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Growth, Production and Bioactive Content of Several Black Cumin (*Nigella sativa* L.) Accessions With Different Harvesting Times in a D3 Type Climate Regime

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Abstract

Black cumin (*Nigella sativa* L.) is a species Ranunculaceae family which grows in the Middle Eastern and Southern Mediterranean countries. Black cumin is also known as *habbatus sauda* , or kalonji in South Asia. Black cumin seeds are used as spice traditional medicine; the essential oil compound in the seeds has been identified as thymoquinone. Thymoquinone has a potent antioxidant effect, which could protect organs from oxidative damage by generating free radical agents. Indonesia is one of the most geographically diverse country in the world. Some regions have scattered low and high plains, abundant sunlight, evenly distributed rainfall throughout the year, and highly diverse soil types. The purpose of this study was to study the growth, production, thymoquinone and thymol content of several accessions of black cumin with different harvesting time in D3 type climate regimes. The research was conducted from April to September 2019 in Ngadirejo Village, Sukapura District, Probolinggo Regency, East Java with an altitude of 1.680 m above sea level. The experiment used a randomized complete block design with one factor for the vegetative phase, namely accession (“American”, “Indian”, “Kuwait”, and “Slovenian”) and two factors for the generative phase, namely accession and harvesting time. The harvesting time of black cumin was conducted at 6, 7, and 8 weeks after the anthesis. “Indian” and “Slovenian” accession demonstrated the best vegetative growth, whereas “Indian” had the highest capsules number per plant, seeds weight per plant, and the highest estimated production compared to other accessions (603 kg seeds. ha^{-1}). “American”, “Indian” and “Kuwait” accessions are well adapted in D3 type climate. The harvesting time of 7 to 8 weeks from anthesis was shown to be optimal for all accessions. Thymoquinone and thymol content for the four accessions was circa 349.64– 3,030.45 µg.g^{-1} of seeds and 385.56 – 2,003.46 µg.g^{-1} of seeds, with potential production values of 0.18 - 1.83 kg.ha^{-1} and 0.19 - 0.45 kg.ha^{-1}, respectively. The optimal harvesting time to maximize seed production was unaffected by the black cumin accession.

Keywords: Indonesia, tropical, thymoquinone, thymol, *habbatus sauda*

Introduction

Black cumin *(Nigella sativa* L.) is a species from Ranunculaceae family which grows in the Middle Eastern and Southern Mediterranean countries. Black cumin is also known as *habbatus sauda*, or kalonji in South Asia; it is originated from Egypt and the Eastern Mediterranean, and widely cultivated in Iran, Japan, China, and Turkey (Assefa et al., 2015). Black cumin seeds contain important bioactive compounds in the form of thymoquinone and thymol (Bourgou et al., 2008; Kooti et al., 2016). Black cumin seeds have been shown to possess pharmacological properties, such as anti oxidant (Mariod et al., 2009), anti-fungal (Rogozin et al., 2011; Mahmoudvand et al., 2014), anti-inflammatory (Fahmy et al., 2014), anti-bacterial (Abdelmalek et al., 2012), and anti-cancer activity (Periasamy et al., 2016; Rafati et al., 2019).

Black cumin can grow with an average temperature range below 20°C, low rainfall, and alkaline pH. Black cumin which grows in Iran, grows with an average temperature of 14°C-19.4°C, rainfall of 36.76 mm-140 mm/year, and pH of 7.6-7.7 (Khoulenjani and Salamati 2011; Ghamarnia et al., 2013), while in Turkey it grows with an average temperature of

16.6°C, rainfall of 122,9 mm per monthly, and pH of 7.71 (Kara et al., 2015). Cultivation efforts have been carried out in Indonesia and the plant adapts well if it is planted in the highlands and B2 climate type. Black cumin grown in B2 climate type grows in a temperature range of 20.9 - 30.3°C, humidity of 53 - 91%, rainfalll of 134 mm per month and 1,188 mm per year, and an irradiation of 4.0-7.9 hours per day (Suryadi 2014; Ridwan 2014; Mardisiwi 2017; Herlina 2018; Al Asad 2019).

Black cumin planted in Indonesia has stemmed from several accessions, including "Saudi Arabian" (Ridwan 2014; Suryadi 2014), "Turkey" (Mardisiwi 2017; Setiawati 2017), “Indian” and “Kuwait” (Herlina 2018; Destiawan 2019), “American” (Al Asad 2019; Destiawan 2019), and “Slovenian” (Destiawan 2019). Importantly, each accession has a different genetic potential. Saudi Arabia accession seed production is 44.8 $kg.ha^{-1}$ (Ridwan 2014), Turkey is 220.59 $kg.ha^{-1}$ (Mardisiwi 2017), “Kuwait” is 215.47 $kg.ha^{-1}$ and “Indian” is 717.59 $kg.ha^{-1}$ (Herlina 2018). Differences in accession also have the potential to affect secondary metabolite content, in this case thymoquinone and thymol. “Indian”'s black cumin has a thymoquinone content of 1,158.58 $\mu g.g^{-1}$ and a thymol content of 157.63 $\mu g.g^{-1}$ while the “Kuwait” accession has a thymoquinone content of 2,745.54 $\mu g.g^{-1}$ and a thymol content of 105.19 $\mu g.g^{-1}$ (Herlina, 2018).

Harvesting time can affect the biomass and secondary metabolite content of black cumin seeds. Specifically, black cumin harvested when ripe exhibits a higher oil content (34.5%) compare to non-ripe seeds (Telci et al., 2014). Optimized harvesting time can also increase the secondary metabolite content of lavender plants (Mahmoud et al., 2018), olives (Alowaiesh et al., 2018), raspberries (Ponder and Hallmann, 2019), tea (Zang et al., 2019) and peppermint (Ostadi, 2020).

Currently, opportunities for the development of black cumin in dry climates have not been explored. This includes growth opportunities in D3 climate type. D3 Climate type according to Oldeman’s classification is a climate type that allows only one planting per year depending on the availability of water for plants. This study aimed to study the growth, production, thymoquinone and thymol content in black cumin seed in D3 climate type, including examining different harvesting times.

Materials and Methods

This study was conducted in Ngadirejo Village, Sukapura District, Probolinggo, East Java at an altitude of 1680 meters above sea level in April 2019 - December 2019. The region has a D3 climate type. Analysis of bioactive compounds was carried out at the Biochemistry Laboratory and the Food Chemistry Laboratory of Food and Science Technology Department, Faculty of Agricultural Technology and Postharvest Laboratory, Department of Agronomy and Horticultural, Faculty of Agriculture, IPB University. Materials for the field study included the seeds of four black cumin accessions, manures, N, P, K fertilizer and dolomite. Black cumin accessions were collections of crop production division of The School of Agronomy and Horticulture, Faculty of Agriculture IPB.

The experiment used a randomized complete block design with black cumin accessions as a single factor at the vegetative phase, i.e. “American”, “Indian”, “Kuwait”, and “Slovenian”. For the generative phase, two factors were tested, accession and harvesting time. The accession factor consisted of four levels, namely “American”, “Indian”, “Kuwait”, and “Slovenian” accessions, and the harvesting time factor used 3 levels: 6, 7, and 8 weeks after the anthesis. This gave a total of twelve treatment combinations. Each treatment combination was replicated three times with 36 experimental units. Each experimental unit consisted of ten plants so there were 360 plants for the whole experiment.

Dolomite and manures were applied according to Suryadi (2014), i.e. 4 and 10 tons per ha, respectively. The study area was divided into 36 plots with a width of 60 cm x length 75 cm per plot and a height of 30 cm. A distance of 50 cm was maintained between these plots. Plant spacing was 30 cm x 15 cm. The seeds are planted directly in the field containing 5 seeds per planting hole. After growing 3 weeks of age, selection is carried out. Fertilizers were applied according to Suryadi (2014), i.e. 120 kg $N.ha^{-1}$, 157 kg of $P_2O_5.ha^{-1}$, and 90 kg of $K_20.ha^{-1}$.

Measurements were conducted on plant height, leaf number, branch number, flower number per plant, capsules number per plant, follicles number per capsule, fruit set percentage per plant, capsule diameter, capsule length, seeds number per capsule, weight of 100 seeds, seeds weight per plant, production estimated per ha, content of per g seed and production per ha thymoquinone and thymol. Significant differences between means were further analysed with the Duncan Multiple Range Test (DMRT) at α=5%.

Results and Discussion

Plant Height, Leaf Number and Branches

The plant heights of four accessions of black cumin at 13 weeks after planting (WAP) displayed significant differences. "Indian" and "Slovenian" accessions have similar plant height, but they were 0.17% and 0.11% taller than the "American" and "Kuwait" accessions (Table 1). The same four accessions planted in a B2 climate type have been previously shown to grow to lesser heights (Destiawan, 2019). Meanwhile, black cumin grown in planting center areas shows heights of 61.8 cm in Pakistan (Iqbal et al., 2010), 26 cm in Turkey (Kara et al., 2015), and 42.4 cm in India (Giridhar et al., 2017), which were shorter than those in our study.

The four accessions of black cumin in this study had similar leaf number with the average of 85.09 (Table 1). The "Kuwait" and "Slovenian" accessions, when grown in a B2 climate type had a lower leaf number than in our study (Destiawan, 2019). Black cumin planted in Egypt has been shown to develop 51.9 leaves (Khalid and Shedeed, 2015), while in India 44.8 grew (Giridhar et al., 2017) respectively. Importantly, these were lower than in our study.

The number of branches of the four cumin accessions showed no significant differences (Table 1). The average branches number of the four black cumin accession is 36.60. The branches number of "American" accession in a B2 climate type is generally less than in our study (Al Asad, 2019). Black cumin growing in Turkey and India also shows fewer branches than in our study, at an average of 4.6 (Kara et al., 2015) and 8.4 respectively (Giridhar et al., 2017). Differences in vegetative growth are influenced by genetic factors, climate, soil type, and the method of cultivation. Genetic factors influence the adaptability of plants to their environment (Buhaira et al., 2014). In addition, black cumin was planted directly in the field in this study. Hence, the plants could exploit the soil nutrients more so than comparable planted in polybags (Suryadi, 2014). Furthermore, climate type appears to be an important factor, with black cumin planted in D3 climate type producing better vegetative growth than in B2 climate type. Importantly, cumin can grow well with dry air conditions and full sun exposure (Lim, 2013).

Number of Flowers, Follicle and Capsule, and Percentage of Fruit Set

Flower number per plant significantly differed among the four accessions. The "Indian" and "Slovenian" accessions have similar flowers number per plant, but they had more flowers than "American" dan "Kuwait". "Slovenian" acession have 0.44% and 0.40% more flowers number per plant compared to the "American" and "Kuwait" accessions (Table 2). This was presumed to be genetic potentials of the accessions. Different genotypes have been shown to influence the flowers number per plant in tomatoes and saffron (Gumelar et al., 2014; Ghanbari et al., 2019). The flowers number per plant of the "American" accession of black cumin expressed in a B2 climate type was lower than in our study (Al Asad, 2019). Black cumin planted in India has a lower flowers number per plant than this research, which is 34 flowers (Balakrishnan and Gupta, 2011).

The follicle number per capsule was significantly different among accessions (Table 2). The "Slovenian" accession had the highest follicles number, whereas the "Kuwait" and "American" accessions showed the lowest follicles number. "Slovenian" accession had about 0.20% more follicles than the other accessions. Hence, variation in the follicles number per capsule among accessions appears to be governed by both genotype and environmental factors. The number of black cumin follicles expressed in plants in a B2 climate type (accessions: "American", "Indian", "Kuwait" and "Slovenian" (Destiawan, 2019) has been observed to be lower than in our study. Hence, it appears that differences in accessions of *Cuminum cyminum* have influenced variations in morphological traits that are influenced by genetic factors on plant (Moghaddam and Pirbalouti, 2017).

Table 1. Plant height, leaf and branch number of several black cumin accessions at 13 WAP

Accession	Plant height (cm)	Leaf number	Branches number
"American"	61.23 c ± 4.90	79.22 ± 16.60	31.97 ± 6.47
"Indian"	71.89 a ± 4.30	91.46 ± 15.75	40.33 ± 8.30
"Kuwait"	64.52 bc ± 4.02	81.31 ± 19.10	33.07 ± 6.63
"Slovenian"	67.81 ab ± 5.48	88.37 ± 18.72	41.04 ± 6.90
Average	-	85.09 ± 17.50	36.60 ± 7.07

Note: values (average ± standard deviation) within the same column followed by the same letters are not significantly different according to DMRT at α=0.05.

Furthermore, the different accessions of black cumin also expressed different capsules number per plant and showed variability in the percentage of fruit set (Table 2). In addition, not all of the black cumin flowers can successfully formed capsules. The “Slovenian” accession showed a significantly lower capsules number and percentage of fruit set compared to the “American”, “Indian” and “Kuwait” accessions. “Slovenian” accession had about 1.01% capsules and the percentage of fruit sets was about 1.59% lower than the other of three accessions (Table 2). This was presumably due to the “Slovenian” accessions fruit setting stage coincided with the dry season, resulting in a low rate of fruit setting. Furthermore, these accessions required a longer time to proceed from the flowering to the harvesting period, and there was a disruption in the pollination process of the black cumin. During the pollination process, environmental stress occurs in the form of high temperatures and lack of water availability. Flowers are a strong sink (Hartati and Sudarsono, 2013), and the demand for a strong sink cannot be balanced by the rate of source formation because the environmental stress will cause the plants to reduce the rate of photosynthesis.

Table 2. Number of flowers, number of capsules, and number of follicles per capsule of several black cumin accessions

Accession	Flowers number per plant	Capsules number per plant	Follicles number per capsules	Fruit set percentage (%)
“American”	44.33 b	25.0 a	5 c	55.35 a
“Indian”	60.33 a	25.3 a	5 b	43.84 a
“Kuwait”	45.66 b	24.3 a	5 c	53.72 a
“Slovenian”	64.00 a	12.3 b	6 a	19.64 b
F test	*	*	*	*

Note: values within the same column followed by the same letters are not significantly different according to DMRT at α=0.05

A further factor that may influence fruit setting is the texture of the soil. The soil in this study contained a high percentage of sand, with a ratio of 66.55% sand, 32.84% silt, and 0.61% clay. This resulted in a low water holding capacity. In addition, high evaporation during the dry season was followed by rising daily temperatures, resulting in a decrease in the formation of capsules (fruit set). The “Slovenian” accession, when grown in a B2 climate type, showed more capsule count than in our study (Table 2).

Capsule Size and Seed Number

The capsule diameter and capsule length were significantly different between the four black cumin accessions. “Kuwait” and “Slovenian” accessions have similar and the highest capsule diameter, and their capsules were wider than the “American” and “Indian” accessions. “Slovenian” accessions have 0.06% of wider diameter than the “American” and “Indian” accessions. The accessions with the highest of capsule length are “Kuwait” and “Slovenian”, whereas the shortest was “American” accession. Capsule length of the “Slovenian” accession is 0.18% longer than “American” accession (Table 3). This is presumed to be due to a combination of genetic and environmental factors. “Slovenian” accession has suitable climatic conditions so that it can maximize genetic potential. Lulseged et al. (2018) reported that the length of black cumin capsules is strongly affected by genotype. “American”, “Indian”, “Kuwait”, and “Slovenian” accessions grown in a B2 climate type display a lower capsule diameter and capsule length than in our study (Destiawan, 2019). Similar observation was reported with black cumin capsules grown in Bangladesh (Ali et al., 2016) and Pakistan (Iqbal et al., 2010).

The seeds number per capsule did not vary among accessions (Table 3). The four accessions of black cumin displayed average seeds number per capsule of 66.44. Black cumin “Slovenian” accessions growing in a B2 climate type develops more seeds in B2 climate than in our study (Destiawan, 2019). For example, in Pakistan, the seeds number per capsule has been shown to be higher than in our study (74.07 seeds; Iqbal et al., 2010). This is likely related to the “Slovenian” accession’s seed filling period coinciding with the dry season. Furthermore, the frequency of watering affects the seeds number per capsule (Mardisiwi, 2017). Water shortages have also been reported to reduce the number of soybean pods and seed (Nugraha et al., 2014).

Interestingly, harvesting time did not affect capsule size and seeds number per capsule with an average diameter of 9.59 mm, capsule length of 14.64 mm, and the seeds number per capsule 66.4, respectively (Table 3). In climate type B2, Turkey acessesion of black cumin harvested at 7 WAA= weeks after anthesis produces a lower capsule diameter and a

Table 3. Capsule size and seed number per capsule of several black cumin accessions

Accession	Capsule diameter (mm)	Capsule length (mm)	Seeds number per capsule
“American”	9.18 b	13.26 c	65.89
“Indian”	9.38 b	14.42 b	73.33
“Kuwait”	9.84 a	15.21 ab	60.11
“Slovenian”	9.99 a	15.70 a	66.44
Average	-	-	66.44 ± 5.41
F Test	*	*	ns
Hasvesting time (WAA= weeks after anthesis)			
6	9.54	14.44	70.58
7	9.63	14.60	68.50
8	9.62	14.90	60.25
Average	9.59 ± 0.05	14.64 ± 0.23	66.44 ± 5.46
F test	ns	ns	ns
Accession x harvesting time	ns	ns	ns

Note: values within the same column followed by the same letters are not significantly different with DMRT at α=0.05. * = significantly different; ns= not significantly different

lesser number of seeds (Mardisiwi 2017; Setiawati 2017). Hence, it appears that black cumin acesssions, specially those with short life cycle, planted in the D3 climate type can maximize the environmental conditions that have a relatively high temperatures, high light intensity and water availability, therefore they can produce the size and seeds number per capsule better than B2 climate type.

Seed Production

The accession of black cumin affects the weight of 100 seeds, seeds weight per plant, and estimated production (Table 4). The “Kuwait” accession has the highest weight of 100 seeds compared to the other three accessions. Meanwhile, the seed weight per plant and the estimated seed production per ha were the same among “American”, “Indian” and “Kuwait” accessions; and higher than the “Slovenian” accession. “Slovenian” accessions have a 100 seed weight 0.86% lower than “Kuwait” accession. The seed weight per plant and production estimation per ha of “Slovenian” accession is about 4.1% and 4.97% lower than others. This is likely to be due to the low capsules number per plant and low percentage of fruit set, thus reducing the seed production of the “Slovenian” accession. In this study, the rainfall, maximum-minimum temperature, and humidity had an average rate of 12.66 mm/month, 39.5 °C - 7.9 °C, and 75%, respectively. Low rainfall and high maximum temperature may have contributed to the low production of the “Slovenian” accessions, particularly at seed filling process. Deficiency of water can reduce the weight per 100 seeds and total black cumin production (Ghamarnia et al., 2010; Hadi et al., 2012; Mardisiwi, 2017). According to Ashraf and Harris (2013), high temperatures result in morphological, physiological and biochemical changes, that can reduce photosynthetic activity, thereby limiting plant growth and productivity. The “Slovenian” accession planted in a B2 climate type experience temperature around 21.64°C with a minimum temperature of 18.66°C and a maximum temperature of 26.18°C and an average humidity of 85.05%. This results in a higher seed weight per plant of 0.26 g (Destiawan, 2019). Black cumin planted in Pakistan has greater weight per 100 seeds than that measured in this study, i.e. 0.34 g per 100 seeds (Iqbal et al., 2010).

Harvesting time affected the weight of 100 seeds, with 7 and 8 WAA being the best harvesting time (Table 4). In the harvest time 7 and 8 WAA, weight 100 seeds was 0.04% heavier than those at 6 WAA. It appears 7 and 8 WAA are the optimum harvesting time, presumably because of more assimilate accumulation after 7 and 8 weeks of growth, resulting in the increase of the weight of 100 seeds.

Seed weight per plant and estimated production per ha did not differ significantly between harvesting times (Table 4). Black cumin planted in a B2 climate type displays an average seed weight per plant and an estimated production per hectare that is lower than in our study (Setiawati, 2017; Mardisiwi, 2017). Despite high temperatures and lack of water, especially at capsule formation and seed filling, the plants in this region can still produce seeds. For comparison, production of black cumin in Turkey is 575 kg.ha^{-1} (Tuntruck et al., 2012), whereas in Iran it is 2075 kg.ha^{-1} (Ghamarnia et al., 2010), both of which are higher than the production in our study.

Thymoquinone and Thymol Content

The “Indian” accession had the highest content of thymoquinone and greatest thymoquinone production. The “Kuwait” accession had the lowest content of thymoquinone and thymol, and highest production contained in the “American” accession. Meanwhile, the “Slovenian” accession had the highest thymol contents (Table 5). Interestingly, the thymoquinone content of “Kuwait” and “American” accessions in the B2 climate type are higher, i.e. 2,745.54 and 5,075.98 μg.g^{-1}, respectively (Herlina, 2018; Al Asad, 2019). This may be explained by the plants being stressed through high day-time temperatures and drought stress leading to the synthesis of thymoquinone through different pathways. Low rainfall, as well as differences in maximum and minimum temperatures

Table 4. Seed weight and seed production of several black cumin accessions

Accession	Weight of 100 seeds (g)	Seed weight per plant (g)	Production estimated (kg.ha^{-1})
“American”	0.25 b	4.93 a	547.9 a
“Indian”	0.23 c	5.42 a	603.0 a
“Kuwait”	0.28 a	5.17 a	523.6 a
“Slovenian”	0.15 d	1.01 b	93.4 b
F test	*	*	*
Harvesting Time (WAA= weeks after anthesis)			
6	0.22 b	4.82	450.6
7	0.23 a	4.06	490.4
8	0.23 a	3.51	384.8
Average	-	4.13 ± 0.66	475.0 ± 51.82
F test	*	ns	ns
Accession x harvesting time	ns	ns	ns

Note: values within the same column followed by the same letters are not significantly different with DMRT at α=0.05. * = significantly different; ns= not significantly different

Table 5. Seed thymoquinone and thymol content of several black cumin accessions

Accession	Thymoquinone (μg.g^{-1} seed)	Thymol (μg.g^{-1} seed)	Thymoquinone production (kg.ha^{-1})	Thymol production (kg.ha^{-1})
“American”	1599.57	817.35	0.88	0.45
“Indian”	3030.45	430.84	1.83	0.26
“Kuwait”	349.64	385.56	0.18	0.21
“Slovenian”	2635.90	2003.46	0.25	0.19
Average	1903.90 ± 1199.06	909.31 ± 754.73	0.78 ± 0.76	0.27 ± 0.12
Harvesting Time (WAA= weeks after anthesis)	Thymoquinone (μg.g^{-1} seed)	Thymol (μg.g^{-1} seed)	Thymoquinone production (kg.ha^{-1})	Thymol production (kg.ha^{-1})
6	1450.43	976.82	0.65	0.44
7	2147.04	927.55	1.05	0.45
8	2114.20	823.54	0.81	0.32
Average	1903.90 ± 393.05	909.31 ± 78.25	0.84 ± 0.20	0.40 ± 0.08

Note: values are average ± standard deviation (n=10) (average values of 12.6 mm/month, 39.5°C - 7.9°C), and humidity (75%) likely influenced secondary metabolite production of all four black cumin accession in the D3 climate type, respectively. In addition, the different types of climate determined the bioactive properties of thymoquinone and thymol seeds of all four black cumin accessions.

Thymoquinone and thymol are secondary metabolite products formed from GPP (Geranyl diphosphate), connected with γ-terpinene and then aromatized into ρ-cymene, followed by hydroxylation of carvacrol and thymohydroquinone, and the oxidation of thymoquinone (Botnick et al., 2012). Importantly, the secondary metabolites content of black cumin seeds is influenced by both biotic and abiotic factors. Abiotic and biotic factors cause different stresses for plants, so that under certain conditions plants respond to stress by producing specific secondary metabolites to cope with these (Verma and Shukla, 2015).

The harvest time at the age of 7 WAA has the highest of thymoquinone and thymol production and thymoquinone content, while the highest thymol content is at the age of 6 WAA (Table 5). This is presumed that at the time of harvest 7 WAA is the peak accumulation of thymoquinone. Thymoquinone bioactive compounds begin to form in the seeds at 40 days after anthesis (DAA), increase after 50 DAA, peak at 65 DAA, and decrease towards the end of 70 DAA maturation (Botnick et al., 2012). Meanwhile thymol content decreased with increasing harvesting time. Thymol is an alternative pathway to replace carvacrol or as an additional pathway for the mechanism of thymoquinone biosynthesis (Botnick et al., 2012).

Conclusion

The black cumin accessions of "Indian" and "Slovenian" origin had the best vegetative growth in the D3 climate environment. "Indian" accession showed the highest capsules numbers per plant, heaviest seeds weight per plant, and the highest estimated production compared to other accessions at 603 kg seeds.ha^{-1}. "American", "Indian" and "Kuwait" accessions are well adapted to the D3 type climate. A harvesting time of 7 to 8 weeks after anthesis was optimum for all accessions. Seed thymoquinone and thymol content of the four black cumin accessions were 349.64 – 3,030.45 and 385.56 – 2,003.46 µg per gram of seeds, respectively, with the potential thymoquinone and thymol production being 0.18 - 1.83 and 0.19 - 0.45 kg.ha^{-1}. Black cumin seed production that was harvested at 6, 7 or 8 weeks after anthesis is similar between accessions.

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