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Response of some Rapeseed (*Brassica napus* L.) varieties to Zn fertilizer Under Dryfarming Conditions

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Abstract

This investigation was conducted during the winter seasons of 2016-2017 at The Qlyasan Agricultural Research Station, College of Agricultural Sciences, University of SuLAmani, using split plot design the main plots conducted in Randomized Complete Block Design (RCBD) with three replicates to study the effect of three levels of zinc fertilizer on the growth, yield and yield component of rapeseed varieties. The three varieties; Serw, Hybrid and Reandy were implemented in the main plots, three zinc fertilizer levels (0, 20 and 40) kg Zn/ha from $ZnSO_4$ source, were implemented in the subplot. Comparisons between means were carried out by the leaset significant difference (L.S.D) at 1 % and 5 % level of significance.
The results of this investigation confirm that variety Reandy produced the best values for most characters, and the application 40Kg Zn/ha was found to be the best level for this crop. The character seed yield showed positive and highly significant correlation with most characters including plant height, number of leaves per plant, number of pods per plant, the weight of pod per plant, average pod weight, 1000-seed weight, dry matter weight per plant and biological yield.
The maximum positive direct effect on seed yield recorded by an average pod weigh with 0.898, while the maximum positive indirect effect on seed yield recorded by biological yield *via* average pod weight with 0.840.

Introduction:

Rapeseed (*Brassica napus* L.) is one of the important oil seed crops throughout the world which ranks third among the oil seed crops after soybean and palm in the production of vegetable oils, while fifth in the production of oilseed proteins. Rapeseed oil is used widely as cooking and salad oil, and in making margarine. It has the lowest saturated fat content of all edible vegetative oils available today ***[1]***, ***[2]***, ***[3]***, and ***[4]***. Apart from its role in direct feeding by humans and animals, it has expanded globally industrial use, including oil producing factories or as a source of bio-fuel in recent years ***[5]***.
Obtaining greater cultivated area of canola is limited due to competition with other crops like wheat, corn fodder and rice ***[6]***. Therefore, it is suggested that instead of increasing cultivated area the yield per hectare must be improved. Higher yield per unit area can be achieved by improving modern cultural practices with better macro and Micronutrient management. Optimum use of fertilizers, their type and

method of application play an important role in sustainable crop production ***[6]***. Zinc is one of the essential micro nutrients for plants, animals and human ***[7]***. Microelements are defined substances that are crucial for crop growth; however, they are used in lower amounts as compared to macronutrients, such as N, P and K ***[8]***. Zinc is an essential micronutrient and plays a key role as a structural constituent or regulatory cofactor of a wide range of different enzymes and proteins in many important biochemical pathways like carbohydrate metabolism, photosynthesis, conversion of sugars to starch, protein metabolism, auxin (growth regulator) metabolism, pollen formation, integrity of biological membranes and resistance to infection by certain pathogens ***[9]***. Zinc is needed in small, but critical concentrations and if the amount available is not adequate, plants will suffer from physiological stress. Under Zinc deficient conditions, flowering and fruit development is reduced, and growth period is prolonged resulting in delayed maturity, leading to lower yield, poor quality and suboptimal nutrient use efficiency. Recent research has shown that a small amount of nutrients, particularly Zn, Fe and Mn applied by foliar spraying significantly increased the yield of crops ***[10]*** and ***[11].*** Zinc is an essential trace element in proteins synthesis and amino acids accumulation in plant tissues, protein synthesis will reduce by Zn deficit in plants which indicates that Zn is the main composition of ribosome. Zn also contributes in the tips of the pollen tube and had a great impact on the pollination ***[12], [13]*** and ***[14]***. Zn increased Rapeseed yield and oil content by developing root system and increasing leaf area to stimulate tryptophan, precursor of Indole acetic acid (IAA), promoting photosynthesis ***[15]***. Zinc is also required for chlorophyll production, pollen function and fertilization and zinc deficiency also affects carbohydrate metabolism, damages the pollen structure, and decreases the yield ***[14]***. Narimani *et al.* (2010) reported that foliar application of microelements improved the effectiveness of macronutrients ***[16]***. Different varieties of rapeseed and zinc fertilizer are the most important factors in limiting rapeseed growth, yield and seed oil percentage formation ***[17]***.

The aim of the present study is to investigate recognize the effect of genotypes and Zn- fertilizer levels on the growth, yield and its related components under SuLAmani conditions.

Materials and Methods:

This study investigated in SuLAmani region, at The Qlyasan Agricultural Research Station, College of Agricultural Sciences, University of SuLAmani (Latitude 35° 34′ 307″ ; N, Longitude 45° 21′ 992″ ; E, 765 MASL), located 2 km North West of SuLAmani city during the winter seasons of 2016-2017.The meteorological data of Bakrajo location is shown in Table (1). The experimental area plots were ploughed twice, harrowed and well leveled. A brief account of some physical and chemical properties of the experimental soil is given in Table (2).

Three rape seed varieties were selected for cultivation, which has been provided by The Baghdad Agricultural Research Center, namely; **Serw**, **Hybrid** and **Reandy**. The experiment was arranged as split-plot layout. The varieties were implemented in the main plots and conducted with Randomized Complete Block Design (RCBD), different levels of Zinc fertilizer (0, 20 and 40 Kg Zn/ha) from Zinc sulfate ($ZnSO_4$) were implemented in the subplots. Each main plot was consisted of three subplots with four rows each, four meters long and 0.25 meter apart. Seed cultivated at rate 12 Kg/ha. The cultural operations and weed control were accomplished according to normal field practices. Half of recommended dose of fertilization were added to the whole experiment which were 80 Kg Nitrogen/ha as urea and divided into two equal doses and were applied at the seeding time and after 20 days from germination also 100 Kg P_2O_5/ha as triple super phosphate (TSP) was applied at the seeding time.

The LSD test was done to find the significant differences between treatment means at 5% probability level. Mature plants were harvested on July 20, of 2017 for estimating seed yield, yield components and growth rate.

Table 1: 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*

Table 2: Physical and chemical properties of the studied soil

Soil properties	***Values***
Texture Class	*Clay*
Sand (g kg^{-1})	*41.0*
Silt (g kg^{-1})	*430.50*
Clay (g kg^{-1})	*528.50*
EC (dS m^{-1})	*0.61*
pH	*7.32*
OM (g kg^{-1})	*21.60*
$CaCO_3$ (g kg^{-1})	*107.0*
Total N (mg kg^{-1})	*1.07*
K+ (mmoles l^{-1})	*0.32*
Na+ (mmoles l^{-1})	*0.41*
Ca++ (mmoles l^{-1})	*1.49*
Cl^{-} (mmoles l^{-1})	*0.57*

Studied Characteristics:

The studied characters were:

- ***Plant height (cm):*** At Maturity, the mean height of the plant from ground level to the tip of five plants were recorded.
- ***No. of leaves per plant:*** At Maturity, the mean number of leaves per plant of the five plants was recorded.
- ***No. of pods per plant:*** At Maturity, the mean number of pods per plant of the five plants was recorded.
- ***Weight of pods per plant (g):*** At Maturity, the mean of pods weight of the five plant samples was recorded.
- ***Pod Legth (cm):*** At Maturity, the mean length of pods of the five plants was recorded.
- ***Average pod weight (g):*** At Maturity, the weight of pods of five plants was averaged and recorded.
- ***Number of seeds per pod:*** At Maturity, the mean number of seeds per pods of five plants was counted and recorded.
- ***1000 seed weight (g):*** At maturity, 100 seeds were weighted then multiplied by (10) and recorded as 1000-seed weight.

- ***Dry matter (g/plant):*** At 50% flowering, the mean weight of five plant sample were dried in oven for 48 houres in 65 ^{o}C then weighted and recorded.
- ***LA:*** At 50% flowering, the mean of leaves aria (mm^2) of the five plant samples was measured by Leaf Area Meter (AREA METER AM100, ADC BIOSCIENTIFIC LTD) and converted to (cm^2) then recorded.
- ***Harvest Index:*** Measured at Maturity by separating the seeds from the other parts of the plant and weighed to calculate the H.I. according to the following equation:

$$\text{H.I.} = \frac{\text{Seed yield (Tons/ha)}}{\text{Biological yield (Tons/ha)}}$$

- ***Biological yield (t/ha):*** At Maturity, the mean of weight of the five plant samples without the roots was recorded in each plot (g/plant) and converted to (t/ha).
- ***The Oil Percentage (%):*** Seeds of five plants sample were milled to determined oil content by soxhlet extraction method by using Diethyl Ether ($CH_3CH_2OCH_2CH_3$) ***[18]***.
- ***Seed yield (t/ha):*** At Maturity, the mean of seeds weight of the five plant samples was recorded in each plot (g/plant) and converted to (t/ha).

Correlation Analysis:

The correlation coefficient was conducted to determine the degree of association of characters with seed yield and also among all the criteria studied. Phenotypic correlations were computed between the characters in the growing season using the formula given by Singh and Chaudhary (1985) ***[19]***.

Path Coefficient Analysis:

The path coefficient analysis was carried out as suggested by Dewey and Lu (1959) ***[20]***. Seed yield was kept as resultant variable and other characters as causal through (Analysis of Moment Structures) AMOS Ver. 18 Software.

Results and Discussion:

Data in Table (3) and appendix (1) confirm that the differences among varieties were highly significant for the studied criteria number of leaves per plant, number pods per plant, weight of pod per plant g, pod length, number of seeds per pod, 1000 seed weight, dry matter weight, and seed yield, while it was significant for the character's plant high, average pod weight and oil percentage. It was observed that the variety **Reandy** were recorded maximum values with 82.489 cm, 15.644, 55.111, 4.966 g, 5.860 cm, 23.118, 3.536 g, 0.888 g and 3.395 t/ha for the character's plant high, number of leaves per plant, number of pods per plant, weight of pod per plant, pod length, number of seeds per pod, 1000 seed weight, dry matter weight, and seed yield respectively. The variety **Serw** produced minimum values for almost all of the characters excepted number of seeds per pod, recording 65.380 cm, 11.126, 34.333, 3.387 g, 5.313 cm, 3.067 g, 0.459 g, 41.004 % and 2.510 t/ha for the character's plant high, number of leaves per plant, number of pod per plant, weight of pod per plant, pod length cm, 1000 seed weight, dry matter weight, oil percentage and seed yield respectively. Different varieties of rapeseed affect the quality and quantity of rapeseed growth, yield and oil percentage formation production, which was typically characteristic of a species, The genetic variations among the varieties under the study may lead to the variation in their responses to the use of different levels of Zn fertilizer. This finding was closely related to Banna, (2011) and Ryan *et al.* (2009) who stated that there were significant differences among rapeseed genotypes in their seed weight and other characters ***[21]***, ***[22]*** and ***[23]***.

The effect of Zn fertilizer application was found to be highly significant for all characters except harvest index and oil percentage which were significant only (Table 4 and Appendix 1).The application of 40 Kg/ha recorded the best values for all characters except the character LA, recording 86.769 cm, 15.978, 59.667, 5.528 g, 5.900 cm, 0.238 g, 22.994, 3.570 g, 0.998 g, 9.420 t/ha and 3.928t/ha for the characters plant high, number of leaves per plant, number of pod per plant, weight of pod per plant, pod length, average pod weight, number of seed per pod, 1000 seed weight, dry matter weight, biological yield and seed yield respectively, while the control treatment recorded the maximum value for the character oil percentage with 41.364 % but gave the lowest values for the other characters with 61.706 cm, 9.592, 32.000, 2.620 g, 5.478 cm, 0.133 g, 16.651, 3.021,0.343 g, 84.497 cm2, 3.754 t/ha and 1.862 t/ha for plant high, number of leaves per plant, number of pod per plant, weight of pod per plant, pod length, average pod weight, number of seed per pod, 1000 seed weight, dry matter weight, LA, harvest index, biological yield and seed yield respectively. Zn is known to have an important role either as a metal component of enzymes or as a functional, structural or regulatory cofactor of a large number of enzymes ***[11]***. Sharifi (2012) reported a significant effect of chemical fertilizer on plant height on canola plants ***[24]***. Enhancement in plant height with the increased use of chemical fertilizer can be related to increases the length of plant cells on main stem ***[25]***. Recent research has shown that a small amount of nutrients, particularly Zn, Fe and Mn applied by foliar spraying will significantly increase the yield of rapeseed ***[10]*** and ***[11]***. Narimani *et al.(2010)* reported that microelements foliar application improve the effectiveness of macronutrients and foliar application of Zn, Mg, Mn and Fe significantly increased growth parameters, yield and its components ***[17]*** and ***[26].*** Application of Zn or Fe has been reported significant positive effects, in most cases, on growth measurements and chemical composition ***[26]***, ***[27]***, and ***[28]***.

Data in Table (5) and Appendix (1) confirm that the interaction between varieties and zinc application levels was highly significant only for the character oil percentage and were significant for the characters number of seeds per pod and seed yield. Regarding the characters of number of seeds per pod the interaction between **Reandy** and 40 Kg/ha of zinc fertilizer recorded maximum number of seed per pod reached 26.507 pods, while the minimum number of seeds per pod was 15.483 seeds recorded by the variety **Serw** and the control treatment. The interaction effect of the variety **Hybrid** with 20 Kg Zn records the maximum oil percentage of 44.190 %, while the variety **Reandy** with the same level of Zn records the minimum oil percentage of 35.722 %. Concerning the character seed yield, the interaction between the variety **Reandy** and the application of 40 Kg/ha recorded maximum yield with 5.120 t/ha, while the interaction between the variety **Serw** and the control treatment recorded the lowest value of seed yield with 1.560 t/ha.

Data in Table (6) expLAn the correlation coefficient among studied characters. Plant height exhibited positive and highly significant correlation with the number of leaves per plant, number of pods per plant, weight of pods, average weight pod, number of seeds per pod, 1000 seed weight , dry matter weight, LA, biological yield and seed yield, but it correlated positively and significantly with pod length and negatively and significantly with harvest index and LA. Number of leaves per plant recorded positive and highly significant correlation with number of pods per plant, weight of pods per plant, average weight pod, number of seeds per pod, 1000 seed weight, dry matter weight, biological yield and seed yield, but it correlated negatively and positively with harvest index. Number of pods per plant recorded positive and highly significant correlation with weight of pods per plant, pod length, number of seeds per pod, 1000 seed weight, dry matter weight per plant, biological yield and seed yield, while it correlated positively and significantly with average pod weight and LA. The characters weight of pod per plant gave positive and highly significant correlation with average pod weight, number of seed per pod, 1000 seed weight, dry matter weight, biological yield and seed yield, while it correlated apositive and significantly with pod length and LA. The characters pod length produced a positive and significant correlation with the number of seeds per pod, 1000 seed weight, dry matter weight, biological yield and seed yield. The character average pod weight recorded positive and highly significant association with the number of seed per pod, dry matter weight, LA, biological yield and seed yield, while it correlated negatively and high significantly with harvest index, and it correlated positively and significantly with 1000 seed weight. Positive and highly significant correlation was recorded between the number of seeds per pod and seed weight, dry matter weight and biological yield, while the correlation between number of seeds per pod with LA and seed yield were positive and significant, while the negative and significant correlation was recorded between the number of seeds per pod and harvest index and oil percentage. The character 1000 seed weight recorded positive and highly significant correlation with dry matter weight and biological yield and seed yield, while it correlated positively and significantly with LA. Positive and highly significant correlation was recorded between dry matter weight and LA, biological yield and seed yield, while it correlated negatively and significantly with harvest index. LA produced positive and highly significant correlation with biological yield and positive and significant correlation with seed yield, but it correlated negatively and significantly with harvest index. The character harvest index produced a negative and significant correlation with biological yield. Biological yield recorded positive and highly significant correlation with seed yield. There are several reports on the correlation of *Brassica* species, in most of these studies pod per plant and number of pods on the main stem had a significant positive correlation with seed yield ***[29], [30], [31], [32],*** and ***[33]***.

Data in Table (7) illustrate the path coefficient analysis between seed yield and other characters. Characters plant height recorded the highest positive direct effect on seed yield reached 0.872, while maximum negative direct effect value of seed yield recorded by 1000 seed weight reached -0.387.

The characters dry matter, number of leaves per plant, 1000 seed weight, biological yield, weight of pods per plant, number of seeds per pod, number of pods per plant, average pod weight, LA, pod length recorded high positive indirect effect on seed yield via the character plant height with 0.847, 0.844, 0.819, 0.798, 0.777, 0.775, 0.772, 0.713, 0.706, 0.659 respectively, while the character harvest index and oil percentage recorded high negative indirect effect also *via* plant height with -0.623 and -0.505 respectively. These results indicated the importance of plant height can be used in indirect selection for seed yield and oil content improvement. Almost similar results are given by Rameeh (2011), while these results are also partial agreement with the earlier findings of Dar *et al.* (2010); Tahira *et al.* (2012) ***[34], [35],*** and ***[36]***.

Conclusion:

It was observed that the variety **Reandy** were recorded maximum values alomost all of the studied characters. The application of 40 Kg/ha recorded the best values for almost all of the studied characters, while the control treatment recorded the maximum value for the character oil percentage only. Plant height was the character with a maximum potential of selection for seed yield improvement and also can be used for increasing the oil content because this character possessed highly significant positive correlation and maximum positive direct effects with seed yield. Almost all of the characters had a high positive indirect effect via this character.

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Table -3: The averages of Rapeseed varieties for the studied characters

Varieties	Pant height (cm)	No. of leaves /plant	No. of pods/ plant	Weight of pods/ plant (g)	Pod length (cm)	Average pod weight (g)	No. of seeds/ pod	1000 Seed weight (g)	Dry matter (g/plant)	LA (cm²/ plant)	HI	Biol. yield (t/ha)	Oil %	Seed yield (t/ha)
Serw	65.380	11.126	34.333	3.387	5.313	0.191	18.539	3.067	0.459	128.671	0.454	5.787	41.004	2.510
Hybrid	77.283	13.544	42.889	3.572	5.554	0.176	18.413	3.329	0.700	139.636	0.449	6.207	40.888	2.648
Reandy	82.489	15.644	55.111	4.966	5.860	0.204	23.118	3.536	0.888	157.464	0.453	7.653	38.966	3.395
L.S.D ($P \leq 0.05$)	**10.713**	**2.321**	**9.776**	**0.844**	**0.290**	**0.017**	**1.929**	**0.237**	**0.133**	**n.s**	**n.s**	**n.s**	**1.450**	**0.425**
L.S.D ($P \leq 0.01$)	**n.s**	**3.198**	**13.469**	**1.163**	**0.399**	**n.s**	**2.658**	**0.327**	**0.183**	**n.s**	**n.s**	**n.s**	**n.s**	**0.585**

Table- 4: Zn-fertilizer levels effect on the studied characters.

Zn-fertilizer (Kg/h)	Pant height (cm)	No. of leaves /plant	No. of pods/ plant	Weight of pods/ plant (g)	Pod length (cm)	Average pod weight (g)	No. of seeds/ pod	1000 Seed weight (g)	Dry matter (g/plant)	LA (cm²/ plant)	HI	Biol. yield (t/ha)	Oil %	Seed yield (t/ha)
0	61.706	9.592	32.000	2.620	5.478	0.133	16.651	3.021	0.343	84.497	0.514	3.754	41.364	1.862
20	76.678	14.744	40.667	3.777	5.350	0.200	20.424	3.340	0.706	176.748	0.426	6.473	40.039	2.763
40	86.769	15.978	59.667	5.528	5.900	0.238	22.994	3.570	0.998	164.527	0.417	9.420	39.455	3.928
L.S.D ($P \leq 0.05$)	**10.713**	**2.321**	**9.776**	**0.844**	**0.290**	**0.017**	**1.929**	**0.237**	**0.133**	**31.624**	**0.076**	**1.673**	**1.450**	**0.425**
L.S.D ($P \leq 0.01$)	**14.761**	**3.198**	**13.469**	**1.163**	**0.399**	**0.024**	**2.658**	**0.327**	**0.183**	**43.571**	**n.s**	**2.305**	**n.s**	**0.585**

Table- 5: The interaction effects of rapeseed varieties and Zn-fertilizer level on the studied characters.

Varieties × Zn- fertilizer	***Pant height (cm)***	***No. of leaves /plant***	***No. of pods/ plant***	***Weight of pods/ plant (g)***	***Pod length (cm)***	***Average pod weight (g)***	***No. of seeds/ pod***	***1000 Seed weight (g)***	***Dry matter (g/plant)***	***LA (cm²/ plant)***	***HI***	***Biol. yield (t/ha)***	***Oil %***	***Seed yield (t/ha)***
Serw × 0	*51.900*	*7.743*	*30.000*	*2.290*	*5.190*	*0.120*	*15.483*	*2.787*	*0.207*	*68.247*	*0.520*	*2.997*	*43.107*	*1.560*
Serw × 20	*69.700*	*12.400*	*35.667*	*3.780*	*5.313*	*0.220*	*19.750*	*3.157*	*0.510*	*185.747*	*0.440*	*6.617*	*40.204*	*2.853*
Serw × 40	*74.540*	*13.233*	*37.333*	*4.090*	*5.437*	*0.233*	*20.383*	*3.257*	*0.660*	*132.020*	*0.403*	*7.747*	*39.700*	*3.116*
Hybrid × 0	*68.350*	*10.133*	*28.667*	*2.433*	*5.547*	*0.130*	*16.680*	*3.010*	*0.330*	*85.800*	*0.500*	*3.915*	*39.624*	*1.833*
Hybrid × 20	*74.167*	*14.067*	*37.333*	*3.173*	*5.063*	*0.170*	*16.467*	*3.407*	*0.670*	*162.883*	*0.450*	*5.770*	*44.190*	*2.563*
Hybrid × 40	*89.333*	*16.433*	*62.667*	*5.110*	*6.053*	*0.227*	*22.093*	*3.570*	*1.100*	*170.223*	*0.397*	*8.937*	*38.851*	*3.547*
Reandy × 0	*64.867*	*10.900*	*37.333*	*3.137*	*5.697*	*0.150*	*17.790*	*3.267*	*0.493*	*99.443*	*0.523*	*4.350*	*41.362*	*2.193*
Reandy × 20	*86.167*	*17.767*	*49.000*	*4.377*	*5.673*	*0.210*	*25.057*	*3.457*	*0.937*	*181.613*	*0.387*	*7.033*	*35.722*	*2.873*
Reandy × 40	*96.433*	*18.267*	*79.000*	*7.383*	*6.210*	*0.253*	*26.507*	*3.883*	*1.233*	*191.337*	*0.450*	*11.576*	*39.814*	*5.120*
L.S.D $_{(P\leq0.05)}$	***n.s***	***n.s***	***n.s***	***n.s***	***n.s***	***n.s***	***3.341***	***n.s***	***n.s***	***n.s***	***n.s***	***n.s***	***2.511***	***0.736***
L.S.D $_{(P\leq0.01)}$	***n.s***	***n.s***	***n.s***	***n.s***	***n.s***	***n.s***	***n.s***	***n.s***	***n.s***	***n.s***	***n.s***	***n.s***	***3.460***	***n.s***

Table- 6: Correlation analysis among the studied characters

Characters	*Pant height (cm)*	*No. of leaves /plant*	*No. of pods/ plant*	*Weight of pods/ plant (g)*	*Pod length (cm)*	*Average pod weight (g)*	*No. of seeds/ pod*	*1000 Seed weight (g)*	*Dry matter (g/plant)*	*LA (cm²/ plant)*	*HI*	*Oil %*	*Biol. yield (t/ha)*
No. of leaves/plant	0.968**												
No. of pods/plant	0.885**	0.836**											
Weight of pods/plant (g)	0.892**	0.849**	0.961**										
Pod length (cm)	0.752*	$0.633^{n.s}$	0.850**	0.793*									
Average pod weight (g)	0.817**	0.823**	0.731*	0.857**	$0.539^{n.s}$								
No. of seeds/pod	0.888**	0.896**	0.853**	0.902**	0.762*	0.838**							
1000 Seed weight (g)	0.940**	0.928**	0.909**	0.905**	0.725*	0.771*	0.817**						
Dry matter (g/plant)	0.971**	0.963**	0.937**	0.920**	0.759*	0.825**	0.886**	0.960**					
LA (cm² /plant)	0.810**	0.876**	0.668*	0.740*	$0.370^{n.s}$	0.854**	0.755*	0.786*	0.802**				
HI	-0.715*	-0.778*	$-0.452^{n.s}$	$-0.527^{n.s}$	$-0.265^{n.s}$	-0.803**	-0.671*	$-0.553^{n.s}$	-0.693*	-0.767*			
Oil %	$-0.580^{n.s}$	$-0.573^{n.s}$	$-0.378^{n.s}$	$-0.418^{n.s}$	$-0.572^{n.s}$	$-0.501^{n.s}$	-0.733*	$-0.352^{n.s}$	$-0.493^{n.s}$	$-0.409^{n.s}$	$0.620^{n.s}$		
Biological yield (t/ha)	0.915**	0.875**	0.904**	0.970**	0.707*	0.935**	0.873**	0.898**	0.927**	0.806**	-0.674*	$-0.425^{n.s}$	
Seed yield (t/ha)	0.884**	0.837**	0.926**	0.988**	0.726*	0.885**	0.855*	0.907**	0.903 **	0.767*	$-0.544^{n.s}$	$-0.343^{n.s}$	0.985**

**. Correlation is significant at the 0.05 level (2-tailed),* $t_{0.05}(7) = 2.365$
***. Correlation is significant at the 0.01 level (2-tailed),* $t_{0.01}(7) = 3.499$

Table- 7: Path coefficient analysis among the studied characters

Characters	Pant height (cm)	No. of leaves /plant	No. of pods/ plant	Weight of pods/ plant (g)	Pod length (cm)	Average pod weight (g)	No. of seeds/ pod	1000 Seed weight (g)	Dry matter (g/plant)	LA (cm²/ plant)	HI	Oil %	Biol. yield (t/ha)
Pant height (cm)	**0.872**	0.844	0.772	0.777	0.656	0.713	0.775	0.819	0.847	0.706	-0.623	-0.505	0.798
No. of leaves/plant	0.000	**0.000**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
No. of pods/plant	0.000	0.000	**0.000**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Weight of pods/plant (g)	0.000	0.000	0.000	**0.000**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pod length (cm)	0.016	0.013	0.018	0.017	**0.021**	0.011	0.016	0.015	0.016	0.008	-0.006	-0.012	0.015
Average pod weight (g)	0.565	0.568	0.505	0.592	0.372	**0.691**	0.579	0.533	0.570	0.590	-0.555	-0.346	0.646
No. of seeds/pod	0.418	0.421	0.401	0.424	0.358	0.394	**0.470**	0.384	0.417	0.355	-0.315	-0.344	0.410
1000 Seed weight (g)	-0.364	-0.359	-0.352	-0.350	-0.281	-0.298	-0.316	**-0.387**	-0.372	-0.304	0.214	0.136	-0.347
Dry matter (g/plant)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**	0.000	0.000	0.000	0.000
LA (cm² /plant)	-0.099	-0.107	-0.081	-0.090	-0.045	-0.104	-0.092	-0.096	-0.098	**-0.122**	0.094	0.050	-0.098
HI	-0.262	-0.286	-0.166	-0.194	-0.097	-0.295	-0.246	-0.203	-0.254	-0.282	**0.367**	0.228	-0.247
Oil %	-0.261	-0.259	-0.171	-0.189	-0.258	-0.226	-0.331	-0.159	-0.222	-0.184	0.280	**0.451**	-0.192
Biological yield (t/ha)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**
Seed yield Correlation	**0.884** **	**0.837** **	**0.926** **	**0.988** **	**0.726** *	**0.885** **	**0.855** *	**0.907** **	**0.903** **	**0.767** *	**-0.544** n.s	**-0.343** n.s	**0.985** **

Appendix- 1: Mean squares of variance analysis for the studied characters

S.O.V	d.f	Pant height (cm)	No. of leaves/ plant	No. of pods/ plant	Weight of pods/ plant (g)	Pod length (cm)	Ave. pod weight (g)	No. of seeds/ pod	1000 Seed weight (g)	Dry matter (g/ plant)	LA (cm²/ plant)	HI	Oil %	Biol. yield (t/ha)	Seed yield (t/ha)
Blocks	*2*	*0.534*	*2.119*	*41.444*	*0.050*	*0.028*	*0.0001*	*3.572*	*0.014*	*0.004*	*353.077*	*0.002*	*1.587*	*0.128*	*0.119*
Varieties	*2*	*692.252* *	*46.022* **	*981.444* **	*6.703* **	*0.676* **	*0.0019* *	*64.671* **	*0.497* **	*0.416* **	*1900.717* n.s	*0.000* n.s	*11.791* *	*8.624* n.s	*2.043* **
Zn-Fertilizer	*2*	*1431.253* **	*103.263* **	*1802.333* **	*19.289* **	*0.746* **	*0.0252* **	*91.621* **	*0.684* **	*0.967* **	*22596.636* **	*0.026* *	*8.615* *	*72.274* **	*9.655* **
Varieties × Zn-Fertilizer	*4*	*62.510* n.s	*2.106* n.s	*282.278* n.s	*1.763* n.s	*0.156* n.s	*0.0007* n.s	*12.817* *	*0.024* n.s	*0.028* n.s	*995.106* n.s	*0.003* n.s	*25.988* **	*2.785* n.s	*0.843* *
Exp. Error	***16***	***114.930***	***5.395***	***95.694***	***0.713***	***0.084***	***0.0003***	***3.725***	***0.056***	***0.018***	***1001.426***	***0.006***	***2.105***	***2.803***	***0.181***