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Evaluation of Leaf Yield of Rocket (*Eruca sativa* Mill.) for use as Salad Vegetable in Iran

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Abstract: This experiment was carried out to examine cultivation of Rocket as a salad vegetable in non -heated greenhouse and its surrounding fieldsat Khoy-Iran. Experiments werecarried out as fall and spring cultivations and in terms of complete randomizedblock design using three replicates. Seeds were sown in fall on 1st, 15th and 30th of September and in spring on 1st, 15th and 30th of April. Delayed fall cultivationresulted in showed time from germinationto harvesting was increased with decreased temperature. In delayed spring cultivations, in both seasons, growth duration in greenhouse was longer compared to field conditions. In terms of plant growth and yield in bothenvironments and seasons, earlier cultivation datehad superiority. In fall cultivations, decrease of temperaturecauseddecrease of plant yield, while in delayed spring cultivations, decrease in plant yieldcould be attributed to an increase in day length and temperature whichcaused earlier flowering and premature harvesting. The maximum yield belonged to field in fall cultivation and greenhouse in spring cultivation. The results of this researchapprovecultivation of rocket in fall and spring of Khoy region and similar climate regions under field and non- heated greenhouse conditions.

Key words: Rocket · Sowing date · Greenhouse · Field · Yield

INTRODUCTION

Rocket (*Eruca sativa*, *syn. E. vesicaria subsp. sativa* Miller Thell., *Brassica eruca* L.) is a perennial plant rocket of the *Brassicaceae* family that is grown in cold regions [1, 2]. Rocket is a native plant of the Mediterranean and west of Asia regions, from Morocco and Portugal in the west to Syria, Lebanon and Turkey in the east [3, 4, 5]. Different parts of Rocket specially seeds are used as medicinal plants are used as appetizer, anti-cough, body amplifier actuator, aphrodisiac and cancer prevention [6, 7, 8]. Also, Rocket in most places of the world like southern Europe and Asia is grown as herb and oil plant [9]. Rocket has low level of glucosinolate in leaves. It is cultivated as fresh herb and green foodin Mediterranean countries [10, 11, 12, 13]. It is also used as cooked as vegetable (Bianco; 1995). Rocket is suitable for planting in the field, as well as greenhouse [14] and is cultured in the fall and spring seasons [15] or both [9, 12]. Rocket was used as a oil plant in Iran. But, nowadays it is not cultivated weed in wheat fields [16]. Available literature shows little information about rocket plant studies in Iran as medicinal plant as weed or as fresh herb in food culture [17, 18, 19, 20, 21, 22]. This study aimed to evaluate Arugula cultivationfor salad leaf yield in Iran.

MATERIALS AND METHODS

This study was carried out using completely randomized blocks design with three replicates in the non- heated greenhouse and its nearby fields at Khoy (Longitude: 44°28', Latitude: 38°56' and Altitude: 1139 m, West Azerbaijan-Iran) during fall 2014- spring 2015. Seeds were sown in fall on September 1, 15 and 30 and in spring on April 1, 15 and 30. Each experimental plot area consisted of $2m^2$, where seeds were cultivated in 5 rows with 20 cm row distance, 6.5-7 cm on plant to plant distance using 150 plants per plot. Nitrogen (Ammonium nitrate33% N) was used at rate of 100 kg per ha, phosphorus (Triple superphosphate 46% P_2O_5) at the rate of 100 kg per ha and potassium (Potassium sulfate 50% K_2O) at the rate of 10 kg per ha were mixed with soil in sowing stage. Irrigation was done by drop method. Weeds were manually removed using hands without

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using herbicides and insecticides. Plants were harvested along with roots after maximum physiological growth (in spring cultivate, before flowering) manually. For decrease of marginal effects, samples were harvested and were measured form 3 middle rows selecting 5 plant per row (totally 15 plant/plot). After morphological studies, samples were placed for 5 days at 70°C in oven to determine percentage of dry material. Concentration of nitrate was measured using 2, 4 Xylenol method [23].

RESULTS

Duration of germination (50% germination of seeds) and growth period in fall and spring sowingduring 2014 and 2015 yearsis given in Table 1. Table 1, shows that duration of planting and seed germination until harvesting of rocket depending on temperaturewas variable. Germination occurred in 6-8 days for fall sowing and 4-6 days for spring sowing. Temperature effected growth period and duration between planting until harvesting, so this periodspanned 2 months in 2 fall sowing (first planting term) and it spanned80 days in green house and 90 days in field that resulted in reduction of plant growth at lower temperatures during this period. While, delay in spring sowing, with increase of duration of days and temperature at last of spring, resulted in decreased duration of planting until yield harvest. In this study, duration of seed germination up to harvest was lower inspring sowing towards the autumn sowingunder greenhouse conditions and filed conditions.

The results of the characteristics in plants grownunder greenhouse and field conditions showed significant differences and are briefly given in Tables 2 and 3. The tables, clearly show that culture medium effected all characters significantly except the blade area and percentage of dry matter.Among the other components investigated, leaf and petiole length inthe greenhouse and number of leaves, petiole thickness, root weight, plant weight and yield in the field were higher. Concentration of nitrate in cultured leaves of plants in the greenhouse was more compared to plants that were cultured under field conditions. Different planting dates had statistically significant on other characters except the concentration of nitrate and dry matter, such that the most of these traits during both seasons decreased decreased towards delayed cultivations.

Table 1: Germination and vegetation period of plants under greenhouse and field conditions (in days)

		Germination (period in days)	Vegetation (period in days)	Germination (period in days)	Vegetation (period in days)
Season and Year	Sowing Date	Greenhouse		Field	
Fall 2014	1 Sep.	7	56	7	59
	15 Sep.	6	62	8	64
	30 Sep.	8	80	7	90
Spring 2015	1 Apr.	5	48	5	55
	15 Apr.	6	41	4	38
	30 Apr.	5	37	5	94

Table 2: Combined analysis of variance for some agronomic traits of rocket

		Mean Square									
S.O.V	D.F.	Number of Leaves	Leaf Length (cm)	Leaf Width (cm)	Leaf stalk Length (cm)	Leaf stalk Diameter (mm)	Root Weight (g)	Plant Weight (g)	Dry Matter (%)	Nitrat (mg/k)	Yield (kg)
Rep.	2	0.245^{ns}	1.116^{ns}	0.708^{ns}	1.157^{ns}	0.134^{ns}	0.043^{ns}	3.870^{ns}	1.219^{ns}	1673.772*	18876.772^{ns}
S.Place	1	38.854**	615.040**	1.562^{ns}	72.250**	1.604**	3.802**	189.063**	14.088^{ns}	2516.694*	910084.072**
S.Date	5	9.840**	117.276**	6.819**	3.900**	0.698**	0.178**	151.529**	1.167^{ns}	1032.093^{ns}	742715.769**
S.D×S.P	5	8.050**	59.710**	10.395**	6.712**	2.848**	0.370**	342.021**	0.075^{ns}	113.206^{ns}	1780494.488**
Error	10	0.900	6.278	0.530	0.703	0.128	0.025	3.866	0.581	479.900	23402.872
CV(%)		10.89	10.68	11.10	11.41	9.88	17.15	11.06	9.19	10.88	11.50

ns: No Significant ** and *: Significant at the 1% and 5% levels of probability, respectively

Table 3: Mean comparison for some agronomic traits of rocket affected by place and sowing date

Factor	Number of Leaves	Leaf Length (cm)	Leaf Width (cm)	Leaf stalk Length (cm)	Leaf stalk Diameter (mm)	Root Weight (g)	Plant Weight (g)	Dry Matter (%)	Nitrat (mg/kg)	Yield (kg)
Sowing Place										
Field	9.75 a	19.31 b	6.35	5.93 b	3.83 a	1.25 a	20.06 a	8.92	192.43 b	1489.28 a
Greenhouse	7.67 b	27.58 a	6.76	8.76 a	3.41 b	0.60 b	15.48 b	7.67	209.15 a	1171.29 b
Sowing Date										
1 September	10.55 a	29.90 a	7.90 a	8.35 a	3.98 a	1.15 a	26.35 a	8.41	202.85	1903.5 a
15 September	8.81 b	25.90 ab	7.65 a	7.95 ab	4.05 a	0.95 ab	20.35 b	8.52	189.28	1558.3 b
30 September	8.25 b	20.55 cd	6.20 b	6.80 bc	3.60 ab	0.75 b	13.80 de	8.89	197.95	1053.3 cd
1 April	9.30 ab	23.75 bc	6.30 b	7.40 abc	3.45 ab	1.05 a	17.20 bc	8.34	199.16	1278.2 c
15 April	8.70 b	23.60 bc	6.30 b	7.50 abc	3.50 ab	0.95 ab	16.50 cd	8.02	208.13	1252.0 c
30 April	6.65 c	17.00 d	5.00 c	6.10 c	3.15 b	0.70 b	12.45 e	7.60	217.38	938.5 d
Sowing Place × Sowing Date										
Field × 1 September	13.70 a	29.80 a	9.00 a	8.00 abcd	5.00 a	1.90 a	38.70 a	8.96	198.20	2732.4 a
Field × 15 September	10.10 b	23.50 bc	8.80 a	7.70 bcd	4.90 a	1.40 b	29.00 b	9.09	190.30	2218.5 b
Field × 30 September	9.20bc	19.00 cd	6.90 bc	6.00 de	4.20 ab	1.10 bcd	19.50 cd	9.66	170.10	1492.3 cd
Field × 1 April	10.00 b	16.50 de	4.90 de	5.00 ef	2.90 e	1.20 bc	12.30 ef	8.90	196.70	926.9 ef
Field × 15 April	9.10bc	16.40 de	4.80 de	5.10 ef	3.10 cde	1.10 bcd	12.10 ef	8.79	194.80	919.6 ef
Field × 30 April	6.40 d	10.70 e	3.70 e	3.80 f	2.90 e	0.80 def	8.80 f	8.14	204.50	647.3 f
Greenhouse × 1 September	7.40 cd	30.00 a	6.80 bc	8.70 abc	2.96 e	0.40 g	14.00 e	7.86	207.50	1073.0 e
Greenhouse × 15 September	7.53 cd	28.30 ab	6.50 bcd	8.20 abc	3.20 cde	0.50 fg	11.70 ef	7.95	208.26	897.6 ef
Greenhouse × 30 September	7.30 cd	22.10 cd	5.50 cd	7.60 cd	3.00 de	0.40 g	8.10 f	8.12	185.80	613.4 f
Greenhouse × 1 April	8.60bcd	31.00 a	7.70 ab	9.80 ab	4.00 bc	0.90 cde	22.10 c	7.78	201.63	1629.0 c
Greenhouse × 15 April	8.30bcd	30.80 a	7.80 ab	9.90 a	3.90 bcd	0.80 def	20.90 c	7.26	221.46	1585.0 cd
Greenhouse × 30 April	6.90 cd	23.30bc	6.30 bcd	8.40 abc	3.40 bcde	0.60 efg	16.10 de	7.07	230.26	1230.9 de

Means, in each column and for each factor, followed by at least one letter in common are not significantly different using Duncan's Multiple Range Test

Table 4: Correlations coefficient for different characters in rocket

	Leaf Number	Leaf Length	Leaf Width	Leafstalk Length	Leafstalk Diameter	Root Weigth	Palnt Weight	Dry Matter	Nitrat	Yield
Leaf Number	1									
Leaf Length	0.214	1								
Leaf Width	0.575	0.786**	1							
Leafstalk Length	0.024	0.950**	0.733**	1						
Leafstalk Diameter	0.720**	0.416	0.872**	0.366	1					
Root Weight	0.921**	-0.059	0.432	-0.205	0.728**	1				
Plant Weight	0.819**	0.500	0.873**	0.399	0.947**	0.781**	1			
Dry Matter	0.608*	-0.398	0.070	-0.549	0.374	0.662*	0.291	1		
Nitrat	-0.304	0.399	0.009	0.423	-0.225	-0.343	-0.070	-0.873**	1	
Yield	0.800**	0.505	0.890**	0.414	0.958**	0.768**	0.998**	0.292	-0.072	1

** and *: Significant at the 1% and 5% levels of probability, respectively

Lower temperature in last period of plant growth inautumn cultivations causedreductionin crop yield and other traits, while indelayed spring cultivation, reduction of crop yield and some agronomic traits, occurred due to long days and high temperatures. But, crop yield in autumn towards spring cultivations was highas observed in Table 3. The highest yield and yield componentswere noted in first autumn cultivation (1903.5 gr/m^2) andminimum crop yield wasnoted fromspring cultivation. The amount of dry matter increased indelayed autumncultivation, but the variations were statistically non-significant.

Interaction effect was noted between cultivation date and medium culture. Except interaction between dry matter and nitrate concentration, differences among all other traits were statistically significant. Study of same date in two seasons showed the high number of leaves, despite low leaf length and petiole under field conditions. The study reports crop yield under two culture conditions on two different dates, crop yield was high (more than twice) on same dates under autumn cultivations under filed conditions, while under spring cultivations, yield performance at the greenhouse was higher compared to field conditions. Field area is cooler than greenhouse

providing more favorable conditions for plant growth. It is assumed that lack of direct solar radiation on plants and higher humidity in the greenhouse, may have provided better conditions for growth and development of plants by delay in flowering. In this study, direct and positive correlation existed between leaf number, leaf width, petiole thickness, root weight and plant weight with crop yield (Table 4). Similar correlation existed between leaf number, petiole thickness, root weight and plant weight with dry matter. Comparing different plant parameters such as leaf width with leaf length and leaf length with petiole thickness had positive and statistically significant correlation at 1% levels of probability.

DISCUSSION

A large number of researchers have reported cultivation date and different planting conditions for rocket. All of them have investigated plant parameters under different ecological conditions using different types of planting. The conclusions of this experiment are parallel with previous studies.

Bianco [14] said germination at least 10°C are needed and the emergence takes place in 6-8 days and harvest of that leaves is done after 40-60 days of sowing. Mohammedien [11] showed possibility of harvests under autumn and winter conditions after 6 weeks of sowing. But in summer, plants are uprooted 3 weeks after sowing when they are still small and before bolting.

Tüzel [10] found that the leaves are harvested after 30 days in summer and 45-60 days in winter. As the duration of the rocket is very short, it is grown continuously. Day length and light intensity cause the rocket to grow and flower quickly. Therefore, short-day growing is recommended.

Esiyok [12] suggested thattemperate and wet climates are appropriate to achieve high quality and acceptable yields.

Pimpini and Enzo [4] noted harvesting of leaves after 20-60 days of emergence according to the species used, the period, environment and market destination.

Morales and Janick [1] indicated that it can be harvested after 20 to 27 days and then sequentially harvested from regrowth. Also Morales and Janick [1] and Morales [2] said, this plant is blooms under long days and high temperature.

Purquerio *et al.* [24] suggested that plants spaced at 0.10 m presented the highest average leaf area and dry mass weight, but the highest yield was obtained with 0.05 m space. In the autumn/winter cropping, the side dressing at 240.0 kg ha^{-1} with N application allowed the highest yield in field and in greenhouse 178.6 kg ha^{-1}. In the summer, in greenhouse, the estimated side dressing nitrogen application rate allowed the highest yield under plant spaced 0.05, 0.07 and 0.10 m that had yield of 240.0, 167.3 and 231.0 kg ha^{-1}, respectively.

Freitas *et al*. [25] observed the best agronomic performances of rocket in the second planting time with spacings of 0, 25 m × 0, 05 m; 0, 25 m × 0, 06 m; 0, 25 m × 0, 07 m e 0, 30 m ×0, 06 m. The second time of planting (in the period September-October) was better compared to the first planting (from June to August).

Tuncay *et al.* [26] foundthe maximum yield during April planting.

Hall, *et al*. [27], observed an interaction between rocket yield and cultivation dates with yield performance during summer (3.3 kg/m^2), winter (2.7 kg/m^2) and spring (1.9 kg/m^2). Also, days to harvest in these seasons were 26, 68 and 29 respectively. Dolezalova *et al*. [28] observed, emergence of rocket plantlets takes place within 6-9 days. Plants from plantlets transplanted to the field in spring season (April) yielded a substantially higher marketable yield in contrast to plants from directly sown seeds.

Common using fertilizer in this vegetable (some like in general leafy vegetables) is Benett *et al*. [29] indicated the use of this fertilizer significantly affects the development of arugula, as evidenced by a linear increase in the shoot dry mass, number of leaves and leaf area. The application of N influenced the components of production and productivity of arugula. S. Mansuroğlu *et al* [30], suggested that fertilizer doses and forms are influence in yield amount and other yield parameters in salad rocket. They found the maximum yield during in 30 kg N da^{-1} and %100 ammonium sulfate forms.

Comparison of this study with the previous studies show that in the areas with a similar climate with Khoy region, autumn cultivations at the first half of September and spring cultivations at the end of April are better compared to other sowing seasons. Also, it is recommended that delayed autumn cultivations done under field conditions is under cover such as greenhouse and high tunnels without heating system; as regards to early autumn cultivationsin greenhouse is provided to warmness compared to fields, decrease chance of success and yield performance in rocket which is a psychrophile plant. In spring season and in greenhouse cultivations, for decrease of negative effects of high temperature and duration of day, research about effect of shading on rocket such as flowering, can be effective on yield performance is important.

CONCLUSION

Rocket harvesting was increased with decreased temperature in fall cultivation. In delayed spring cultivations, in both seasons, growth duration in greenhouse was longer than that of the compared to field conditions. In terms of plant growth and yield in both environments and seasons, earlier cultivation date had significantly superiority. In fall cultivations, decrease of temperature caused decrease of plant yield, while in delayed spring cultivations; decrease in plant yield could be attributed to an increase in day length and temperature, which caused earlier flowering and premature harvesting. The maximum yield belonged to field in fall cultivation and greenhouse in spring cultivation. The results of this research approve cultivation of rocket in fall and spring of Khoy region and similar climate regions under field and non- heated greenhouse conditions.

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