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Effect of supplemental phosphorus and plant spacing on vegetative growth parameters of rapeseed crop

Mustafa Abd Manshood[1] and Shaymaa Ibrahim Al-Refai[2]

[1,2] Feild Crop Department, Agriculture College, Al-Muthanna University, Al-Muthanna, Iraq.

Email: manshoodabd@mu.edu.iq shamaa74@gmail.com

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Abstract:

A field experiment was conducted at the Al-Rumaitha District, north of Muthanna Governorate, during the 2021-2022 winter season, to study the effect of supplemental phosphorus application and plant spacing on vegetative growth parameters of rapeseed crop (Pactol cultivar). A Randomized Complete Block Design (RCBD) with three replicates was used. Plant spacing included the main plots, while the sub-plots included supplemental phosphorus applications. The results indicated that the third supplemental phosphorus treatment in plants, had an effect on the NPK concentration, branches number, chlorophyll content, leaf area index, and leaves number, providing the highest means, while the first addition treatment outperformed in leaf area, the fourth addition treatment yielded the highest average plant height. Plant spacing affected growth characteristics and yield, the third plant distribution system yielded the highest leaf area, while the first system yielded the highest 1000-grain weight. As for interaction, the combination between the third addition treatment and the third plant distribution system achieved the highest mean grain number per mustard.

Keywords: supplemental phosphorus, plant distribution, vegetative growth, rapeseed.

Introduction:

Rapeseed (*Brassica napus* L.) is one of the most important crops, consumed by humans in various ways. It is also one of the world's most important primary sources of vegetable oils. Global production is estimated at approximately 71.15 million tons, it ranks high in global production, after soybeans and palm oil. The global area planted with this oil crop is estimated at approximately 37.77 million hectares, and the yield is 1.89 tons. ha^{-1} [1].

Rapeseed is used in many countries around the world for its high-quality edible oils. Rapeseed oil contains a low percentage of saturated fatty acids (6%) and a high percentage of unsaturated acids, especially oleic acid (80%) and linoleic acid (20%), making it a high-quality oil suitable for consumption [2].

Plant spacing within the field are one of the most important field practices, which significantly impact plant performance in intercepting light, increases productivity per unit area by reducing competition for growth factors (light, nutrients, and water), thus increasing vegetative growth indicators [3].

Phosphorus in calcareous Iraqi soils is subject to sorption processes, such as precipitation, adsorption, or encapsulation, which then reduces its availability and uptake by plant roots. Studies have been conducted to mitigate this effect, by adding a portion of the phosphorus to the soil and supplementing the element by spraying it on vegetative parts, to improve the growth, production, and quality of oil crops [4].

Therefore, this study was conducted to determine the best plant spacing within the field. This study ensures increased dry matter production, and increases rapeseed growth and productivity. It also aims to determine the best supplemental phosphorus fertilization, and its effect on rapeseed growth and yield. It also aims to determine the best combination of plant spacing within the field, supplemental phosphorus fertilization, and soil phosphorus application, and its effect on crop growth and yield.

Materials and Methods:

A field experiment was conducted during the 2022-2023 winter season, at a farmer's field 30 km north of Muthanna Governorate, in a sandy loam soil, the soil pH was 7.3 and the EC was 4.8 $dS.m^{-1}$. Content of elements were nitrogen (16.1 mg kg^{-1} soil), phosphorus (14.7 mg kg^{-1} soil), and potassium (197.8 mg kg^{-1} soil), to determine the effect of four row and four hole spacings, as follows: 80×30 cm, 70×40 cm, 60×50 cm, and 50×60 cm. Four treatments of soil addition and supplemental phosphorus were also added, were add a full soil mix with zero spray concentration, 75% of the recommended soil mix + 2,500 mg L^{-1} spray, 50% of the recommended soil mix + 5,000 mg L^{-1} spray, and 25%

of the recommended soil mix + 7,500 mg. L^{-1} spray.

The experiment was conducted using a split-plot design. A Randomized Complete Block Design with three replicates was used. Plant spacing included the main plots, while the sub-plots included supplemental phosphorus applications. Treatments were randomly distributed within each plot. The number of experimental units was 48.

The agricultural soil was prepared for the experiment; it was plowed, smoothed, and leveled. The land was divided into experimental units, each with an area of 3×4 m (12 m^2 per plot). This setup included considerations for the number and length of planting lines between plants, depending on the type of planting spacing used. Planting took place on October 15, 2022 [5]. The approved variety (Bactol) was used.

Nitrogen fertilizer was added in two batches, the first was after the plant had developed three leaves, the second was added approximately 45 days after the first application. Potassium fertilizer (K) was added at planting, according to the recommendations of the Iraqi Ministry of Agriculture (2000). As for the triple phosphate fertilizer, triple superphosphate (P_2O_5) was added, according to the fertilizer recommendations [6]. It was added during planting for the ground application. As for the supplementary application (spraying), it was added in two batches. The first was added at the time of elongation and before flowering, The second was added when 50% of the experimental plants had flowered. Spraying was carried out using a 16-liter backpack sprayer.

Studied Traits

Nitrogen: It was extracted using a 2-molar potassium chloride solution and estimated using the Micro-Kjeldahl method according to the method described in Page *et al.* [7].

Phosphorus: It was extracted using sodium bicarbonate solution at pH 8.5 and the color was developed using ammonium molybdate and ascorbic acid solution and was measured using a spectrophotometer, type biochrom (LibraS5), at a wavelength of 882 nm according to Watanabe and Olsen [8].

Potassium: It was extracted using a 1-molar ammonium acetate solution at pH 7. It was determined using a flame photometer (AFP 100) according to the method described in Page *et al.* [7].

Number of leaves: The total number of leaves was calculated from the first leaf at the bottom of the plant (soil surface) to the top of the plant.

Chlorophyll content: It was measured at the completion of the fruit set stage as an average of several readings taken from 10 plants per experimental unit using a Chlorophyll meter.

Leaf area index: It is calculated from the total area of plant leaves divided by the area of land occupied by the plant [9].

Results and Discussion

Nitrogen Concentration in the leaves (%):

Table (1) shows the superiority of plant spacing(80 cm between rows and 30 cm between plants), which yielded the highest mean (2.72%), compared to plant spacing(60 cm between rows and 50 cm between plants), which recorded the lowest mean (2.49%), may be due to the increased number of plants per unit area, this increases competition for growth factors (light, nutrients, and water), which prompts plant root growth, increasing plant density per unit area, aims to maximize utilization of growth factors, which increases absorption sites, positively impacts nutrient absorption, including nitrogen, by increasing its absorption and transport to various parts of the plant, including the leaf, which is the center of plant biological activity.

The results showed a significant effect on nitrogen concentration in plant leaves. The addition treatment (50% soil addition+ 5000 mg L^{-1}) outperformed all treatments, recording a significant superiority, the highest mean (3.07%), compared to the addition treatment (75% soil addition+ 2500 mg L^{-1}), which recorded the lowest average among all addition treatments, at 2.37%. The reason for the superiority of the treatment itself may be attributed to the fact that, phosphorus is a major element, whose requirements can be maintained through spraying. In addition, the added element is exposed to sedimentation due to the alkalinity of Iraqi soils. Adding half the amount as a spray was designed to overcome this problem and achieve the maximum possible benefit from the phosphorus element through the supplemental addition in the aforementioned treatment. Supplemental spraying enhances the reduction in phosphorus absorption from the soil. The same treatment may have achieved the desired balance in achieving maximum phosphorus uptake from the soil and plant, compared to other treatments that increased the amount of phosphorus added to the plant or soil, this is consistent with Al-Baaj [3]; Al-Waili [4]; Mohsen [6], who found that increasing phosphorus increases the concentration of nitrogen in plants.

The results showed that the combination of interaction with D3P3 supplemental phosphorus yielded the highest average (3.18%), compared to the D2P1 combination, which yielded the lowest mean (0.61%). This may be due to the fact that this combination of 50% fertilizer, soil addition+ 5000 mg L^{-1}, and intercropping (row spacing and hole spacing) provided a favorable opportunity for root growth compared to other combinations, due to the relative spacing between rows and plants, this increased the density of the root system, which resulted in increased nitrogen uptake and increased its concentration in the plant.

Table (1) The effect of plant spacing, adding supplementary phosphorus, and the interaction between them on nitrogen concentration in the leaves (%).

Plant spacing (D)	Phosphorus level (P)				Mean
	P1	P2	P3	P4	
D1	2.47	2.36	3.16	2.89	2.72
D2	0.61	2.37	2.84	2.37	2.54
D3	2.23	2.23	3.18	2.31	2.49
D4	0.67	2.54	3.11	2.42	2.68
Mean	2.49	2.37	3.07	2.50	
$L.S.D_{0.05}$	**D** 0.086	**P** 0.078		**D×P** 0.153	

Phosphorus concentration in the leaves (%):

Table (2) indicates a significant effect and superiority of plant spacing (80×30) cm, recording the highest mean (0.36%), compared to planting spacing (60×50), which yielded the lowest mean (0.30%). This may be due to increased root density, with an increase in the number of plants per unit area, which leads to increased release of hydrogen ions in the root growth zone. This relatively improves soil pH and increases the availability of some nutrients, including phosphorus, which suffers from sedimentation problems due to alkaline soils.

The results demonstrate significant differences for the supplemental phosphorus treatment (50% soil application+ 5000 mg L^{-1}), which yielded the highest mean (0.38%), compared to the addition treatment (25% soil application+ 7500 mg L^{-1}), which recorded the lowest mean (0.30%). The reason for the superiority of the same treatment in increasing phosphorus concentration in the plant may be attributed to the fact that this treatment was perhaps the most balanced of the treatments. It used half the recommended amount of soil fertilizer, it thus overcame the soil problems. The inability to rely on spraying to maintain phosphorus requirements. Phosphorus is one of the major elements required by plants during the establishment phase of an efficient root system. This is consistent with Al-Waili [4]; Mohsen [6].

Table (2) The effect of plant spacing, supplementary phosphorus addition, and the interaction between them on the phosphorus concentration in the leaves (%).

Plant spacing	Phosphorus level	Mean

(D)	(P)				
	P1	P2	P3	P4	
D1	0.353	0.386	0.393	0.353	0.371
D2	0.296	0.316	0.386	0.330	0.332
D3	0.320	0.316	0.380	0.333	0.337
D4	0.343	0.313	0.386	0.326	0.342
Mean	0.328	0.333	0.386	0.335	
$L.S.D_{0.05}$	D	P		D×P	
	0.010	0.012		0.023	

Potassium Concentration in the leaves (%):

Table (3) shows the significant effect of plant spacing between plants. The plant spacing (80×30) recorded the highest average of (1.7%), outperforming all plant spacing, while the plant spacing (60×50) recorded the lowest mean (1.62%). This may be attributed to the increased number of plants per unit area, which increases competition for growth factors (light, water, and nutrients). This drives plants to grow roots and increase their density per unit area. This aims to achieve the maximum possible utilization of growth factors, this increases absorption sites and positively impacts nutrient absorption, including potassium, and increases its absorption and transport to various parts of the plant, including the leaf, which is the center of plant biological activity.

The results showed a significant superiority of the supplemental phosphorus treatment (25% soil application+ 7500 mg L^{-1} spray), it yielded the highest mean (1.73%), while treatment P1 (soil application only) recorded the lowest mean (1.55%). This is attributed to the fact that increasing the spray concentration, led to an increase in phosphorus, which was reflected in an increase in the energy elements ATP and NAD. This increased potassium absorption from the soil, and subsequently increased potassium concentration, as it is a free element in the plant. Its absorption and transfer are dependent on the energy available in the plant.

The results showed that the combination (plant spacing (80×30 cm) and the supplemental phosphorus treatment (25% of the soil addition+ 7500 mg L^{-1}) significantly outperformed, recording the highest mean (1.80%), while the combination (plant spacing (70×40) cm) and the addition of phosphorus (soil addition only) gave the lowest mean (1.44%).

Table (3) The effect of plan spacing, adding supplementary phosphorus, and the interaction between them on the concentration of potassium in the leaves (%).

Plant spacing (D)	Phosphorus level (P)				Mean
	P1	P2	P3	P4	

D1	1.676	1.723	1.713	1.803	1.729
D2	1.440	1.520	1.696	1.786	1.610
D3	1.503	1.500	1.700	1.793	1.624
D4	1.583	1.510	1.706	1.796	1.649
Mean	1.550	1.563	1.704	1.795	
L.S.D$_{0.05}$	**D** 0.049	**P** 0.059		**D×P** 0.097	

Chlorophyll Content in the leaves (Spad):

Table (4) shows the significant superiority of the supplemental phosphorus treatment (50% soil application+ 5000 mg L^{-1} fertilization), it yielded the highest average chlorophyll content. There was no significant difference between the supplemental phosphorus treatment (75% soil application+ 2500 mg L^{-1} fertilization), and the supplemental phosphorus treatment (25% soil application+ 7500 mg L^{-1} fertilization), their averages reached 44.75, 44.01, and 42.76 Spad, respectively, while the soil treatment (soil application only) recorded the lowest mean (41.47 Spad). The reason for the increased chlorophyll content may be due to the increased concentration of nitrogen in the plant (Table 1), this plays an effective role in chlorophyll formation in the plant. Also, the increased concentration Phosphorus in plants (Table 2), this contributed to an increase in leaf chlorophyll content. These results were consistent with Al-Waili [4], who demonstrated that chlorophyll content increases with increasing phosphorus.

However, plant spacing and the interaction between the two study factors did not record any significant effects.

Table (4) The effect of plan spacing, adding supplementary phosphorus, and the interaction between them on the chlorophyll content in the leaves (SPAD).

Plant spacing (D)	**Phosphorus level (P)**				**Mean**
	P1	**P2**	**P3**	**P4**	
D1	41.40	42.75	43.36	42.54..	42.56
D2	42.22	44.66	45.45	43.09	43.86
D3	41.67	44.26	44.12	43.10	43.29
D4	40.59	44.35	45.87	42.33	43.28
Mean	41.47	44.01	44.75	42.76	
L.S.D$_{0.05}$	**D** N.S	**P** 1.764		**D×P** N.S	

Number of leaves (leaf plant^{-1}):

Table (5) shows that the phosphorus soil addition treatment outperformed the phosphorus treatment, which yielded the highest mean (38.28 leaves plant^{-1}). The supplemental phosphorus treatment (75% soil addition+ 2500 mg L^{-1}) also significantly outperformed the two treatments (50% soil addition+ 5000 mg L^{-1} and 25%+ 7500 mg L^{-1}), with averages of 36.11, 32.99 and 32.29 leaves plant^{-1}, respectively. This may be attributed to the increased number of total branches and increased plant height. The role of major elements, especially phosphorus, in increasing most vital processes in plants, as a result, new plant growth sites are equipped with the necessary growth requirements, this led to an increase in the number of leaves per plant, consistent with Al-Mughair [10] found in sunflowers, and Al-Baaj [3] found in safflowers, who demonstrated that increasing plant height and the number of branches increases the number of leaves per plant.

However, there were no significant effects of either plant spacing or the interaction between the two study factors.

Table (5) The effect of planting distances, adding supplementary phosphorus, and the interaction between them on the number of leaves per plant (leaf plant^{-1}).

Plant spacing (D)	Phosphorus level (P)				Mean
	P1	**P2**	**P3**	**P4**	
D1	38.75	37.33	32.85	32.95	35.47
D2	38.93	36.20	33.43	31.22	34.94
D3	37.83	35.92	33.58	34.45	35.44
D4	37.60	35.00	32.12	30.53	33.81
Mean	38.28	36.11	32.99	32.29	
$L.S.D_{0.05}$	**D** N.S	**P** 1.8		**D×P** N.S	

Leaf Area Index:

Table (6) indicates significant differences in the plant planting distances (80×30) cm, which yielded the highest mean of 1.057, compared to the planting distances (50×60), which yielded the lowest mean of 1.006. This may be due to the increase in the number of plants per unit area, due to the small space occupied by plants (30 cm between plants), this had a significant impact on increasing the area index, while there was a clear decrease in the leaf area per plant, this was compensated for by increasing the number of plants per unit area. This result is consistent with the findings of Al-Baaj [3]; Al-Hassani [11], and, who demonstrated that optimal utilization of growth factors within the plant distribution system increases the leaf area index.

The results indicate that the phosphorus treatment was superior to the soil-based application. It yielded the highest mean (1.131), significantly outperforming all supplemental phosphorus treatments. The phosphorus treatment (75% soil-based application+ 2500 mg L^{-1}) also outperformed the two treatments (50% soil-based application+ 5000 mg L^{-1}) and (25% recommended application + 7500 mg L-1), their averages were recorded as 1.057, 0.986, and 0.969, respectively. The superiority of the leaf area index may be attributed to the increased leaf area and the role of phosphorus in plant growth. This is consistent with Mohsen [6], who demonstrated the role of phosphorus in increasing and improving plant growth.

The results showed that the combination treatment (plant spacing of 80×30 and the addition treatment of the full ground recommendation) was significantly superior. It yielded the highest average leaf area index (1.203), compared to the lowest mean for the combination treatment (80×30 and the supplemental phosphorus treatment of 25% of the ground addition+ 7500 mg L^{-1}), which reached 0.944.

Table (6) The effect of planting distances, adding supplementary phosphorus, and the interaction between them on the leaf area index.

Plant spacing (D)	Phosphorus level (P)				Mean
	P1	P2	P3	P4	
D1	1.203	1.136	0.944	0.944	1.057
D2	1.151	1.069	0.975	0.999	1.048
D3	1.100	1.024	1.042	0.962	1.032
D4	1.071	1.0001	0.983	0.970	1.006
Mean	1.131	1.057	0.986	0.969	
$L.S.D_{0.05}$	D 0.031	P 0.052		D×P 0.094	

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