

# The Influence of Seed Rate and Inter-Row Spacing on Seed Yield and Yield Attributes of Black Cumin in Arsi Highlands, Ethiopia

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## Abstract

Black cumin is the major and the most important spice in Southeast highlands of Ethiopia. However, the yield of the crop is very low mainly due to lack of optimum plant density. A field experiment was done with the objective to assess the influence of different seed rates and inter-row spacing on yield and yield attributes of black cumin at Kulumsa. This experiment was done in the cropping years of 2017, 2018 and 2019 at Kulumsa Agricultural Research Center, Southeast Ethiopia. Twelve treatment combinations of four seed rates (5 kg ha<sup>-1</sup>, 10 kg ha<sup>-1</sup>, 15 kg ha<sup>-1</sup> and 20 kg ha<sup>-1</sup>) and three inter-row spacing (20 cm, 30 cm and 40 cm) were studied on a black cumin variety – 'Aden', which was laid out in a randomized complete block design (RCBD) with factorial arrangement in three replications. The interaction effect of seed rate and inter-row spacing was not statistically significant ( $P > 0.05$ ) on all growth and yield parameters. However, the main effect of seed rate was significant ( $P < 0.05$ ) on most of the parameters studied while inter-row spacing was significant only on days to emergence and plant height. Yield and yield attributing factors such as number of primary branch plant<sup>-1</sup>, number of secondary branch plant<sup>-1</sup>, number of pods plant<sup>-1</sup> and seed yield ha<sup>-1</sup> (kg) were significantly influenced by the seed rate. Seed yield increased from 462 kg ha<sup>-1</sup> to 634 kg ha<sup>-1</sup> as seed rate increased from 5 kg ha<sup>-1</sup> to 20 kg ha<sup>-1</sup> and showed a decrease in yield from 601 kg ha<sup>-1</sup> to 507 kg ha<sup>-1</sup> as inter-row spacing increased from 20 cm to 40 cm although it was not significant. Hence, 15 kg ha<sup>-1</sup> seed rate and 30 cm inter-row spacing could be recommended for optimum black cumin production in the study area. However, further research needs to be undertaken in different black cumin producing areas of the country on recent varieties to achieve the optimum seed rate and inter-row spacing with information related to cost of production for better recommendation.

**Keywords:** competition, crop management, *Nigella sativa*, plant density

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## 1. Introduction

Black cumin (*Nigella sativa* L.) is an annual seed spice and a medicinal herb belongs to the *Ranunculaceae* family. Sometimes it is referred to as nigella or black seeds or 'Tiku azmud' in Amharic (Habtewold *et al.* 2017). This species is originated in Egypt and East Mediterranean, but is widely cultivated in Iran, Japan, China and Turkey (Shewaye Lakew 2011). Ethiopia is among the major black cumin producing and exporting countries like India, Sri Lanka, Bangladesh, Afghanistan, Pakistan, Egypt, Iran, Iraq, Syria and Turkey (Samima *et al.* 2018). The majority of Ethiopia's black cumin exports go to Arabic and some Muslim countries and it reached to 98% of the national exports (Orgut 2007). According to Ethiopian Investment Agency Report, Ethiopian annual production of black cumin seed was 18 thousand metric tons in the cropping year of 2015 (EIC 2016).

Black cumin grows as a rain fed crop within 1500 to 2400 meters of altitude on heavy black soils and prefers loamy sand soils (Datta *et al.* 2001), on soil pH of 7.0 to 7.5 (Orgut 2007). In Ethiopia it has a similar agro-ecological requirement as teff (*Eragrostis tef*) and chick pea (*Cicer arietinum*) and usually cultivated on residual moisture following the latter crops. It is a major crop in Dembia in South Gonder, Shirka in Arsi Zone and Goro in Bale Zone (Alemaw *et al.* 2010).

In addition to its use for spice and culinary purposes, black cumin has multiple uses in cosmetic as well as medicinal industries (Ali & Blunden 2003; Arici *et al.* 2005; Black *et al.* 2005; Kokdil *et al.* 2005; Kokdil *et al.* 2006; Ashraf & Orooj 2006). In Ethiopia, it is commonly used to make 'Berbere' for the preparation of traditional Ethiopian stews such as 'wot' and preservation of butter. It is principally used to flavor food, either as whole grain, in powdered form or as an oleoresin extract (Hedberg *et al.* 2003).

The national average productivity of black cumin was reported to be 0.79 t ha<sup>-1</sup> (Kifelew *et al.* 2017); while Zigyalew Gashaw (2020) reported 0.64 t ha<sup>-1</sup>, which is well below the global average and some major producing countries such as India (2.2 t ha<sup>-1</sup>). However, high seed yield of up to 1.7 t ha<sup>-1</sup> at Adet and 1.8 t ha<sup>-1</sup> at Woreta were obtained (Adam Abebe 2006). The low yields are mainly due to the low productivity of the varieties (Ermias Assefa *et al.* 2015) and the poor agronomic practices used by the farmers (Hammo 2008). Among the factors, suitable planting density play the major role to affect crops' yield and agronomists believe that the establishment

of optimum density for a given crop plant in a field is the basis for the successful cropping that could boost the productivity. Optimum plant density is a density at which all environmental factors including water, air, light, soil etc. are fully exploited by the plants and at the same time, intra-species and extra-species competitions are minimized (Alizadeh & Kouchehi 1995). Black cumin lacks research recommendations on optimum plant density (seed rate) and row spacing that could lead to the poor yield of the crop. Hence, it is vital to identify the suitable seed rates and row spacing for black cumin production. Therefore, this study was initiated with the objective of finding out the optimum seed rate and inter- row spacing for better growth and yield attributes of black cumin.

## 2. Materials and methods

### 2.1 Description of the study area

The study was conducted at Kulumsa Agricultural Research Center (KARC) in the main growing season of 2017, 2018 and 2019 located at 8° 00' to 8° 02'N latitude and 39° 07' to 39° 10'E longitude at an elevation of 2210 m.a.s.l in Tiyo District, Arsi Administrative Zone of the Oromia Regional State, 167 km Southeast of Addis Ababa. It is located on a very gently undulating topography with a gradient of 0 to 10% slope (Abayneh *et al.* 2003). The agro-climatic condition of the area is wet with 832 mm mean annual rain fall and has a uni-modal rainfall pattern with extended rainy season from March to September while the peak season is from June to August. The mean annual maximum and minimum temperatures are 23.2 and 10 °C, respectively and has three major soil types: EutricVertisol, VerticLuvisol and VerticCambisol (Abayneh *et al.* 2003).

### 2.2 Experimental materials, design and treatments

The experiment was carried out using a popular black cumin variety 'Aden', which was released by Ethiopian Institute of Agriculture Research (EIAR), Melkasa Agricultural Research Center (MARC) (MoANR 2009). 'Aden' is a widely popularized and cultivated variety with a yield potential of up to 1.5 t ha<sup>-1</sup> under research management and 0.8 to 1.2 t ha<sup>-1</sup> under farmers' management (Alemaw *et al.* 2010, Table 1). Two factors were included in the experiment namely four seed rates (5 kg ha<sup>-1</sup>, 10 kg ha<sup>-1</sup>, 15 kg ha<sup>-1</sup> and 20 kg ha<sup>-1</sup>) and three inter-row spacing (20 cm, 30 cm and 40 cm) which were combined into twelve treatments. Each experimental plot measured 4.32 m<sup>2</sup> and the number of planted rows per plot varied accordingly based on the inter-row spacing treatments (12, 8 and 6 rows for 20 cm, 30 cm and 40 cm row-spacing respectively). Each treatment was assigned to the experimental plots using Randomized Complete Block Design (RCBD) in three replications. All agronomic practices including (fertilization, pest management, cultivation etc.) except seed rate and row-spacing were applied uniformly to each experimental unit as recommended.

Table 1. Description of the black cumin variety (Aden) used in the present study

Variety	Release		Altitude (masl)	Maturity (days)	Productivity (t ha <sup>-1</sup> )		Oleoresin (%)	Essential Oil (%)
	Year	<sup>1</sup> Breeder			Research	Farmer		
Aden	2009	MARC/EIAR	1500-2400	134-150	1.5	0.8-1.2	27.2-32.4	0.6-1.2

<sup>1</sup>MARC: Melkasa Agricultural Research Center, EIAR: Ethiopian Institute of Agricultural Research, Source: (Alemaw *et al.* 2010)

### 2.3 Parameters and data collection

Data for different parameters were collected from the middle rows of the experimental plots and five randomly selected plant samples per plot were used to make plant based measurements. Days to emergence (DE), Days to 50% flowering (DF), Days to maturity (DM), Plant height (PH), Number of primary branch per plant (NPB), Number of secondary branch per plant (NSB), Number of pod per plant (NPDPP), Number of seed per pod (NSPPD), Seed yield per pant (SYLDPP) and Seed yield per hectare (SYLDHA) were the parameters for which data were collected for this study.

Data for the aforementioned parameters were subjected to Analysis of Variance (ANOVA) using SAS Statistical Package Program (SAS 2009). The significant differences among treatment means were compared using the Least Significant Difference Test (LSD) at 5% probability level.

## 3. Results

ANOVA revealed that the interaction effects of seed rate and inter-row spacing was not obtained on any of the parameters studied (Table 2). However most of the parameters including days to emergence, plant height (cm), number of primary branch per plant, number of secondary branch per plant, number of pods per plant, and seed yield per hectare were significantly affected by the main effect of the seed rate ( $P < 0.05$ ). In contrary, days to 50% flowering, days to maturity, number of seeds per pod and seed yield per plant were not significantly affected by the seed rate ( $P > 0.05$ ). However, inter-row spacing affected only days to emergence and plant height.

Days to emergence was not significantly changed when the seed rate varied from 5 to 15 kg ha<sup>-1</sup>, however it

started to increase when the seed rate increased to 20 kg ha<sup>-1</sup> (Table 2). The higher the seed rate the longer the time the seed took to emerge from the soil and the lower the seed rate the earlier the emergence (Figure 1,  $r^2 = 0.94$ ). Likewise, the inter-row spacing significantly affected days to emergence (Table 2). The narrow the spacing the late the emergence, while the wider the spacing the earlier it became (Figure 1,  $r^2 = 0.91$ ). Plant height was also significantly affected by the main effects of the seed rate and inter-row spacing (Table 2). When the seed rate increased, plant height was also increased and vice versa (Figure 1,  $r^2 = 0.76$ ); while when the inter-row spacing became wider, plant height was highly reduced (Figure 1,  $r^2 = 0.97$ ). Conversely, increasing the seed rate significantly reduced the number of primary branches per plant (Figure 2,  $r^2 = 0.67$ ) as well as the number of secondary branches per plant (Figure 2,  $r^2 = 0.50$ ). Likewise, the number of pods per plant was also reduced with increasing the seed rate from 5 to 20 kg ha<sup>-1</sup>. However, the seed yield per hectare increased significantly with increased seed rate with no point of return (Table 2).

Table 2. Effect of seed rate and inter-row spacing on seed yield and yield attributes of Black cumin

Treatments	DE	DF	DM	PH (cm)	NPB	NSB	NPD PP	NSP PD	SYLDPP (g)	SYL DHA (kg)
<b>Seed Rate (kg ha<sup>-1</sup>)</b>										
5	19.52 <sup>a</sup>	93.07	153.56	74.23 <sup>b</sup>	5.56 <sup>a</sup>	19.53 <sup>a</sup>	25.10 <sup>a</sup>	94.23	2.68	462 <sup>b</sup>
10	19.33 <sup>a</sup>	93.00	154.18	75.41 <sup>ab</sup>	5.09 <sup>6b</sup>	15.78 <sup>b</sup>	20.62 <sup>b</sup>	93.94	2.29	506 <sup>ab</sup>
15	18.44 <sup>ab</sup>	93.18	153.78	75.00 <sup>ab</sup>	5.22 <sup>ab</sup>	17.40 <sup>ab</sup>	21.76 <sup>b</sup>	101.01	2.65	584 <sup>ab</sup>
20	18.04 <sup>b</sup>	92.96	153.81	76.70 <sup>a</sup>	5.00 <sup>b</sup>	15.73 <sup>b</sup>	20.84 <sup>b</sup>	96.30	2.36	636 <sup>a</sup>
LSD	0.45	0.69	0.86	2.38	0.36	2.48	2.80	11.21	0.42	139
Significance	**	ns	ns	**	**	**	**	ns	ns	**
<b>Inter-Row Spacing (cm)</b>										
20	19.03 <sup>a</sup>	92.69	153.78	76.62 <sup>a</sup>	5.13	16.84	21.70	92.47	2.49	601
30	18.92 <sup>ab</sup>	93.28	153.89	75.23 <sup>ab</sup>	5.33	17.71	22.78	98.74	2.43	533
40	18.56 <sup>b</sup>	93.19	153.83	74.14 <sup>b</sup>	5.20	16.77	21.74	97.89	2.56	507
LSD	0.39	0.60	0.74	2.06	0.32	2.15	2.42	9.71	0.37	120
CV (%)	4.26	1.33	0.99	5.63	12.46	25.85	22.58	20.70	30.22	45.20
Significance	*	ns	ns	*	ns	ns	ns	ns	ns	ns

Means within a column having the same letters are not significantly different. \* - Significant at 5% level, \*\* - Significant at 1% level. DE=Days to Emergence, DF= Days to 50% flowering, DM=Days to maturity, PH=Plant height, NPB= Number of primary branch per plant, NSB=Number of secondary branch per plant, NPDPP= Number of pod per plant, NSPPD= Number of seed per pod, SYLDPP= Seed yield per pant, and SYLDHA= Seed yield per hectare.

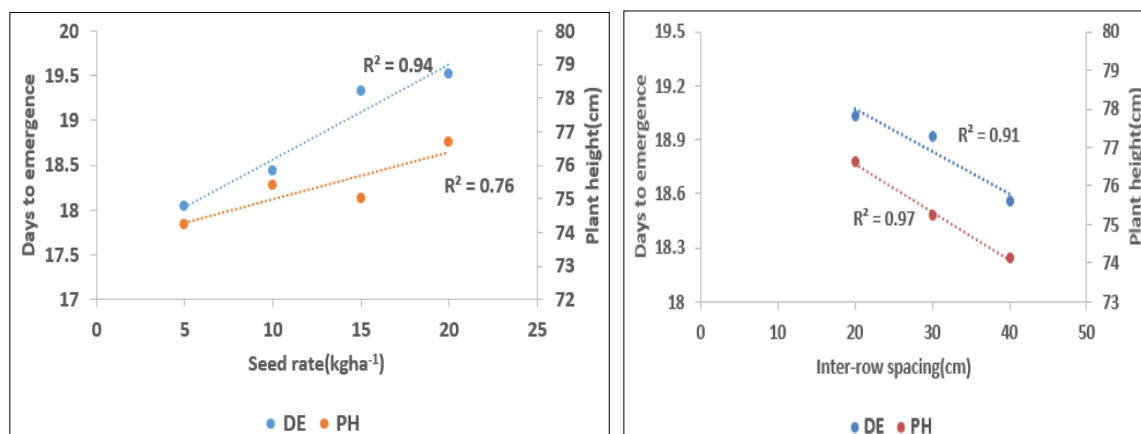


Figure 1. Responses of days to emergence and plant height to seed rate (left) and inter-row spacing (right). DE=Days to emergence, PH=Plant height.

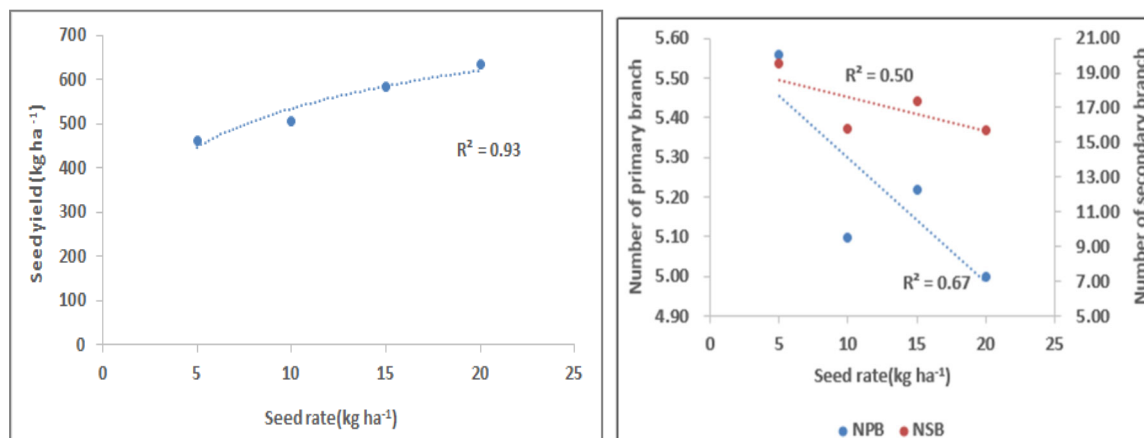


Figure 2. Responses of seed yield (left), and number of primary and secondary branch (right) to seed rate. NPB=Number of primary branch, NSB=Number of secondary branch.

#### 4. Discussion

The results of the present study showed that plant height was affected by the seed rate and inter-row spacing. The highest seed rate (20 kg ha<sup>-1</sup>) and the smallest inter-row spacing (20 cm) produced the highest average plant heights (76.70 cm and 76.62 cm) respectively; while the lowest values (74.23 cm and 74.14 cm) were obtained at the lowest seed rate (5 kg ha<sup>-1</sup>) and the largest inter-row spacing (40 cm) respectively (Table 2). The results also affirmed the presence of significant and linear relationship between the seed rate ( $r^2 = 0.76$ ) and inter-row spacing ( $r^2 = 0.97$ ) with plant height respectively (Figure 1). These findings on plant height were in accordance with Toncer & Kizil (2004); Tuncturk *et al.* (2005) and Roussis *et al.* (2017) who obtained similar results, although did on a different genotype and environment. Tuncturk *et al.* (2005) found that an increasing seed rate in black cumin increased plant height; while the highest value (40.68 cm) was obtained from 15 kg ha<sup>-1</sup> seed rate and the lowest (34.68 cm) from 10 kg ha<sup>-1</sup>. Similarly, Roussis *et al.* (2017) showed increasing trends in plant heights from 18.9 cm to 22.7 cm with increased seed rate from 50 to 60 kg ha<sup>-1</sup>, although it is much higher compared to the rates used in the presented study as well as in Tuncturk *et al.* (2005). Toncer & Kizil (2004) reported comparable results with the present study in that many of the growth and yield parameters were affected by seed rates in the range of 10 to 40 kg ha<sup>-1</sup>; except thousand seed weight and seed number per capsule. The higher seed rates (40 and 50 kg ha<sup>-1</sup>) reduced number of branch, number of capsule per plant, seed yield per plant and seed yield per hectare.

Similar results also reported by Koli (2013), who stated that increasing the plant density of black cumin (higher seed rate and closer inter-row spacing) within an area of land increased plant height, this may be due to higher competition among the plants.

Likewise, the number of branches (both primary and secondary) per plant were influenced by the seed rate. The number of branches per plant decreased with increased seed rate; which varied from 5.56 to 5 (primary branch) and 19.53 to 15.73 (secondary branch) for the increasing seed rate from 5 to 20 kg ha<sup>-1</sup>. This finding was also reported in related works of Tuncturk *et al.* (2005) & Roussis *et al.* (2017). In contrary to plant height, the highest values for the number of branches per plant in the present study either for the primary (5.56) or for the secondary (19.53) was due to the lowest seed rate (5 kg ha<sup>-1</sup>) used and the lowest values (5 and 15.73) however were obtained from the highest seed rate (20 kg ha<sup>-1</sup>). In similar fashion, Tuncturk *et al.* (2005) obtained the highest number of branches (9.56) at the lowest seed rate (5 kg ha<sup>-1</sup>) and the lowest branches (6.46) at the highest seed rate (20 kg ha<sup>-1</sup>). Roussis *et al.* (2017) also demonstrated similar result trends although not significant between the seed rates used (50 and 60 kg ha<sup>-1</sup>). According to Kizil (2002), when seed rate increased, the number of branches per plant decreased linearly probably due to a higher interplant competition.

The number of pods (capsules) per plant varied between the seed rates with the highest mean value of 25.20 at the lowest seed rate (5 kg ha<sup>-1</sup>) and the lowest value (20.62) at the highest seed rate (20 kg ha<sup>-1</sup>). The number of pods per plant was positively related with the number of branches per plant as it was high at the lowest seed rate and low at the highest seed rate. Tuncturk *et al.* (2005) demonstrated that, the highest number of pods per plant (14.65) was obtained from the lowest seed rate (5 kg ha<sup>-1</sup>) and the lowest value (9.48) from the highest seed rate (20 kg ha<sup>-1</sup>). However, Roussis *et al.* (2017) got insignificant results although increased seed rate reduced the number of pods per plant.

Unlike the other yield and yield components discussed, neither the seed rate nor the inter-row spacing treatments influenced the number of seeds per pod (Table 2), which was supported by the results of Roussis *et al.* (2017) who also got non-significant results. Nevertheless, Tuncturk *et al.* (2005) found the highest number of seeds

per pod (71.12) at 10 kg ha<sup>-1</sup> seed rate and the lowest (66.45) at 20 kg ha<sup>-1</sup> however significant differences were not obtained between the 10 and 15 kg ha<sup>-1</sup> seed rates.

Seed rate significantly influenced the seed yield per hectare, nevertheless the inter-row spacing did not (Table 2). The seed yield increased in the range of 462 to 636 kg ha<sup>-1</sup> when the seed rate increased from 5 to 20 kg ha<sup>-1</sup>. The highest average seed yield (636 kg ha<sup>-1</sup>) was obtained at the highest seed rate (20 kg ha<sup>-1</sup>) and the lowest (462 kg ha<sup>-1</sup>) was obtained from the lowest seed rate (5 kg ha<sup>-1</sup>). According to Tunçturk *et al.* (2005), a significant increment in seed yield of black cumin was obtained as seed rate increased from 5 to 15 kg ha<sup>-1</sup> then declined when reached at 20 kg ha<sup>-1</sup>. However, the highest (7.01 q ha<sup>-1</sup>) and the lowest (3.64 q ha<sup>-1</sup>) average yields were obtained from 15 kg ha<sup>-1</sup> and 5 kg ha<sup>-1</sup> seed rate applications respectively. Our results were also in agreement with what was obtained by Akintoye *et al.* (2009) in that, the yield per unit area tends to increase as plant density (seed rate) increases up to a point and then declines. Although a declining yield trend was not experienced in our findings, there was a room to increase the yield with increasing the seed rates until the optimum point was reached (Figure 2). Kizil & Toncer (2005) studied the effect of row spacing on seed yield and yield components of black cumin and found similar results on plant height, seed per capsule (pod) and seed yield per hectare with the present study. However, in contrary to our findings, Kizil & Toncer (2005) found that, branches per plant, capsule per plant, and seed yield per plant were significantly affected by row spacing treatments which varied from 20 to 50 cm.

Norman (1992) reported that increasing plant density does not affect individual plants if the plant density is below the level at which competition occurs between plants. This finding was reflected in our results of seed yield per plant although it was not significant. Increasing neither the seed rate nor the inter-row spacing affected the seed yield per plant (Table 2) for the reason that the plant densities studied were below the level for the competition to occur between plants. This phenomenon was also observed for the seed yield per hectare in that although increasing seed rates increased the seed yield per hectare, the magnitude of the plant densities used did not reach at a level to create maximum competition, which could have been depicted by a point of return (Figure 2). Besides, although the number of pods per plant was significantly affected by the seed rate, its contribution to the seed yield per plant was not observed as it decreased with increasing the seed rate. The contribution of the number of seeds per pod rather affected the seed yield per hectare as it showed increasing trend with increasing seed rate (Table 2).

Abdolrahimi *et al.* (2012) studied the effect of inter and intra-row spacing on three black cumin varieties and found that, both factors affected different growth and yield parameters. Compared with our findings, the narrow inter-row spacing (20 cm) was found to be the best as it yielded better results and the yield particularly reduced when the row spacing increased to 40 cm. Nevertheless, contradictory results obtained by Koli (2013), who did research on the influence of plant spacing on two black cumin varieties, showed increasing yield of black cumin varieties with increasing inter-row spacing from 15 to 25 cm. However, it did not show whether the yield increment would continue or not at wider row spacing beyond 25 cm. Giridhar *et al.* (2017) studied several growth, yield and yield components of black cumin in response to different plant densities. In accordance with the findings of the present study, many of the parameters including branches per plant, capsules per plant, and seed yield were significantly influenced by the plant densities. However, the results on parameters like days to emergence, plant height, number of seed per capsule and seed yield per plant were not in agreement with that of the present study.

In general terms, Mazumder *et al.* (2007) stated that plants grown under normal spacing could have optimum population density per unit area which provides optimum conditions for luxuriant crop growth and better plant canopy area due to maximum light interception, photosynthetic activity, assimilation and accumulation of more photosynthates into plant system and hence produce more seed yield with best quality traits. Besides, Alizadeh & Koucheiki (1995) added that, at optimum plant density, all environmental parameters such as water, air, light, and soil are fully exploited by plants and at the same time competitions are minimized. Due to the fact that, at a higher seed rate and narrow inter-row spacing (or high plant density) plants compete for light and prefer to proportionate the available soil nutrients, moisture and of course the photosynthate to vertical growth than lateral growth. However, at lower seed rates and wider inter-row spacing, plants rather allocate more food/or energy for lateral growth than height due to availability of enough space, and sufficient light interception. As a result of these, plant growth traits such as plant height, branches per plant, pods per plant, and seed per pod and ultimately seed yield per unit area could vary with different row spacing and seed rates (plant densities). However, the genotype, environmental conditions and agricultural practices also have influence on the variations in results between similar studies (Tunçturk *et al.* 2005).

## 5. Conclusions and recommendations

The interaction effect of seed rate and inter-row spacing was not found significant for all growth and yield contributing parameters including seed yield itself. However, the main effect of the individual factors was significant on most of the parameters studied. Statistically, significant variations were obtained on growth and seed yield attributes of black cumin with increasing seed rates. Increasing the seed rates from 5 kg ha<sup>-1</sup> to 20 kg ha<sup>-1</sup> resulted in increased in average black cumin seed yield in the range of 462 kg ha<sup>-1</sup> to 636 kg ha<sup>-1</sup>. Nevertheless, the inter-row spacing of 20 cm, 30 cm and 40 cm caused statistically non-significant differences for most of the

growth and yield related traits except for days to emergence and plant height. Although increasing seed rate showed increasing trend of seed yield with no point of return, as a recommendation, 15 kg ha<sup>-1</sup> seed rate combined with 30 cm inter-row spacing could be used for black cumin production as most yield and yield related traits showed reasonable performances and were not statistically different from the maximum seed rate (20 kg ha<sup>-1</sup>) and inter-row spacing (40 cm). However, further research needs to be undertaken in different black cumin producing areas of the country on recent varieties if any, to achieve the optimum seed rate and inter-row spacing with information related to cost of production for better recommendation.

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