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Effect of sowing window and crop geometry on seed quality parameters of nigella (*Nigella sativa* L.) varieties

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Abstract
The field experiment was conducted at Horticultural Research and Extension Centre, Devihosur, Haveri (Karnataka), India, during *rabi* seasons of 2019-20 and 2020-21. The experiment was laid out in split-split plot design with treatments of three sowing window (October II, November I and II fortnights) as main plots, two nigella varieties (AN 1 and AN 20) as sub plots and four crop geometry (22.5 x 10 cm, 30.0 x 10 cm, 37.5 x 10 cm and 45.0 x 10 cm) as sub-sub plots and replicated thrice. The pooled data of two years revealed that, sowing of nigella during November I fortnight with AN 1 variety at 45.0 x 10 cm spacing ($D_2V_1S_4$) recorded significantly higher content of essential oil and protein in seeds (0.70% and 205.70 g kg^{-1}, respectively). The oil yield due to interaction effect was significantly higher in sowing window of November I fortnight with AN 1 variety at spacing of 30.0 x 10 cm ($D_2V_1S_2$, 9.71 kg ha^{-1}). The interaction of sowing window, variety and crop geometry differed non-significantly for germination, field emergence and total seedling length.

Keywords: *Nigella sativa*, sowing window, crop geometry, seed quality

Introduction
Nigella sativa is emerging seed spice and medicinal crop, it is also called as a miracle herb. It has a rich historical and religious past and is endemic to Southern Europe, North Africa, and Southwest Asia, and is frequently referred to as black seed. Many countries around the world, including the Middle East Mediterranean region, South Europe, India, Pakistan, Syria, Turkey, and Saudi Arabia, cultivate this plant (Khare, 2004) [9]. It is a member of the Ranunculaceae family with chromosome number 2n=12. It is an annual herbaceous plant grows to a height of 50 to 60 cm, leaves are finely split and linear and having dicotyledonous seeds. Since many centuries, *Nigella sativa* seeds and oil have been widely utilized in the treatment of a variety of diseases. It is also an important medicine in Indian traditional systems such as Unani and Ayurveda (Sharma *et al.* 2005 and Goreja, 2003) [15, 6]. It is mentioned in one of the Prophetic hadiths that black seed is the solution for all diseases save death, Muslims consider it to be one of the most powerful forms of curative medication accessible. In Tibb-e-Nabwi (Prophetic Medicine), it is also suggested for daily use (Al-Bukhari, 1976) [2].
Most of the seed spices are grown in western India particularly in the states of Gujarat and Rajasthan. Many farmers in the southern states are keen to cultivate this crop due to its increasing market price and medicinal usage. The cultivation package is lacking in Southern states. With this background, the present research study was taken up to develop agro-techniques and its impact on seed quality parameters.

Material and Methods
The field experiment was conducted at Horticultural Research and Extension Centre, Devihosur, Haveri (Karnataka), India, during *rabi* seasons of 2019-20 and 2020-21. The experimental site comes under the Northern transition zone (Zone 8) of Karnataka with medium deep balck clay soils. The experiment was laid out in split-split plot design. The treatments included three sowing window (October II, November I and II fortnights) as main plots, two nigella varieties (AN 1 and AN 20) as sub plots and four crop geometry (22.5 x 10 cm, 30.0 x 10 cm, 37.5 x 10 cm and 45.0 x 10 cm) as sub-sub plots and replicated thrice. The other crop husbandry practices were followed as per the recommended package of practices.

The seed quality tests were conducted one month after the harvest of the crop for both the years (2019-20 and 2020-21). The essential oil was extracted from the seed by Soxhlet apparatus (Socsplus-SCS 04R) by using solvent extraction method and hexane was the solvent used. Essential oil yield was worked out by multiplying the essential oil per cent with seed yield (kg ha^{-1}). The seed protein content was assayed using the Lowry protocol based on Folin reaction (Lowry *et al.*, 1951) [11]. The estimated protein content was converted to g $kg^{-1}$of seed. The germination test was carried out in the laboratory in four replications by adopting the "between paper" method as per the procedure given by ISTA Rules (Anonymous, 1996) [3]. The number of normal seedlings were counted on 8^{th} day of germination testing treatment wise. The average was expressed as germination percentage. Field emergence studies were carried out on medium deep black clay soil. Four replicates of 100 seeds each were taken at random from the samples drawn separately from the total produce of each treatment and were used for field emergence studies. Seeds were hand dibbled to a depth of about five cm. The seedling was considered emerged when the plumule of the seedling was just visible on the surface of the soil. The emergence of plumule was recorded on eighth day after sowing in percentage. The shoot length of ten randomly selected eight days old normal seedlings from germination test was recorded and the mean was expressed as shoot length (cm). The root length of ten randomly selected eight days old normal seedlings from germination test was recorded and the mean was expressed as root length (cm). Seedling length (cm) was calculated adding the mean values of shoot and root length. The seedling vigour index was computed using the following formula (Abdul-Baki and Anderson, 1973) [1] and was expressed in whole number.

Seedling vigour index (SVI) = Germination percentage x Seedling length (cm)

Results and Discussion

Effect of sowing window

November I fortnight (D_2) sowing recorded (Table 1) significantly higher essential oil content and yield (0.61% and 8.23 kg ha^{-1}, respectively, Fig. 1) compared to D_1 *i.e.*, October II fortnight sowing. The higher oil content and yield of quality parameters of nigella was mainly due to the congenial weather condition prevailed during the crop growth and developmental stages. Similar findings were also reported by Shrook and Saad (2009) [16]. They reported the quality changes among three planting dates in nigella (1^{st} November, 15^{th} November, and 1^{st} December) with the 1^{st} November recorded highest fixed oil (140.1 kg ha^{-1}) and essential oil (2.4 liter ha^{-1}).

The seed quality parameters like per cent germination and field emergence (Table 2) were also found significantly higher with November I fortnight (97.16% and 89.84%, respectively, Fig. 2). The seedling vigour index (Fig. 2) was also found significantly higher (984.50) with November I fortnight compared to other sowing window. The increased quality parameters was mainly due to favourable weather conditions prevailed during the crop growth and developmental stages which enhanced better seed yield and seed quality parameters.

Table 1: Essential oil content, yield and protein content of nigella varieties as influenced by sowing window and crop geometry

Treatment		Essential oil content (%)			Essential oil yield (kg/ha)			Protein content (g/kg)		
		2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
Sowing Window (D)										
D_1	October II fortnight	0.56a	0.60a	0.58b	5.74b	7.76b	6.75b	197.13b	196.21a	196.67a
D_2	November I fortnight	0.60a	0.63a	0.61a	7.22a	9.25a	8.23a	200.41a	200.29a	200.35a
D_3	November II fortnight	0.58a	0.62a	0.60a	6.89a	8.94a	7.92a	199.57ab	199.96a	199.77a
S. Em.±		0.01	0.01	0.01	0.32	0.31	0.21	0.77	1.06	0.86
Variety (V)										
V_1	AN 1	0.59a	0.63a	0.61a	6.92a	9.14a	8.03a	199.73a	199.35a	199.54a
V_2	AN 20	0.57a	0.60a	0.59a	6.31b	8.15b	7.23b	198.35a	198.29a	198.32a
S. Em.±		0.01	0.01	0.01	0.15	0.23	0.12	0.74	0.56	0.60
Spacing (S)										
S_1	22.5 x 10 cm	0.51c	0.55c	0.53c	6.64b	8.42ab	7.53b	186.42c	189.23c	187.82c
S_2	30.0 x 10 cm	0.57b	0.61b	0.59b	7.60a	9.51a	8.55a	199.81b	199.29b	199.55b
S_3	37.5 x 10 cm	0.61ab	0.65ab	0.63ab	6.60b	9.10a	7.85b	204.35a	202.96a	203.65a
S_4	45.0 x 10 cm	0.63a	0.67a	0.65a	5.63c	7.56b	6.60c	205.58a	203.82a	204.70a
S. Em.±		0.02	0.02	0.01	0.29	0.37	0.23	0.92	0.86	0.84
Interaction (D x V x S)										
$D_1V_1S_1$		0.48ab	0.53ab	0.51ef	6.00b-d	7.97a-e	6.99b-g	184.42de	184.19f	184.30de
$D_1V_1S_2$		0.58ab	0.61ab	0.60a-e	7.56ab	9.44a-d	8.50a-d	200.87ab	199.57a-d	200.22ab
$D_1V_1S_3$		0.60ab	0.65ab	0.62a-d	6.22b-d	8.94a-d	7.58b-d	203.09a	202.20ab	202.65a
$D_1V_1S_4$		0.63ab	0.65ab	0.64a-c	4.91cd	6.42de	5.67gh	205.50a	202.96ab	204.23a
$D_1V_2S_1$		0.45b	0.51b	0.48f	5.07cd	7.39b-e	6.23f-h	180.98e	178.97f	179.97e
$D_1V_2S_2$		0.55ab	0.59ab	0.57b-f	6.13b-d	8.64a-e	7.38b-g	194.96bc	196.69b-e	195.83bc
$D_1V_2S_3$		0.58ab	0.63ab	0.60a-e	5.57b-d	7.59a-e	6.58d-h	202.16ab	200.94a-c	201.55ab
$D_1V_2S_4$		0.62ab	0.62ab	0.62a-d	4.47d	5.66e	5.07h	205.07a	204.18a	204.62a
$D_2V_1S_1$		0.55ab	0.57ab	0.56b-e	7.57ab	9.09a-d	8.33a-e	190.45cd	194.10c-e	192.28c
$D_2V_1S_2$		0.57ab	0.64ab	0.60a-e	8.72a	10.70a	9.71a	201.92ab	201.03a-c	201.47ab
$D_2V_1S_3$		0.62ab	0.68ab	0.65ab	7.31a-c	10.20ab	8.76ab	205.12a	203.83ab	204.48a
$D_2V_1S_4$		0.68a	0.72a	0.70a	6.99ab	9.50a-d	8.25a-e	206.67a	204.73a	205.70a
$D_2V_2S_1$		0.55ab	0.58ab	0.56b-f	7.57a-c	8.86a-d	8.22a-e	189.34cd	193.04de	191.19c
$D_2V_2S_2$		0.57ab	0.59ab	0.58b-f	7.31a-c	9.08a-d	8.20a-e	199.05ab	198.16a-e	198.61ab
$D_2V_2S_3$		0.60ab	0.62ab	0.61a-e	6.48a-d	8.96a-d	7.72b-f	205.30a	204.41a	204.86a

$D_2V_2S_4$	0.63ab	0.66ab	0.65ab	5.80b-d	7.60a-e	6.70c-h	205.43a	203.04ab	204.24a
$D_3V_1S_1$	0.52ab	0.56ab	0.54c-f	7.06a-c	8.97a-d	8.02a-f	187.03de	192.23e	189.63cd
$D_3V_1S_2$	0.57ab	0.59ab	0.58b-f	7.99ab	9.35a-d	8.67a-c	200.60ab	199.71a-d	200.15ab
$D_3V_1S_3$	0.64ab	0.68ab	0.66ab	7.04a-c	10.01a-c	8.53a-d	205.11a	203.67ab	204.39a
$D_3V_1S_4$	0.60ab	0.70ab	0.65ab	5.72b-d	9.13a-d	7.43b-g	205.97a	204.02a	204.99a
$D_3V_2S_1$	0.52ab	0.54ab	0.53d-f	6.58a-d	8.23a-e	7.40b-g	186.29de	192.83de	189.56cd
$D_3V_2S_2$	0.58ab	0.62ab	0.60a-e	7.89ab	9.83a-c	8.86ab	201.46ab	200.57a-c	201.01ab
$D_3V_2S_3$	0.62ab	0.64ab	0.63a-d	6.97a-c	8.92a-d	7.94a-f	205.28a	202.70ab	203.99a
$D_3V_2S_4$	0.61ab	0.65	0.63a-d	5.88b-d	7.07c-e	6.47e-h	204.86a	203.97a	204.42a
S. Em.±	0.04	0.05	0.03	0.71	0.91	0.57	2.26	2.10	2.06

Means followed by the same letter (s) within a column do not differ significantly by DMRT (P=0.05)

Table 2: Germination, field emergence and seedling vigor index of nigella varieties as influenced by sowing window and crop geometry

Treatment		Germination (%)			Field emergence (%)			Seedling vigour index		
		2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
Time of sowing (T)										
D_1	October II fortnight	87.09b	94.54b	94.81b	85.98b	89.11b	87.55b	874.20b	957.94b	916.07b
D_2	November I fortnight	89.13a	97.19a	97.16a	88.04a	91.63a	89.84a	939.95a	1029.06a	984.50a
D_3	November II fortnight	88.95ab	96.73ab	96.84a	87.75a	91.45a	89.60a	918.20ab	1017.86a	968.03a
S. Em.±		0.41	0.55	0.42	0.44	0.45	0.44	11.47	12.22	10.62
Variety (V)										
V_1	AN 1	88.56a	96.33a	96.45a	87.41a	91.04a	89.23a	922.49a	1019.94a	971.22a
V_2	AN 20	88.23a	95.97a	96.10a	87.10a	90.42a	88.76a	899.07a	983.29a	941.18a
S. Em.±		0.80	0.86	0.80	0.79	0.95	0.87	12.13	16.52	13.16
Spacing (S)										
S_1	22.5 x 10 cm	86.75a	94.34a	94.55a	85.62a	88.62a	87.12a	820.43b	918.09b	869.26b
S_2	30.0 x 10 cm	87.97a	95.82a	95.90a	86.84a	90.47a	88.66a	913.18a	1003.70a	958.44a
S_3	37.5 x 10 cm	89.43a	97.18a	97.31a	88.29a	91.93a	90.11a	943.88a	1034.10a	988.99a
S_4	45.0 x 10 cm	89.42a	97.27a	97.34a	88.28a	91.92a	90.10a	965.63a	1050.58a	1008.11a
S. Em.±		1.34	1.21	1.22	1.35	1.35	1.35	26.37	29.01	25.93
Interaction (D x V x S)										
$D_1V_1S_1$		84.47a	92.10a	92.28a	83.27a	86.80a	85.03a	761.05bc	901.78ab	831.41ab
$D_1V_1S_2$		88.87a	95.63a	96.25a	87.73a	91.37a	89.55a	927.72a-c	1024.16a	975.94a
$D_1V_1S_3$		88.57a	95.90a	96.23a	87.43a	91.07a	89.25a	906.67a-c	1005.89a	956.28a
$D_1V_1S_4$		86.67a	94.43a	94.55a	85.53a	89.17a	87.35a	942.76a-c	1026.39a	984.57a
$D_1V_2S_1$		86.03a	92.50a	93.27a	85.17a	84.90a	85.03a	740.06c	729.00b	734.53b
$D_1V_2S_2$		84.43a	92.53a	92.48a	83.30a	86.93a	85.12a	851.47a-c	939.39ab	895.43ab
$D_1V_2S_3$		88.33a	96.43a	96.38a	87.20a	90.83a	89.02a	905.39a-c	996.39a	950.89a
$D_1V_2S_4$		89.33a	96.77a	97.05a	88.20a	91.83a	90.02a	958.48a-c	1040.51a	999.50a
$D_2V_1S_1$		87.93a	96.37a	96.15a	86.80a	90.43a	88.62a	901.75a-c	992.52a	947.13a
$D_2V_1S_2$		89.00a	97.10a	97.05a	87.87a	91.50a	89.68a	936.80a-c	1026.98a	981.89a
$D_2V_1S_3$		90.27a	98.07a	98.17a	89.17a	92.77a	90.97a	986.80a	1073.08a	1029.94a
$D_2V_1S_4$		90.47a	98.93a	98.70a	89.50a	92.97a	91.23a	993.50a	1088.82a	1041.16a
$D_2V_2S_1$		87.00a	95.10a	95.05a	85.83a	89.50a	87.67a	853.90a-c	944.43ab	899.16ab
$D_2V_2S_2$		88.30a	96.33a	96.32a	87.30a	90.80a	89.05a	921.64a-c	1009.36a	965.50a
$D_2V_2S_3$		89.83a	97.60a	97.72a	88.77a	92.33a	90.55a	959.90a-c	1046.06a	1002.98a
$D_2V_2S_4$		90.27a	98.03a	98.15a	89.07a	92.77a	90.92a	965.29ab	1051.23a	1008.26a
$D_3V_1S_1$		87.83a	95.00a	95.42a	86.63a	90.33a	88.48a	861.18a-c	977.56a	919.37ab
$D_3V_1S_2$		88.37a	96.67a	96.52a	87.17a	90.87a	89.02a	918.80a-c	1013.00a	965.90a
$D_3V_1S_3$		90.17a	97.93a	98.05a	88.97a	92.67a	90.82a	962.29a-c	1050.31a	1006.30a
$D_3V_1S_4$		90.10a	97.86a	97.98a	88.90a	92.60a	90.75a	970.54ab	1058.84a	1014.69a
$D_3V_2S_1$		87.23a	95.00a	95.12a	86.03a	89.73a	87.88a	804.65a-c	963.27a	883.96ab
$D_3V_2S_2$		88.87a	96.63a	96.75a	87.67a	91.37a	89.52a	922.65a-c	1009.34a	965.99a
$D_3V_2S_3$		89.40a	97.17a	97.28a	88.20a	91.90a	90.05a	942.25a-c	1032.84a	987.54a
$D_3V_2S_4$		89.67a	97.57a	97.62a	88.47a	92.17a	90.32a	963.21a-c	1037.70a	1000.46a
S. Em.±		3.29	2.97	2.99	3.31	3.32	3.30	64.60	71.07	63.51

Means followed by the same letter (s) within a column do not differ significantly by DMRT (P=0.05)

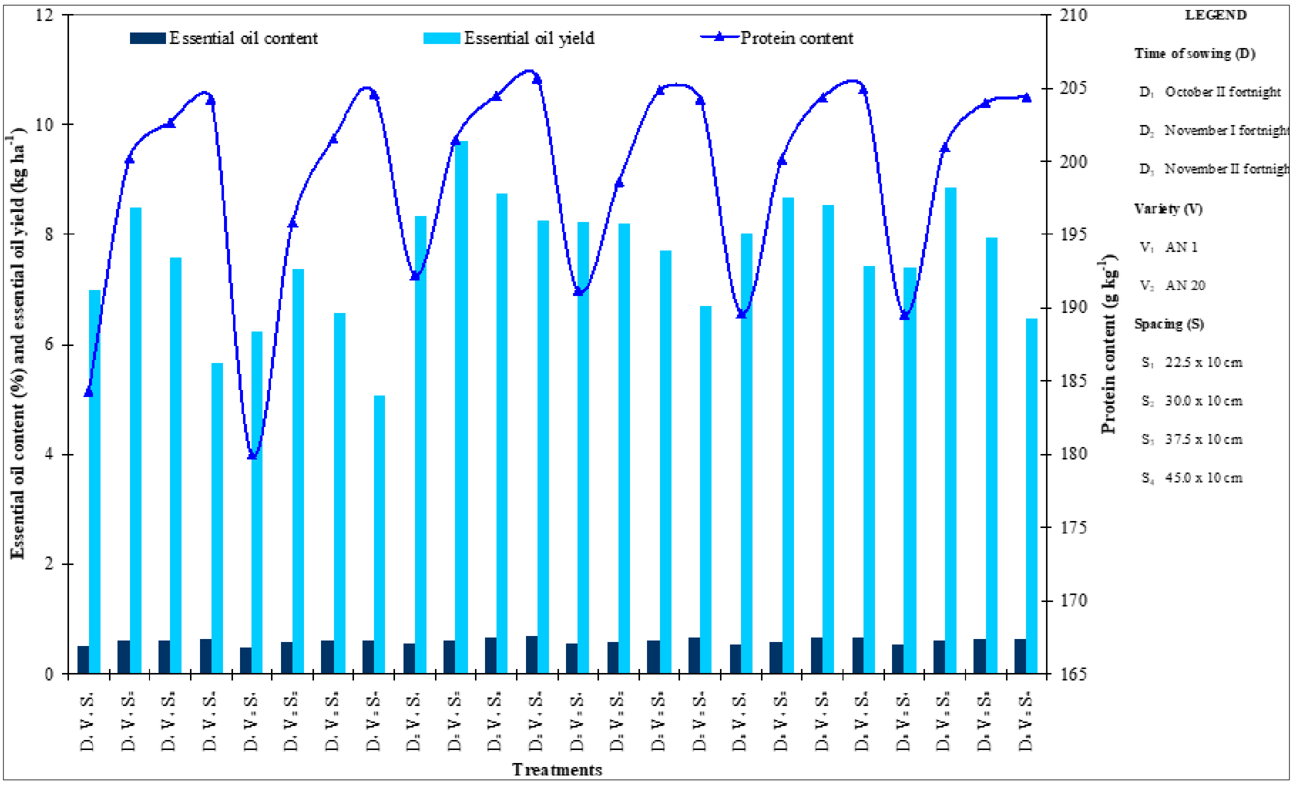

Fig 1: Essential oil content, yield and protein content of nigella varieties as influenced by sowing window and crop geometry

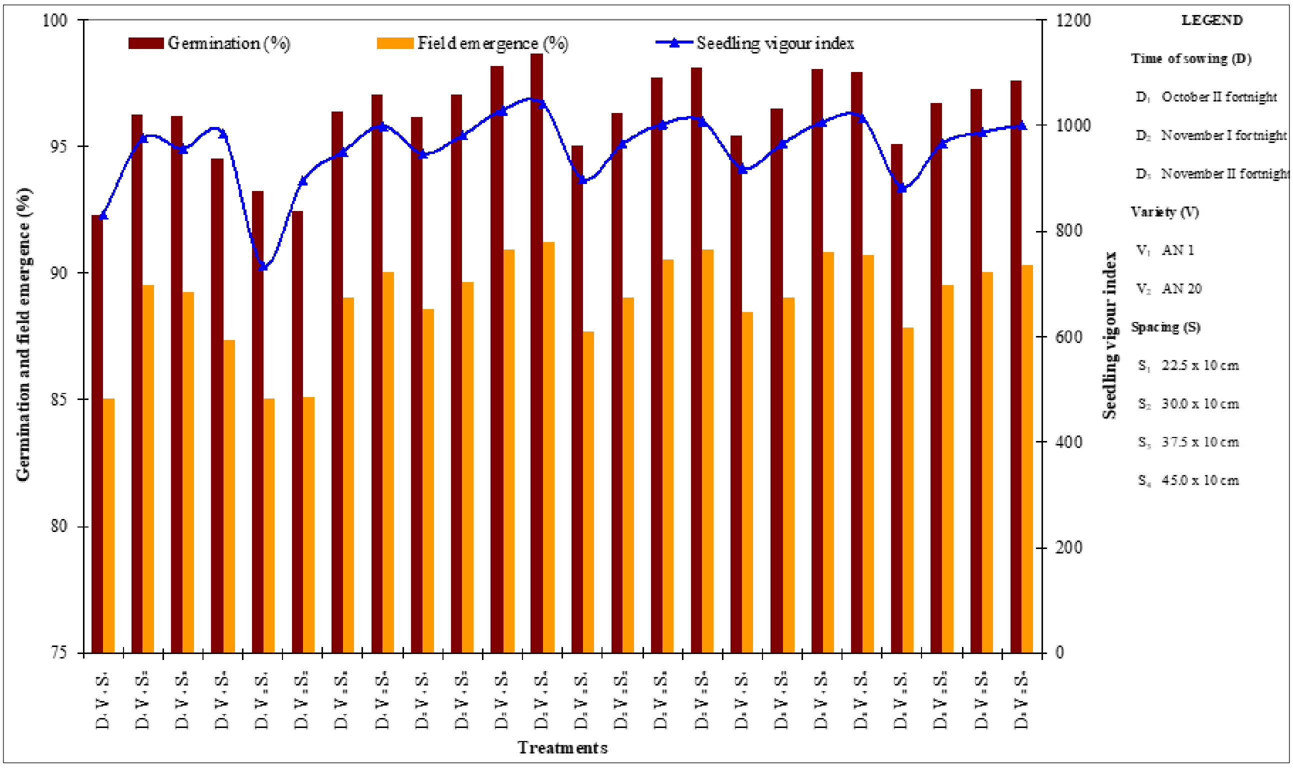

Fig 2: Germination, field emergence and seedling vigor index of nigella varieties as influenced by sowing window and crop geometry

Effect of varieties

Though the nigella varieties did not differ significantly for the content of important quality parameters *viz.*, essential oil and protein, the AN 1 variety recorded significantly higher essential oil yield (8.03 kg ha^{-1}, Fig. 1). This was mainly due to increased seed yield level with the variety AN 1 compared to AN 20. Similar finding was also made by Assefa *et al.* (2015) [4] while studying the quality of the released (Dirishaye, Eden and Deribera) and check varieties. The varieties did not differ significantly for the moisture content, essential oil content and oleoresin yield.

The varieties did not differ significantly for the seed germination (Fig. 2 and 3)), field emergence, seedling vigour index and other quality parameters.

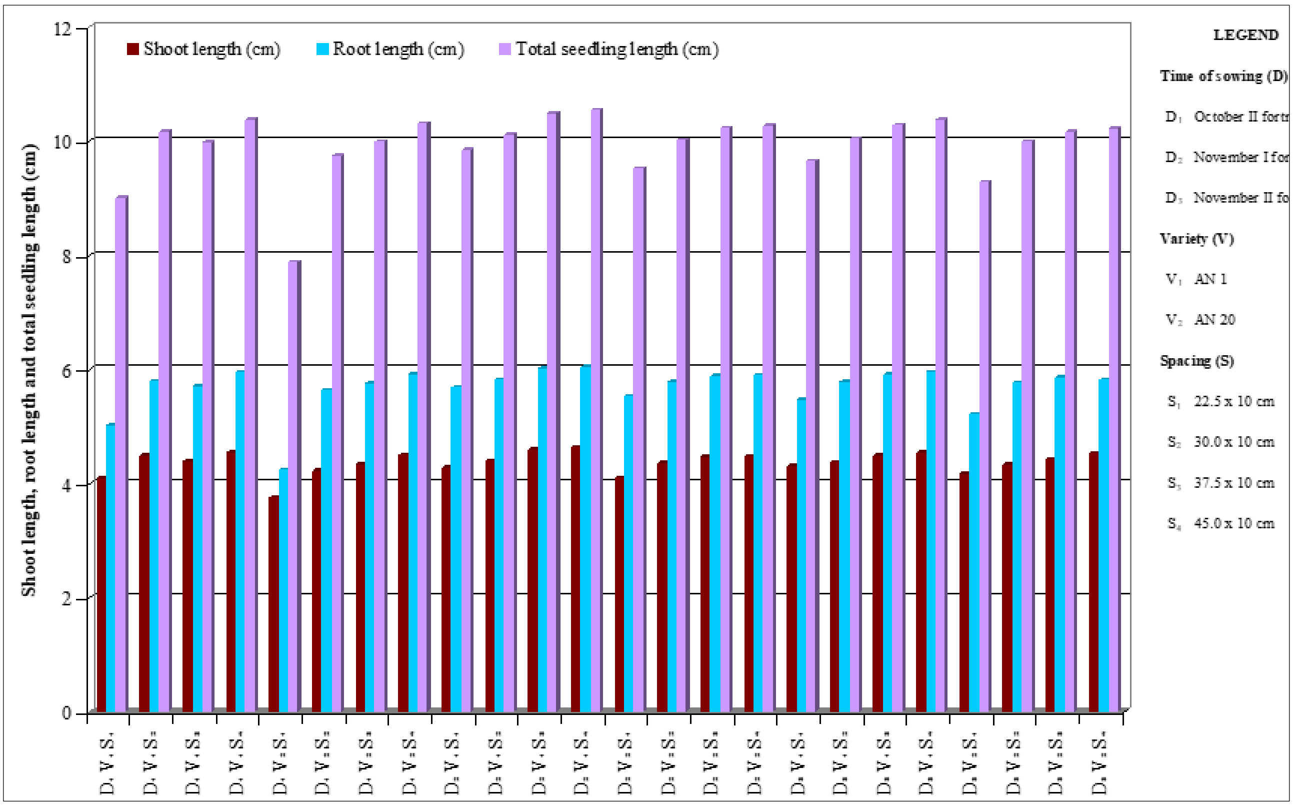

Fig 3: Shoot length, root length and total seedling length of nigella varieties as influenced by sowing window and crop geometry

Effect of crop geometry

The essential oil content did not differ significantly due to the influence of row spacing. The essential oil yield was found significantly higher (8.55 kg ha^{-1}) with spacing of 30.0 x 10 cm which was mainly due to increased seed yield. Significantly higher protein content (204.70 g kg^{-1}) was observed with wider spacing of 45.0 x 10 cm which was on par with 37.5 x 10 cm. Nourouzpour and Moghaddam (2007) [13] also reported the similar findings of crop response to five plant densities (150, 200, 250, 300 and 350 plants m^{-2}) in Iran and observed that plant density did not have significant effects on fixed oil and essential oil content but fixed oil and essential oil yield differed significantly. Maximum yield was recorded with 250 plants m^{-2} (411 and 14.1 kg ha^{-1}, respectively).

The seed germination and field emergence did not differed significantly due to the impact of spacing. However, the wider spacing of 45.0 x 10 cm recorded significantly higher seedling vigour index (1008.11) and was on par with 37.5 x 10 and 30.0 x 10 cm spacing. Significantly least seedling vigour index was noticed with closer spacing of 22.5 x 10 cm. This was mainly due to higher plant population at closer spacing which might have reduced the seed filling due to more competition.

Interaction effect

The interaction of November I fortnight sowing with AN 1 variety at 45.0 x 10 cm spacing recorded significantly higher essential oil content in seeds ($D_2V_1S_4$, 0.70%). The increase in the content of essential oil was very narrow and negligible compared to other interactions (Fig. 1). The slight increase in essential oil content was mainly due to the favourable weather, less plant density per unit area with varietal character which promoted more accumulation of photosynthates in sink and resulted in better filling of the seeds. Similar findings were also noticed by Ozel *et al.* (2009) [14], Meena *et al.* (2012) [12] and Goutam Rahul *et al.* (2016) [7] compared the narrow spacing of 15.0 cm and 22.5 cm. A wider row spacing of 30.0 cm recorded significantly higher oil content in seed (0.77%).

The essential oil yield due to interaction effect was significantly higher in sowing window of November I fortnight with AN 1 variety at spacing of 30.0 x 10 cm ($D_2V_1S_2$, 9.71 kg ha^{-1}). This was also found on par with other interactions *viz.*, $D_1V_1S_2$, $D_2V_1S_1$, $D_2V_1S_3$, $D_2V_1S_4$, $D_2V_2S_1$, $D_2V_2S_2$, $D_3V_1S_1$, $D_3V_1S_2$, $D_3V_1S_3$, $D_3V_2S_2$ and $D_3V_2S_3$. Increased oil yield was mainly due to increased seed yield in the respective interactions. Similar results were also reported by Koli (2013) [10] and Giridhar (2015) [5].

The increase in essential oil was mainly due to increased seed yield, yield and growth attributing characters under favourable weather conditions which enhanced the more accumulation of photosynthates in the sink (Giridhar, 2015) [5]. There was also increased space and nutrients which might have enhanced the essential oil biosynthesis through their direct or indirect role in the metabolism of the plant resulting in more plant metabolites.

The protein content was also found significantly higher for the interactions involving the wider row spacing of 45.0 x 10 cm (S_4) and 37.5 x 10 cm (S_3) irrespective of the sowing window and variety. Significantly higher protein content was noticed with the interaction $D_2V_1S_4$ (205.70 g kg^{-1}) followed by $D_3V_1S_4$ (204.99 g kg^{-1}, Fig. 1).

These findings are in conformity with the Hammo (2008) [8], the protein content rose from 20.67 to 24.40 per cent with a reduction of seed rate from 0.12 to 0.08 g per m^2. Goutam Rahul *et al.* (2016) [7] found significantly higher protein content (21.25%) with wider row spacing of 30.0 cm compared to narrow spacing of 15.0 cm and 22.5 cm. In early sown crop, reduced protein content may be related to the influence of environmental conditions like photoperiod and temperature, which might not be optimal for protein synthesis,

whereas, the same factors were favourable for the late seeded crop. The higher protein content (synthesis) in widely spaced crops was likely owing to more readily available resources such as nutrients, water and light. Hammo (2008) [8] noted a decrease in protein content with increased plant population.
The interaction of sowing window, variety and crop geometry differed non-significantly for germination (92.28% to 98.93%), field emergence (85.03% to 91.23%) and total seedling length (7.88 cm to 10.55 cm). However, significantly least seedling vigour index was noticed with the interaction $D_1V_2S_1$ (734.53). Rest all other interactions were significantly on par and higher (831.41 to 1041.16). The reduced seedling vigour index in early sowing window with closer spacing was mainly due to non-congenial weather conditions like temperature, light and relative humidity during the plant vegetative and reproductive stages combined with more plant density (closer spacing, S_1) which led to more competition for resources. This created stress among the plants and lesser accumulation of photosynthates in the sink and ultimately the grain filling was affected which in turn reduced the seed quality (vigour).

Table 3: Shoot, root and total seedling length of nigella varieties as influenced by sowing window and crop geometry

Treatment		Shoot length (cm)			Root length (cm)			Total seedling length (cm)		
		2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
Sowing window (D)										
D_1	October II fortnight	4.28a	4.31a	4.29a	5.18a	5.84a	5.51a	9.22a	10.14a	9.68a
D_2	November I fortnight	4.42a	4.41a	4.42a	5.51a	6.16a	5.83a	9.69a	10.57a	10.13a
D_3	November II fortnight	4.40a	4.39a	4.40a	5.33a	6.12a	5.72a	9.48a	10.52a	10.00a
S. Em.±		0.04	0.04	0.04	0.10	0.09	0.08	0.10	0.07	0.07
Variety (V)										
V_1	AN 1	4.42a	4.43a	4.43a	5.38a	6.15a	5.77a	9.56a	10.59a	10.07a
V_2	AN 20	4.31a	4.30a	4.31a	5.30a	5.92a	5.61a	9.37a	10.23a	9.80a
S. Em.±		0.04	0.06	0.05	0.09	0.12	0.08	0.12	0.14	0.12
Spacing (S)										
S_1	22.5 x 10 cm	4.12a	4.12a	4.12a	4.78a	5.61a	5.20a	8.66a	9.73a	9.20a
S_2	30.0 x 10 cm	4.35a	4.38a	4.36a	5.44a	6.10a	5.77a	9.54a	10.48a	10.01a
S_3	37.5 x 10 cm	4.45a	4.46a	4.45a	5.51a	6.21a	5.86a	9.72a	10.66a	10.19a
S_4	45.0 x 10 cm	4.53a	4.54a	4.54a	5.63a	6.24a	5.94a	9.93a	10.78a	10.35a
S. Em.±		0.09	0.09	0.09	0.16	0.19	0.15	0.23	0.25	0.22
Interaction (D x V x S)										
$D_1V_1S_1$		4.10a	4.10a	4.10a	4.36a	5.68a	5.02a	8.22a	9.78a	9.00a
$D_1V_1S_2$		4.38a	4.60a	4.49a	5.47a	6.14a	5.80a	9.61a	10.74a	10.17a
$D_1V_1S_3$		4.39a	4.39a	4.39a	5.27a	6.15a	5.71a	9.43a	10.54a	9.98a
$D_1V_1S_4$		4.54a	4.55a	4.54a	5.63a	6.29a	5.96a	9.93a	10.82a	10.38a
$D_1V_2S_1$		3.76a	3.76a	3.76a	4.36a	4.12a	4.24a	7.88a	7.88a	7.88a
$D_1V_2S_2$		4.21a	4.22a	4.22a	5.31a	5.97a	5.64a	9.29a	10.19a	9.74a
$D_1V_2S_3$		4.34a	4.34a	4.34a	5.44a	6.09a	5.76a	9.54a	10.43a	9.99a
$D_1V_2S_4$		4.51a	4.50a	4.50a	5.60a	6.25a	5.92a	9.86a	10.75a	10.31a
$D_2V_1S_1$		4.27a	4.26a	4.27a	5.37a	6.01a	5.69a	9.40a	10.28a	9.84a
$D_2V_1S_2$		4.40a	4.40a	4.40a	5.50a	6.15a	5.82a	9.66a	10.55a	10.11a
$D_2V_1S_3$		4.60a	4.61a	4.60a	5.69a	6.34a	6.02a	10.05a	10.94a	10.49a
$D_2V_1S_4$		4.62a	4.63a	4.63a	5.72a	6.37a	6.05a	10.11a	11.00a	10.55a
$D_2V_2S_1$		4.10a	4.11a	4.11a	5.20a	5.86a	5.53a	9.07a	9.97a	9.52a
$D_2V_2S_2$		4.36a	4.36a	4.36a	5.46a	6.10a	5.78a	9.58a	10.46a	10.02a
$D_2V_2S_3$		4.48a	4.48a	4.47a	5.56a	6.21a	5.89a	9.79a	10.68a	10.23a
$D_2V_2S_4$		4.42a	4.49a	4.48a	5.58a	6.23a	5.90a	9.83a	10.71a	10.27a
$D_3V_1S_1$		4.29a	4.30a	4.30a	4.89a	6.04a	5.47a	8.96a	10.34a	9.65a
$D_3V_1S_2$		4.38a	4.37a	4.37a	5.46a	6.11a	5.79a	9.59a	10.48a	10.04a
$D_3V_1S_3$		4.49a	4.49a	4.49a	5.58a	6.25a	5.91a	9.83a	10.73a	10.28a
$D_3V_1S_4$		4.54a	4.55a	4.54a	5.63a	6.30a	5.96a	9.93a	10.83a	10.38a
$D_3V_2S_1$		4.18a	4.18a	4.18a	4.50a	5.94a	5.22a	8.44a	10.12a	9.28a
$D_3V_2S_2$		4.34a	4.34a	4.34a	5.43a	6.10a	5.77a	9.53a	10.44a	9.99a
$D_3V_2S_3$		4.43a	4.42a	4.42a	5.51a	6.21a	5.86a	9.69a	10.63a	10.16a
$D_3V_2S_4$		4.52a	4.53a	4.53a	5.62a	6.01a	5.82a	9.91a	10.54a	10.22a
S. Em.±		0.21	0.23	0.21	0.39	0.47	0.38	0.56	0.61	0.54

Means followed by the same letter (s) within a column do not differ significantly by DMRT (P=0.05)

Conclusion

Sowing of nigella during November I fortnight with AN 1 variety at 45.0 x 10 cm spacing ($D_2V_1S_4$) recorded significantly higher content of essential oil and protein in seeds (0.70%, 205.70 g kg^{-1}, respectively). The oil yield due to interaction effect was significantly higher in sowing window of November I fortnight with AN 1 variety at spacing of 30.0 x 10 cm ($D_2V_1S_2$, 9.71 kg ha^{-1}). The interaction of sowing window, variety and crop geometry differed non-significantly for germination, field emergence and total seedling length. However, significantly least seedling vigour index was noticed with the interaction $D_1V_2S_1$ (734.53). Rest all other interactions were significantly on par and higher (831.41 to 1041.16).

Reference

1. Abdul Baki AA, Anderson JD. Vigour determination in soybean by multiple criteria. Crop Sci 1973;13:630-633.
2. Al-Bukhari MI. In: The collection of authentic sayings of prophet Mohammad (peace be upon him), division 71 on medicine. 2nd ed. Al-Bukhari Sahi., editor. Ankara: Hilal Yayinlari 1976.
3. Anonymous. International rules for seed testing. *Seed Sci. Technol.*, (Supplement) 1996;24:1-335.
4. Assefa E, Alemayehu A, Mamo T, Adaptability study of black cumin (*Nigella sativa* L.) varieties in the mid and high land areas of Kaffa zone, South West Ethiopia. Agric. For. Fish 2015;4(1):14-17.
5. Giridhar K. Effect of sowing time, plant density, nitrogen and phosphorus levels on growth, yield and quality of black cumin (*Nigella sativa* L.) in vertisols of Andhra Pradesh. *Ph.D. Thesis*, Dr. Y.S.R. Horticultural University, Hyderabad, Telangana 2015.
6. Goreja WG. Black seed: Nature's miracle remedy. New York, NY: Amazing Herbs Press 2003.
7. Goutam Rahul K, Naruka IS, Shaktawat RPS, Kushwah SS, Kanwar Jyoti. Growth, yield and quality of nigella (*Nigella sativa* L.) as Influenced by row spacing and nitrogen levels. Int. J Agric. Sci 2016;8(52):2521-2523.
8. Hammo YH. Effect of high levels of nitrogen and phosphorus fertilizer, pinching, and seed rate on growth and yield components of *Nigella sativa* L. Vegetative growth and seed yield. Mesopotamia J Agric. Sci 2008;36(1):19-29.
9. Khare CP. Encyclopedia of Indian medicinal plants. New York: Springer-Verlag Berlin Heidelberg 2004.
10. Koli SA. Effect of variety and plant spacing on seed yield and yield attributes of black cumin (*Nigella sativa* L.). *M. Sc., Thesis*, Sher-E-Bangla Agricultural University, Dhaka 2013.
11. Lowry OH, Rosebrough NJ, Farr AL, Randall RJ. Protein measurement with the Folin phenol reagent. J Biol. Chem 1951;193(1):265-275.
12. Meena SS, Mehta RS, Lal G, Kant K, Sharma YK, Saxena SN *et al.* Essential oil, fatty oil and seed yield of nigella (*Nigella sativa* L.) as influenced by sowing dates and crop geometry. Indian J Hortic 2012;69(4):591-593.
13. Nourouzpour G, Moghaddam PR. Effect of different irrigation intervals and plant density on oil yield and essences percentage of black cumin (*Nigella sativa*). Pajouhesh-Va-Sazandegi 2007;73:133-138.
14. Özel A, Demirel U, Güler İ, Erden K. Effect of different row spacing and seeding rates on black cumin (*Nigella sativa* L.) yields and some agricultural characters. J Fac. Agric. Harran Univ. (Turkey) 2009;13(1):17-25.
15. Sharma PC, Yelne MB, Dennis TJ, Database on medicinal plants used in Ayurveda, New Delhi 2005, 420-440.
16. Shrook MK, Saad A. Effect of plant growth regulators and planting dates on seed, yield fixed and volatile oil in *Nigella sativa* L. Al-anbar J Agric. Res 2009;7(4):109-117.