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Effect of Phosphorus Fertilization on Dry matter Accumulation and it's Remobilization in Oil seed Flax (*Linum usitatissimum* L.) under rainfed condition

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***Abbreviations**: DM dry matter, NG non reproductive grain, P phosphors fertilizer*

Abstract

This experiment was carried at Qlyasan Research Station. Faculty of Agricultural Sciences, University of Sulaimani, during 2016-2017 to study the effect of four levels of phosphorus fertilizer in the form of P_2O_5 (0 control, 100, 200 and 300 kg $P_2O_5ha^{-1}$) on two oilseed flax varieties (Poland and Syria local) dry matter and Phosphor accumulation and their translocation from source to sink . Results showed that Poland variety with the 200kg P_2o_5 ha^{-1} in all studied parameters significantly being higher than Syria local, and other levels of P_2O_5 fertilizer. Compared to control 200kg P_2O_5 increased DM accumulation at 50% anthesis by (44.48 and 27.04%), DM translocation efficiency by (24.46and 38.19%), Contribution of leaves DM to final grain by (53.57 and 44.060%), P accumulation in vegetative tissues at 50% anthesis by (69.59 and 81.65 %), P translocation efficiency by (51.85 and 70.02%), leaf P contribution to final grain by (50.69 and 73.63%), also at maturity increased biological yield by (27.16 and 29.72%), and increased grain yield by (20 and 27%) for Poland and Syria local respectively, with no significant increment above that level. In both varieties at 50% anthesis the leaves DM were increased and reached peak at 200kg $P_2O_5ha^{-1}$ but as the plant reached maturity the leaves DM significantly lower by ten times than stem DM+NG. These results suggest that 1.The leaves in oil seed flax are the major DM and P contributor to grain after anthesis whereas the stem and NG are the stronger demand for DM and P post anthesis.2. Variety of Poland under the 200kgP_2O_5 ha^{-1} could be suitable for grain yield under rainfed condition in Sulaimani province.

Introduction

Flax (Linum usitatissimum L.) is the member of the family linaceae, and it is considered as the oldest cultivated crop [13]. There are two main purposes for Flax cultivation, firstly for oil from its seed and secondly for fibar from its stem .Flaxseed is rich in oil (41%) and protein (20%), the oil has a high percentage of essential fatty acids, 75% polyunsaturated fatty acids, 57% alpha-linolenic acid, which is an omega-3 fatty acid, and 16% linoleic acid, which is an omega-6 fatty acid [11].

Historically, the oil from the linseed has been used as a drying agent for oil varnishes and printing ink. Recently, the oil from the linseed oil is consider as the healthy vegetable oil for human consumption, as mentioned earlier the oil are very high of alpha linolenic acid (omega-3 fatty acid) essential for humans health: and the highest content of plant (lignans) of all plant or seed products also use in human food [11]. For economic productions of flax, good management practices including use of recommended varieties; good seed bed preparation, proper seeding rate and recommended fertilizer are essential [4].

Phosphorus (P) is considered as an essential plant nutrient required for crop production [16], as phosphorus has the role in storage energy comes from plant metabolisms which is plant need it in growth and development [14]. To optimize crop nutrition, P must be available to the crop in adequate amounts during the growing season [16].

Results showed that phosphorus is mobile in the plant, so it is absorbed during early growth and it is later redirected for use in seed formation, so the application of phosphorus with sowing of seeds is necessary [22], the phosphorus remobilization and transporting along with the dry matter transporting increased from the non reproductive organs to the grain with increasing the levels of phosphorus fertilization in the form of calcium superphosphate from 15 to 45 kg P/ha^{-1}[24].Increased phosphorus application levels in the form of P_2O_5 from 15-45 kg h^{-1} increased the plant dry matter accumulation when measured at anthesis as a result seed yield increased by 45% [24], the increasing of yield and N use efficiency with high level of phosphors also confirmed by [2]. The medium to high soil P levels to optimize flax yields was recommended by Mousa et al., (2010) [17] and Chaubey and Dwivedi (1995) [5] found that flax seed yield significantly increased with increasing phosphorus application up to 10 kgh^{-1} . Furthermore, Ali et al.,(2002) [1]stated that the two genotypes of linseed namely Chandni and LS-49 were significantly responded to phosphorus application in Pakistan, the number of capsules per plant, number of seed per plant, 1000 seed weight and seed yield were markedly increased by the application of 90 kgh^{-1} in the form of triple super phosphate. It has been is highly recommended that nutrient availability management is extremely important to increase nutrient use efficiency, enhancement of photosynthesis products transporting from sources to sink and increasing seed yield [24].

Amis of this study

The aim of this study was to investigate the effect of different levels of phosphorus fertilization in the form of P_2O_5 on dry matter accumulation, dry matter transportation and phosphorus remobilization in oil seed flax under rainfed condition in Sulaimani region/ Kurdistan Iraq.

Materials and Methods

The field experiment was carried out during the 2016- 2017, at the Faculty of Agricultural Sciences, Sulaimani University, with latitude 35^0 32 '30‟ N, longitude 45^0 12'00‟ E and 738 masl, Laboratory work was perform at the laboratories of Soil and water department at Faculty of Agricultural Sciences. The experiment designed according to RCBD in three replicates. The plot area was $1m^2$ consists 3 rows; the distance between rows was 0.3 m and between plants within rows was 0.1m. Treatment layout was two varieties of oil flax seed (Poland and Syria local) and four levels of phosphorus fertilizer in the form of P_2O_5 {0 (control), 100, 200 and 300 kg ha^{-1}}. Planting date was on 1^{th} December. All cultural practices were conducted as usual for rainfed condition crops. The phosphorus fertilizer in the form of P_2O_5 was applied with sowing seeds at four levels (0, 10, 20 and 30 g m-^{2}).Physical and chemical analysis of the experimental plots are presented in table (1) and metrological data for growing season 2016-2017 are presented in table (2).

Table- 1: Physical and chemical analysis of the experimental sites.

	Soil Properties	*Qlyasan location*
	P.S.D	*Clay*
	Sand (g Kg^{-1})	*41.00*
	Silt (g Kg^{-1})	*430.50*
	Clay (g Kg^{-1})	*528.50*
	E.C. (dS m^{-1})	*0.61*
	pH	*7.32*
	O.M (g Kg^{-1})	*11.60*
	Total N (mg Kg^{-1})	*1.07*
	Available Phosphate (mg Kg^{-1} Soil)	*5.95*
	$CaCO_3$ (g Kg^{-1})	*107.00*
Soluble Cataions and Anions (Mmole L^{-1})	*Calcium (Ca^{+2})*	*0.39*
	Potassium (K^+)	*0.12*
	Sodium (Na^+)	*0.31*
	Carbonate ($CO_3^=$)	*0.00*
	Bicarbonate ($HCO_3^=$)	*3.11*
	Chloride (Cl^-)	*0.49*
	Sulphate ($SO_4^=$)	*0.7*

Table -2: Average air temperature and rainfall during the growing seasons of 2016-2017 at Qlyasan Location.

Months	*Average Air Temperature (°C)*		*Rainfall (mm)*
	Max.	*Min.*	
November	*21.3*	*7.6*	*44.5*
December	*11.1*	*3.0*	*158.0*
January	*11.10*	*1.46*	*59.2*
February	*13.02*	*0.26*	*96.5*
March	*17.73*	*7.45*	*111.5*
April	*23.89*	*10.97*	*54.5*
May	*31.63*	*13.48*	*27.7*
Total			*551.9*

At 50% anthesis, five individual plants were taken randomly from each experimental total above ground biomass { stem, leaf and non grain reproductive(including flower bud, sepal carp podium and peduncle)} and root dry weight were measured

At full maturity, five individual plants were harvested randomly from each experimental plots and the stem, leaf weifht , non grain reproductive weight , grain and 1000 grain weight were measured also yield and its components (number of capsule/plant, number of seed / plant, and biological yield were taken.

At each sampling dates 5 plants randomly selected from the central row of a plot and separated into leaves, stem, non organ reproductive and grains, and all separately dried at 105^0C for 2 h and then at 80 ^{0}C until constant weight, the dried samples were ground and the constants phosphate in the various plant organ were determined according to [9].

The dry matter translocation, dry matter translocation efficiency, phosphorus translocation and phosphorus translocation efficiency were calculated by the following methods according to [19].

DM translocation (g m^2) = DM at anthesis (leaf)- DM at maturity

DM translocation efficiency (%) = (DM translocation/ DM at anthesis) × 100

Phosphorus translocation (g m^2) = (P accumulation at anthesis (leaf)- P accumulation at maturity

Phosphorus translocation efficiency (%) = (P translocation/P accumulation at anthesis) × 100

In the above following equation the inpute of DM into respiration was ignored, and it was assumed that the vegetative tissues are the source of DM and P translocation pre anthesis to the grain [3, 7, 21, and 23].

The relative contribution of DM lost from leaves to the grain was calculated according to [18] by using the equation

$$R_t = Wi_m - Wi_h / Wi_k \times 100$$

Where R_t, is the relative contribution of vegetative organ to grain DM , $Wi_{m.}$, is the maximum dry weight of the leaves, Wi_h, is the dry weight of the same organ at maturity , and W_k, is the grain dry weight at maturity.

The relative contribution of P from leaves to final grain was determined using the following equation

$$R_P = Wp_m - Wp_h / W_g \times 100$$

Where R_P, is the relative contribution of a vegetative organ to grain P content, Wp_m, is the maximum P content of the leaves, Wp_h, is the P content of the same organ at maturity, and W_g, is the grain P content at maturity.

Statistical analysis

Data were statistically analyzed using Software (XLSTAT) version16, and the significant differences between means were compared using Duncan multiples range, $P \leq 0.05$.

Results and Discussion

Dry matter accumulation and partitioning

Data presented in table (3) Show significant $p < 0.05$ differences between two varieties and different levels of phosphorus fertilizers in different plant parts dry matter accumulation and partitioning. Poland variety had significantly accumulated dry matter and partitioned higher amount of dry matter than Syria local, this may be due to genetic variation between two varieties used [10]. Moreover, in both varieties significant dry matter accumulation and partitioning was obtained under 200 kg P_2O_5 ha^{-1} at both anthesis and harvest stages compared to other P_2O_5 levels.

As the plants reached maturity leaf DM in both varieties became less but the stem dry matter and total DM became more than that accumulated at anthesis. At anthesis means leaf DM for Poland variety were (2.273, 3.590, 4.317 and 4.250 g m^2) and for Syria local were (2.103, 2.557, 3.183 and 2.340 g m^2) under (0,100, 200, and 300 kgP_2O_5 ha^{-1}) respectively. Means stem + NG DM for Poland were (10.237, 15.343, 18.207 and 7.860 g m^2) and for Syria were 7.860, 8.650, 10.473 and 9.760 g m^2) under (0,100, 200, and 300 kgP_2O_5 ha^{-1}) respectively, At maturity the leaf DM become less for both varieties with mean values of (1.473, 1.963, 2.163 and 2.130 g m^2) for Poland and for Syria local were (1.387, 1.280, 1.430 and 1.170 m^2g) under (0,100, 200, and 300 kgP_2O_5 ha^{-1}) respectively . In contrast, the Stem+ NG DM with mean values of (10.273, 15.343, 18.207, and 15.043 g m^2) for Poland and with mean values of (7.860, 8.650, 10,473 and 9.760 g m^2) for Syria local increased and recorded mean values of (207.910, 240.093, 286.330 and 201.400 g m^2) for Poland and with mean values of (192.167, 258.930, 274.283 and 188.373g m^2) for Syria local under (0,100, 200, and 300 kgP_2O_5 ha^{-1}) respectively. As a result the total DM at maturity increased by (13.71 to 27.16 %) in Poland and (25.56 to 31.48 %) in Syria local when the level of phosphorus fertilizer increased from 100 to 200kg P_2O_5 ha^{-1} compared to control , with no any increment above this levels. This mean that phosphorus application significantly increased dry matter accumulation and partitioning in oil seed flax due increased photosynthesis and photo assimilate partitioning but at the range of 200kg ha^{-1} the increased levels to 300 kg ha^{-1} did not lead to any increase in dry matter accumulation for both varieties, this might be due to toxicity resultant form over fertilizer application The same result previously reported by [24]. Previously, the increased dry matter accumulation and translocation among the plant organs in response to phosphorus fertilizer reported in other field crop such as in wheat [8].

In addition, the results of this study lend more supports to that found by Xie et al., (2014) [24] who reported that leaves are the dominants source for the grain dry matter accumulated in grain in oil seed flax. However in other crops such as wheat the both stem and leaves are the source of DM translocated pre anthesis to grain post anthesis [20].

Table- 3: Dry matter (g m^2) in the {stem+ non grain reproductive of the panicle (NG)}, leaves, and grain at anthesis and maturity of two oil seed flax varieties, and under four levels of phosphorus fertilization in 2016 under rain fed condition.

Variety	Phosphorus ertilizer Kg ha^{-1}	Anthesis			Maturity				
		Leaf	Stem + NG	Total biomass	Leaf	Stem	NG	Grain	Total biomass
Poland	0	2.273 b	10.237 bc	12.505 cd	1.473 ab	207.910 ab	0.607 b	1.600 bc	211.590 bc
	100	3.590 ab	15.343 ab	18.933 ab	1.963 ab	240.093 ab	1.080 ab	2.067 ab	245.203 ab
	200	4.317 a	18.207 a	22.524 a	2.163 a	286.330 a	1.183 ab	2.000 ab	290.493 a
	300	4.250 a	15.043 ab	19.293 ab	2.130 ab	201.400 ab	1.283 a	1.467 bc	291.676 ab
Syria local	0	2.103 c	7.860 c	9.963 d	1.387 ab	192.167 b	0.897 ab	1.533 bc	195.984 c
	100	2.557 bc	8.650 c	11.207 cd	1.280 ab	258.930 ab	0.930 ab	2.127 a	263.267 ab
	200	3.183 ab	10.473 bc	13.656 bc	1.430 ab	274.283 ab	1.060 ab	2.100 ab	278.873 ab
	300	2.340 bc	9.760 bc	12.100 cd	1.170 b	188.373 b	1.053 ab	1.433 c	192.029 c

Means followed by the same letter do not differ significantly at P < 0.05 by Duncan's new multiple range test

Phosphorus accumulation and partitioning

Data in table (4) show that different plant organs phosphate contents significantly $p < 0.05$ affected by different levels of phosphorus fertilization. For both varieties the leaf P content reached the peak at anthesis then decreased when the plants reached maturity, while, the stem+ NG P content increased and reached peak at maturity. At anthesis leaf P content significantly increased by (35.01 to 72.32 %) in Poland and increased by (94.80 to 97.84 %) in Syria local when the fertilizer levels increased from 100 to 200kg $P_2O_5ha^1$

compared to control. While, at maturity stem +NG P content dramatically increased by (73.46 to 77.22%) in Poland and increased by (49.95 to 77.%) in Syria local when the fertilizer levels increased from 100 to 200kg P_2O_5ha-[1] compared to control . This means that the leaves in oil flax seed pre anthesis are main resource for P in NG+ stem and grain post anthesis. Consequently, in both varieties under 200kgP_2O_5 the total above ground P content were two times more than other levels of phosphorus fertilizers .

The P accumulation in the grain increased dramatically after anthesis and these results are in agreement with that found recently by Xie et al., (2014) [24] who reported that the grain P content increased significantly after anthesis and increased with P fertilizer application and the stem +NG are partially contributed to the dry matter and P accumulated in grain. But in other field crop such as wheat both leaves and stem are the source of P and dry matter accumulation in grain [8].

Table- 4: Phosphorus accumulation (g m^2) in the leaves, stem + non grain reproductive (NG) tissues of the panicles, and in the grain of two varieties of oil seed flax at anthesis and maturity under four levels of phosphorus fertilization in 2016 under rain fed condition.

Variety	Phosphorus fertilizer kg ha-[1]	Anthesis			Maturity			
		Leaf	Stem +NG	Total	Leaf	Stem	Grain	Total
Poland	**0**	0.310 bc	0.280 b	0.590 b	0.207 ab	0.177 b	0.237 b	0.521 c
	100	0.477 bc	0.450 b	0.927 ab	0.390 ab	0.667 ab	0.455 b	1.512 bc
	200	1.120 ab	0.820 a	1.940 a	0.347 ab	0.777 ab	0.877 ab	2.011 ab
	300	0.840 bc	0.100 b	0.940 ab	0.280 ab	0.807 ab	0.950 b	2.037 ab
	0	0.030 c	0.320 b	0.350 b	0.083 b	0.227 b	0.243 b	0.553 c
	100	0.577 bc	0.267 b	0.844 ab	0.240 ab	0.420 ab	0.932 a	1.592 bc
Syria local	**200**	1.387 a	0.420 b	1.907 a	0.570 a	0.987 a	0.989 a	2.546 a
	300	0.837 bc	0.175 b	0.912 ab	0.270 ab	0.483 ab	0.837 ab	1.590 bc

Means followed by the same letter do not differ significantly at P < 0.05 by Duncan's new multiple range tests.

Dry matter translocation

DM that is accumulated before anthesis and translocated to grain at maturity was measured in two varieties in oil seed flax. As shown in table (5) Poland variety was translocated more DM from vegetative tissues at anthesis to grain post anthesis. The maximum values were obtained by fertilized Poland variety compared to control and Syria local. Poland translocated highest value of (2.154 g m^{-2}) DM at 200 kg P_2O_5 ha^{-1} compared to 1.753 g m^{-2} which was the highest value recorded for Syria local at 200kg P_2O_5 ha^{-1} . However, the lowest value was recorded by control plants for both cultivars. The same results for oil seed flax reported by Xie,Niu,et at., (2014) [24]. Also as shown in table(5) and (Fig. 1) the plant translocation efficiency was affected by P_2O_5 fertilization, the increased levels of fertilization increased translocation efficiency by (22.34 to 29.46 %) for Poland and by (31.8 to 38.18 %) for Syria local when levels of P_2O_5 increased from 100 to 200 kg P_2O_5 ha^{-1} , as a result the contribution of pre anthesis DM to the grain was impacted by P_2O_5 fertilization and the highest contribution was at 200kg P_2O_5 ha^{-1} with value of (53.57%) for Poland and (44.%) for Syria local compared to control.

Table- 5: Dry matter and P translocation, percent contribution of pre anthesis assimilates to the grain , and in two oil seed flax varieties as affected by P fertilization in 2016 under rainfed condition.

Variety	*Phosphorus fertilizerKg ha^{-1}*	*Dry matter*		*Phosphorus*	
		Translocation	*Contribution%*	*Translocation*	*Contribution%*
	0	*0.800 bc*	*50.00 d*	*0.103 cd*	*43.459 cd*
Poland	***100***	*1.627 ab*	*78.713 cd*	*0.087 d*	*18.241 e*
	200	*2.154 a*	*107.700 ab*	*0.773 ab*	*88.141 a*
	300	*2.120 a*	*144.512 a*	*0.560 bc*	*58.947 cd*
	0	*0.716 c*	*46.705 d*	*0.053 d*	*21.810 de*
	100	*1.277 ab*	*60.037 cd*	*0.317 cd*	*34.012 de*
Syria local	***200***	*1.753 ab*	*83.476 bc*	*0.817 a*	*82.719 b*
	300	*1.170 ab*	*81.646 bc*	*0.567 bc*	*67.741 c*

Means followed by the same letter do not differ significantly at P < 0.05 by Duncan's new multiple range tests.

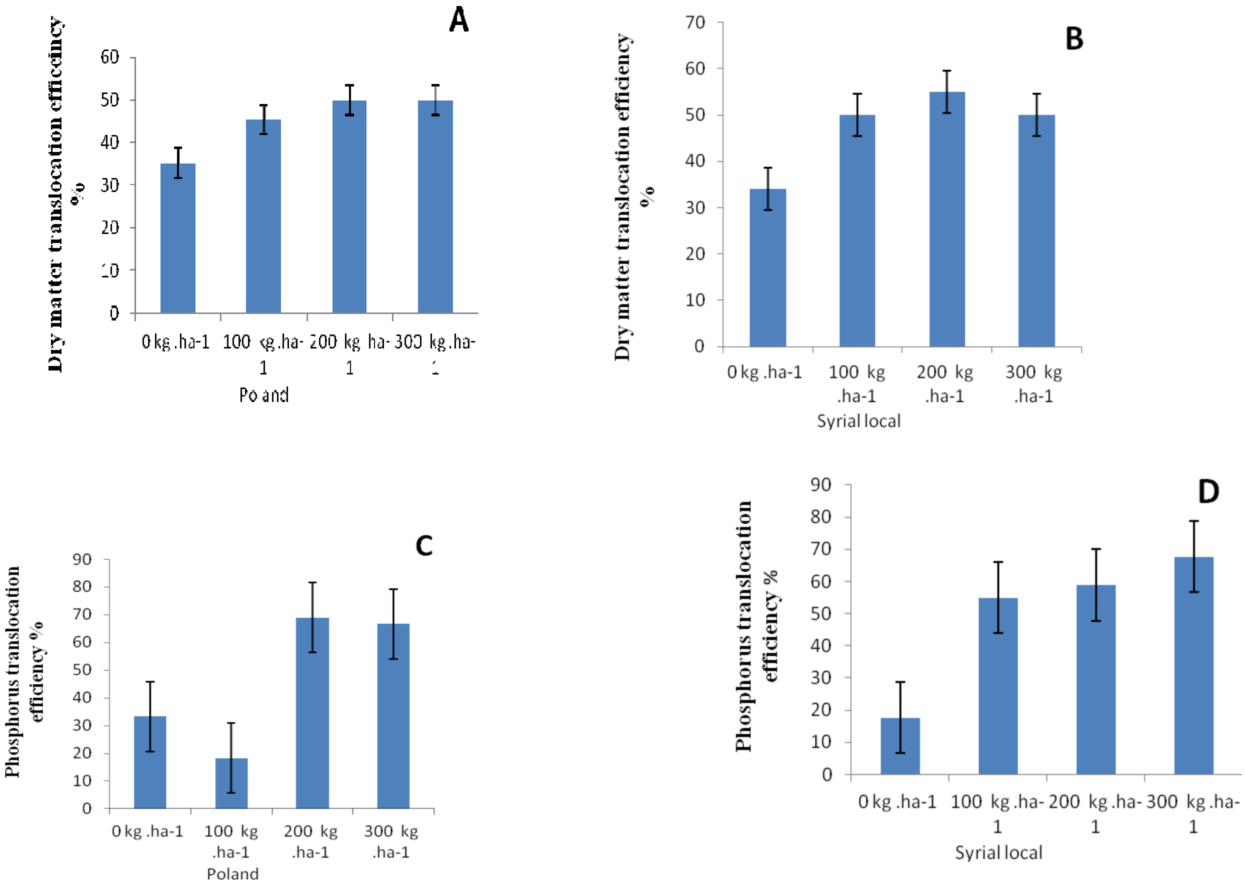

Figure- 1: Dry matter translocation efficiency in leaves of Poland (A) and Syria local (B) varieties &Translocation efficiency of P in leaves of Poland (C) and Syria local (D) varieties of oilseed flax , under (0, 100, 200 and 300kg $ha^{-1)}$, Bars represent standard error (SE)(n=4) .

Phosphorus translocation

In this study the pattern of P translocation from anthesis to grain similar to DM translocation from anthesis to the grain and also affected by P_2O_5 fertilization as in table (5) the highest amount of P translocation in the leaves were obtained at 200kg P_2O_5 ha^{-1} fertilization which increased by (86.68) in Polant and increased by (93.51 %) in Syria local as compared to control. As shown in (Fig.1) the P translocation efficiency were (51.86 and 70.02%) for Poland and Syria local respectively, at 200kg P_2O_5 ha^{-1} compared to control as a result the contribution of vegetative pre anthesis contribution to grain in both varieties increased by (50.69 and 73.63%) for Poland and Syria local respectively, at 200kg P_2O_5 ha^{-1} fertilization compared to control. the same result was reported in other crops such as wheat [8] and legumes [6].

Yield and yield components

Data presented in table (6) show that grain yield and some of yield components for both varieties were significantly affected by phosphorus fertilization $p < 0.05$. The greater grain yield and yield contributor (number of capsule per plant , weight of all capsule per plant, weight of empty capsule per plant, , grain yield) and biological yield in both cultivars were obtained at 200kg P_2O_5 ha^{-1} compared to control and other P_2O_5 levels with no increment when the level of P_2O_5 increased except of(number of grain per capsule, weight of one capsule with grain, and weight of 1000 grain) which were no significant difference found between two varieties plants and under the four levels of P_2O_5 fertilization. Over all, the 200kg P_2O_5 ha^{-1} Increased grain yield by (20%) in Poland and by (27%) in Syria local and increased biological yield by (27.16%) in Poland and by (29.72%) in Syria local, both compared to control plants. As mentioned earlier the increased levels of phosphorus fertilizer positively reflected on dry matter accumulation due to increased photosynthesis and translocation of photo assimilates and remobilization of P which led to increased in grain yield. In agreement with this study it has been frequently reported that phosphorus fertilization increased grain yield and biological yield in oil seed flax [1, 12, and15].

Table- 6.:yield and yield components in two oil seed flax varieties as affected by different levels of phosphorus fertilization under rainfed condition.

Variety	Phosphorus fertilizer Kg ha^{-1}	Weight of all empty capsule. (g $plant^{-1}$)	Weight of all capsule with seeds (g $plant^{-1}$)	Number of all capsule. $plant^{-1}$	Weight of one capsule with seeds (g)	Number of seeds one $capsule^{-1}$	Weight of seeds. one capsule (g)	Weight of 1000 grain (g)	grain yield (g $plant^{-1}$)	Biological yield (g $plant^{-1}$)
Poland	0 control	0.607 c	2.207 c	13.000 c	0.063 a	10.000 a	0.047 a	4.667 b	1.600 bc	211.59 bc
	100	1.080 ab	3.147 ab	17.667 ab	0.063 a	8.000 ab	0.047 a	5.867 ab	2.067 ab	245.203 ab
	200	1.183 ab	3.183 a	18.000 a	0.063 a	7.333 b	0.043 a	5.950 ab	2.000 ab	290.493 a
	300	1.283 a	2.750 bc	18.667 a	0.077 a	9.000 a	0.057 a	6.380 a	1.467 bc	291.676 a
Syria local	0	0.897 bc	2.430 bc	13.000 c	0.073 a	8.333 ab	0.053 a	6.420 a	1.533 bc	195.984 c
	100	0.930 bc	3.057 ab	12.667 c	0.070 a	8.000 ab	0.050 a	6.400 a	2.127 a	263.267 ab
	200	1.060 ab	3.160 ab	15.000 bc	0.070 a	9.000 a	0.053 a	5.900 ab	2.100 ab	278.873 ab
	300	1.053 ab	2.486 bc	14.000 bc	0.070 a	7.667 b	0.047 a	5.867 ab	1.433 c	192.029 c

Means followed by the same letter do not differ significantly at $P < 0.05$ by Duncan's new multiple range tests

Conclusion

From the results obtained in this study it can be concluded that the application of phosphorus fertilization in the form of P_2O_5 increased the dry matter accumulation, dry matter translocation, P accumulation and P translocation from vegetative tissues pre anthesis to the grain in oil seed flax under rainfed condition in Sulaimani province. As a result of increased dry matter and P accumulation and translocation the grain and biological yield increased, therefore phosphorus fertilizer impacted the source – sink relationship in oil seed flax. The highest values of dry matter and P accumulation, biological yield and grain yield were obtained by Poland cultivar at 200 kg P_2O_5 ha^{-1} compared to Syria local and other levels of P_2O_5 fertilization. This is the first results reported on oilseed flax grown under rainfed condition in Sulaimani province under the effect of P_2O_5 fertilization, so that other experiments should carry out on other oil seed flax cultivars and other levels and forms of phosphorus fertilizer should take into account. In addition, the advanced techniques may be used to quantify the amount of P remobilized from vegetative tissues to grain.

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