optimal oil content in prickly oil lettuce was achieved at 10 cm spacing. As mentioned by the research by Altundag and Karademir (2021) stated that different spacings significantly impact seed cotton yield and fiber characteristics. Fekadu *et al.* (2021) found that higher lettuce planting densities increased total yield, but they reduced leaf weight/plant, with spacing and variety significantly impacting overall productivity. Supporting findings by Jaffar and Al-Refai (2021), who highlighted that a specific NPK fertilizer combination significantly improved safflower seed and biological yields. Moratagi *et al*. (2021) demonstrated that, spacing levels (60 × 45 cm) resulted in significant differences on cauliflower (*Brassica oleracea* var. *botrytis* L.) cultivars, and found that, spacing treatment (45 × 45 cm) recorded the highest growth and yield parameters i.e. plant height, stalk length, number of leaves per plant, petiole length, leaf area, leaf area index and total dry matter content. Devi *et al.* (2022) studied cauliflower growth and yield, they found that, 50 × 60 cm spacing exhibited superior growth and yield characteristics. Sefaoğlu and Özer (2022) also showed that narrower spacings and increased planting rates enhanced planting growth rates and safflower seed yields. The findings align closely with earlier studies, Tamboli *et al.* (2020) pointed out that the best results were found by sowing at 50 cm spacing, which led to the highest growth and yield. The highest oil yield came from sowing at 35 cm of fennel plants. Sarkar *et al.* (2023) found that minimal spacing maximized onion seed yield. Kumar *et al.* (2024) studied basil, discovering that a specific nutrient application at 40 × 40 cm spacing enhanced essential oil qualities.

Nitrogen supported chlorophyll synthesis and vegetative growth, phosphorus enhanced root development and energy transfer, and potassium improved stress tolerance and overall plant health. The superiority of the 25 cm spacing with 200:100:100 Kg NPK/fed can be attributed to several physiological and ecological factors like photosynthetic efficiency which moderate spacing minimized shading effects while maximizing light interception. Adequate nutrient levels ensured robust chloroplast function, contributing to higher photosynthetic rates and carbohydrate synthesis. The lowest fertilizer level (100:50:50 kg/fed, NPK 1) limited nutrient availability, while the highest level (300:150:150 kg/fed, NPK 3) likely introduced nutrient imbalances or toxicity, inhibiting plant metabolic processes. Regarding the effect of NPK application, the moderate fertilizer level of 200:100:100 kg/fed (NPK 2) provided an optimal nutrient supply without inducing toxicity. A moderate rate (200:100:100 kg/fed, NPK 2) generated the highest carbohydrate content, enhancing photosynthesis and storage. In contrast, excessive fertilization (300:150:150 kg/fed, NPK 3) reduced carbohydrate levels, while moderate supply (NPK 1) increased phenol biosynthesis, likely due to nutrient toxicity disrupting physiological processes, because excessive fertilization can impair carbohydrate synthesis by creating metabolic imbalances. Treatment of NPK 1 recorded the highest levels of chlorophyll a, chlorophyll b and carotenoid levels. These results suggest that a balanced nutrient supply supports photosynthetic pigment synthesis. In contrast, the 300:150:150 kg/fed treatment (NPK 3) produced the lowest of all traits, likely due to nutrient toxicity or metabolic imbalances that inhibit pigment production. The lowest nutrient contents were observed with the 100:50:50 kg/fed treatment (NPK 1), which produced lower N, P and K %. This demonstrates that insufficient nutrient supply limits the plant's ability to achieve optimal nutrient profiles, despite possible efficiency in potassium uptake.

Conversely, excessive fertilization (300:150:150 kg/fed, NPK 3) resulted in a significant decline in plant height, branching, and biomass. This reduction can be attributed to nutrient toxicity, which disrupts metabolic processes and impairs overall growth and the study of El-Ghamry *et al.* (2017) examined how different levels of nitrogen, phosphorus, and potassium fertilizers affect snap bean (*Phaseolus vulgaris* L.) growth. Their study found that optimal NPK levels (up to 100% recommended) enhanced growth, while excessive application (150%) led to reduced efficiency.

Nitrogen (N) and potassium (K^+) are essential for crop growth and fruit harvesting. Adequate supply of N and K^+ promotes the growth of root system (Shah *et al*., 2017). Mao *et al*. (2022) showed that short-term stress from nitrogen or potassium helped in the growth of lateral roots and root hairs of cucumber plants compared to the control group. As a life element, N is the basis of protein and chlorophyll synthesis (Li *et al*., 2021) and has a significant effect on the photosynthetic response and leaf growth of sorghum Hou *et al*. (2021). While, both excess and deficiency of N destroy leaf structure and adversely affect the length, width and density of stomata, plant height and dry biomass of rice (Khan *et al*., 2021). Moreover, K^+ has a fundamental role in stomata, osmotic regulation and carbohydrate transport (Zhu *et al*., 2020). However, plant height, leaf area and biomass accumulation of K-deficient crops are significantly reduced, and photosynthesis is inhibited (Fontana *et al*., 2020).

Recent studies have emphasized the crucial role of plant spacing and nutrient management in enhancing crop yields across various species. For example: Research by Radman *et al.* (2015) on stinging nettle, finding that moderate nitrogen fertilization (100 kg N/ha) enhanced its production of potassium, and boosted phenol production. Also, Radman *et al.* (2016) on stinging nettle herbage quality. They found that the treatment of 200 kg N/ha negatively impacted dry matter and mineral content compared to unfertilized plants. Amare *et al.* (2020) investigated onion production, revealing optimal seed yields with targeted NP fertilizer levels and spacing. Bentamra *et al.* (2023) indicated that excessive use of NPK fertilizers can lead to low levels of plant growth and phenolic compounds in plants due to nutrient toxicity or metabolic issues. The study examined the effects of different amounts of NPK fertilizer (15, 20, and 25 kg/ha) on tomato growth, yield. The best results were obtained by a medium dosage.

The balance between plant density and fertilizer application optimized root competition, facilitating efficient uptake of macronutrients (N, P, K). Oil biosynthesis enhanced metabolic activity, supported by optimal spacing and fertilization, promoted the synthesis of fixed oils, reflecting improved secondary metabolite production. The highest carbohydrate levels in leaves and seeds occurred with 25 cm spacing and NPK 1, while the lowest levels were seen with 30 cm spacing and NPK 3. Additionally, phenol content peaked in treatments with moderate or wider spacing alongside NPK 3, particularly 25 cm distance + 300:150:150 kg/fed and 30 cm distance + 100:50:50 kg/fed), suggesting that stress from excessive nutrients and lesser plant density boosts phenol biosynthesis. Moderate spacing (25 cm) and balanced fertilization (NPK 1) enhance chlorophyll and carotenoid synthesis, improving photosynthesis. In contrast, wider spacing (30 cm) with high nutrients (NPK 3) results in adequate pigment accumulation, supporting previous research findings.

Similarly, Ashik *et al.* (2014) determined that phosphorus application (72 kg P_2O_5) combined with 40 × 25 cm spacing maximized lettuce height, leaf count, and overall yield. Eryiğit *et al*. (2015) focused on the effects of nitrogen rates and intra-row spacing on safflower, revealing that both markedly affected yield, although seed oil content remained unchanged. While Seifu (2015) found that higher nitrogen rates and wider spacings delay maturity of onion (*Allium cepa* L. var. *Cepa*). Hasan *et al.* (2017) found optimal yields of lettuce (*Lactuca sativa* L.) and economic returns with 150 kg/ha nitrogen and 40 × 25 cm spacing when testing varying nitrogen levels and plant spacings. Meanwhile, Kumar *et al.* (2018) highlighted that increased spacing and nitrogen fertilizers improved onion plant height and bulb diameter. These outcomes concur with the findings. The study by Rathnayake *et al.* (2019) found that optimal results of *Pogostemon heyneanus* Benth., were found with 90 × 90 cm spacing and organic fertilizer, enhancing antioxidant capacity and phenol content. Gashaw and Haile (2020) identified that lettuce yields peaked at 9.45 ton/ha with 150 kg/ha nitrogen and a 25 × 30 cm spacing. Kaur *et al.* (2020) showed that optimal cauliflower growth occurred with 100% nitrogen in either 60 × 45 cm or 45 × 30 cm spacing. Rabia *et al.* (2021) further confirmed that 23 cm spacing with 150 kg N/ha led to higher cotton yield and quality. Ibrahim *et al.* (2022) assessed plant spacing and nitrogen rates for cotton, discovering that 40 cm spacing combined with 100% nitrogen significantly enhanced growth traits and seed cotton yield. Kumar *et al.* (2024) emphasized that targeted nutrient management and adequate spacing notably enhanced yields in basil.

CONCLUSION

Overall, the results of the paper indicated that inter-hole spacing significantly affects the growth and yield of *Urtica dioica* L. Optimal spacing of 25 cm promotes plant development by balancing resource use and competition. Moderate NPK fertilization (100:50:50 kg/fed) enhances productivity and metabolite accumulation across various metrics. The best results emerge from combining 25 cm spacing with moderate fertilization, leading to improved vegetative growth and biomass. While moderate conditions optimize photosynthetic pigments and nutrient uptake, closer spacing of 20 cm improves seed production and oil content. However, excessive fertilization (300:150:150 kg/fed) can harm overall plant performance.

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دراسات فسيولوجية على نبات القراص اللاذع

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أجريت التجربة خلال موسمين شتويين متتاليين ٢٠٢٣/٢٠٢٢ و٢٠٢٤/٢٠٢٣ بمزرعة مركز البحوث الزراعية بالجميزة بمحافظة الغربية بمصر. وكان الهدف من البحث دراسة تأثير ثلاث مسافات بين الجور (٢٠ ، ٢٥ و ٣٠ سم)، ومعدلات إضافة السماد النتروجيني والفوسفوري والبوتاسى (١٠٠ ن: ٥٠ فو :٥٠ بو كجم/فدان، ٢٠٠ ن : ١٠٠ فو : ١٠٠ بو كجم/فدان ، ٣٠٠ ن : ١٥٠ فو : ١٥٠ بو كجم/فدان من سلفات نشادر: سوبر فوسفات الكالسيوم: سلفات بوتاسيوم ، على التوالي) والتفاعل بينهما على معايير النمو والتركيب الكيماوى لنبات القراص. ولقد كانت أفضل نتائج لكل من طول النبات ومحتوى الزيت بالأوراق ووزن البذور ومحتوى الأوراق من الكربوهيدرات ونسبة البوتاسيوم بالأوراق تم الحصول عليها من معاملة التفاعل بالزراعة على مسافة ٢٥ سم + ١٠٠: ٥٠: ٥٠ كجم/فدان ن:فو:بو. وتم الحصول على أعلى وزن طازج وجاف للنبات ومحتوى البذور من الكربوهيدرات ومحتوى الأوراق من الفينولات مع معاملة التفاعل بالزراعة على مسافة ٢٥ سم + ١٠٠: ٥٠: ٥٠ كجم/فدان ن:فو:بو. ولقد أعطت معاملة التفاعل بالزراعة على مسافة ٢٠ سم + ١٠٠: ٥٠: ٥٠ كجم/فدان ن:فو:بو أكبر عدد أفرع. والأكثر من ذلك، فإن معاملة الزراعة على مسافة ٢٥ سم + ٢٠٠: ١٠٠: ١٠٠ كجم/فدان ن:فو:بو أنتجت أعلى محتوى أوراق من كلوروفيل (أ) و (ب) والكاروتينويدات. بينما الزراعة على المسافة الأوسع (٣٠ سم) مع أعلى كميات من الأسمدة (٣٠٠: ١٥٠: ١٥٠ كجم/فدان) أعطت أعلى نسبة من كلوروفيل (أ) / كلوروفيل (ب). كما أن أعلى نسبة من النيتروجين بالأوراق نتجت عن معاملة التفاعل بالزراعة على مسافة ٣٠ سم + ١٠٠: ٥٠: ٥٠ كجم/فدان ن:فو:بو وأعلى نسبة من الفوسفور والبوتاسيوم كانت مع مسافة ٢٥ سم + ٣٠٠: ١٥٠: ١٥٠ كجم/فدان ن:فو:بو، وذلك خلال الموسمين.