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Nigella sativa: A seed spice crop: Importance and cultivation practices

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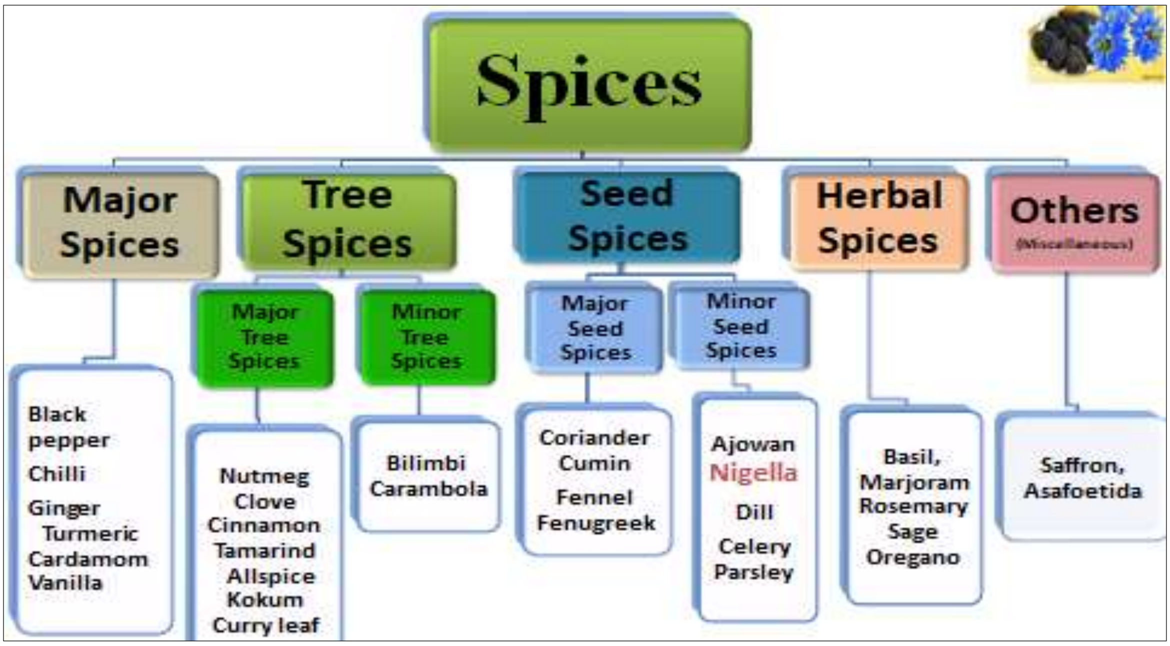
Abstract
Our country's economy relies heavily on seed spices due to high internal consumption and rising export demand. Nigella (*Nigella sativa* L.) is a relatively unknown seed spice that goes by the names kalonji (Hindi) and Kalajira (Urdu). The seeds of this annual and biennial (winter) herbaceous plant are cultivated for their commercial value. It has great value to humanity as a spice, medicine, food, and agricultural input. Profitable development of this crop across India requires research into agricultural practises along scientific lines to maximise yields per acre and harvest season. Recent years have seen remarkable growth in the production, productivity, and quality of seed spices thanks to the use of better verities, best agronomic practises, and horticultural and agricultural-based cropping methods. Midway through October to the first week of November is ideal for seeding nigella; a 25-30 cm distance between rows and a 10-15 cm distance within rows has been shown to produce the highest seed production. With a nutrition ratio of 30:40:45 kg NPK ha^{-1} + FYM @ 15 t ha^{-1} + Azophos 25 g kg^{-1} seeds, we were able to achieve a 922 kg ha^{-1} seed yield, which was the greatest of any treatment. The maximum seed yield of 881 kg ha^{-1} and the highest net returns of Rs. 60,728 ha^{-1} were achieved with the herbicide oxadiargyl at 75 g ha^{-1} (PE) + hand weeding at 45 DAS.

Keywords: *Nigella sativa*, spice crop, NPK

Introduction
India, known as the land of spices, has been a popular destination for traders worldwide. With nearly 76 seeds grown, including seeds like coriander, cumin, fenugreek, fennel, ajwain, dill, anise, nigella, and caraway celery, these seeds are used in food and medicine. They are primarily grown in semi-arid and arid zones with dry or wet cool weather conditions. Rajasthan, Gujarat, and parts of Madhya Pradesh contribute over 80% of India's annual seed spice production. Together the states of Rajasthan and Gujarat and parts of Madhya Pradesh are called as the ‘bowl of seed spices” contributing more than 80% of the country’s annual seed spice production (Singh and Solanki 2015) [17].
Large local consumption and rising export demand provide seed spices a major impact on our country's economy. The current yearly output of seed spices is 11.75 lakh tonnes, grown on a total area of 16.53 lakh ha. Seed spices contribute about 46% of total area and 21% of production (Fig. 1) of spices in the country (Malhotra, 2017) [9]. Because of their short growing seasons, these crops are often produced in a symbiotic relationship with annual food crops or as inter/mixed crops in rainfed or irrigated environments. While the states of Rajasthan and Gujarat account for the vast majority of seed spice cultivation in India, other states like Madhya Pradesh, Haryana, Punjab, Uttar Pradesh, Andhra Pradesh, Karnataka, etc. also devote considerable land to the industry. The economy relies heavily on the cultivation of just four of the seventeen seed spices found in the country: coriander, cumin, fennel, and fenugreek. There is also a small amount of contribution from ajwain seed, dill seed, celery, nigella, and poppy seed. Chilli is the major spice crop contributing 23 per cent (Fig. 2) of total spices production in the country. Seed spices accounts for 21% of production of total spices in the country. Turmeric accounts for 17% and pepper 2% of production of the total spices in the country.

Classification of Spices
Spices are classified into different groups based on the importance and the usage. The major spice group includes most important and commercially grown spice crops like black pepper, chilli, ginger etc.; likewise the classification is as mentioned below.



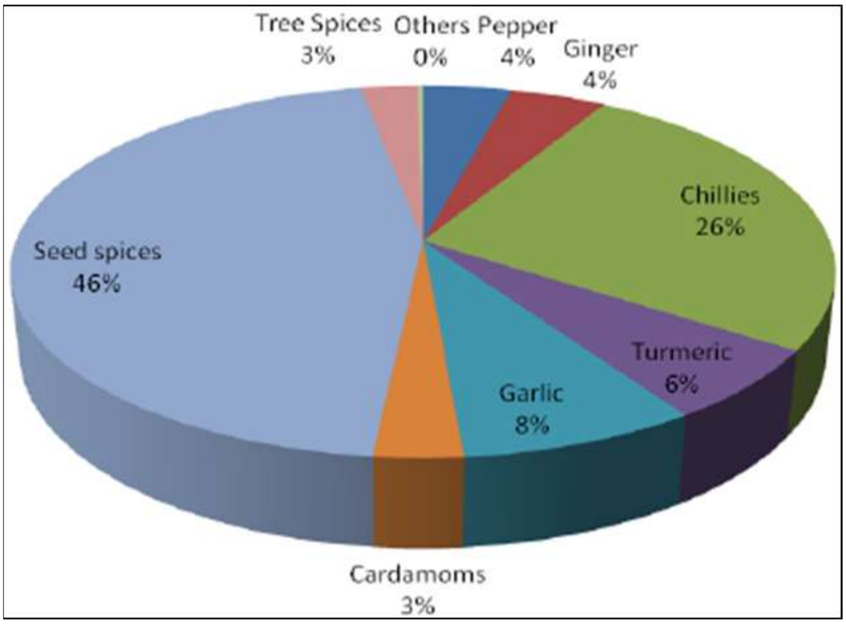


Fig 1: Spice-wise share of area under spices in India

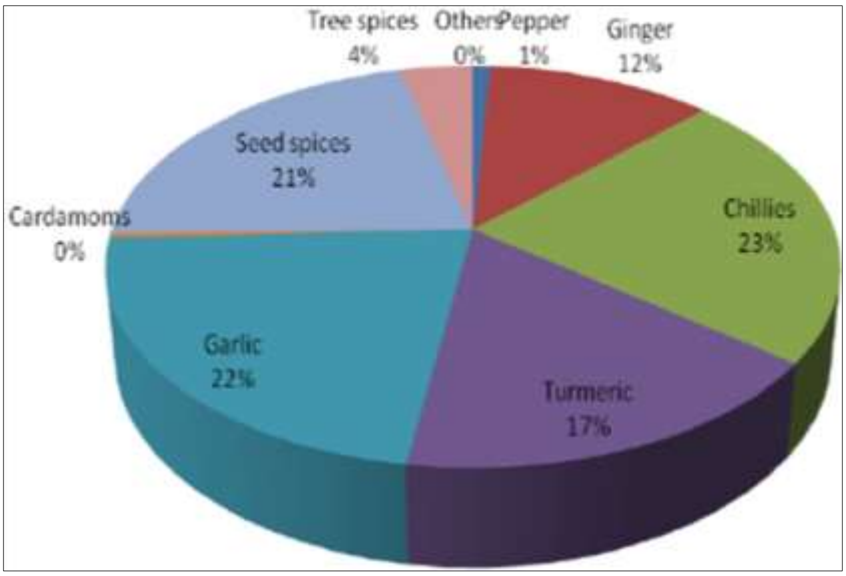


Fig 2: Spice-wise share of production of spices in India

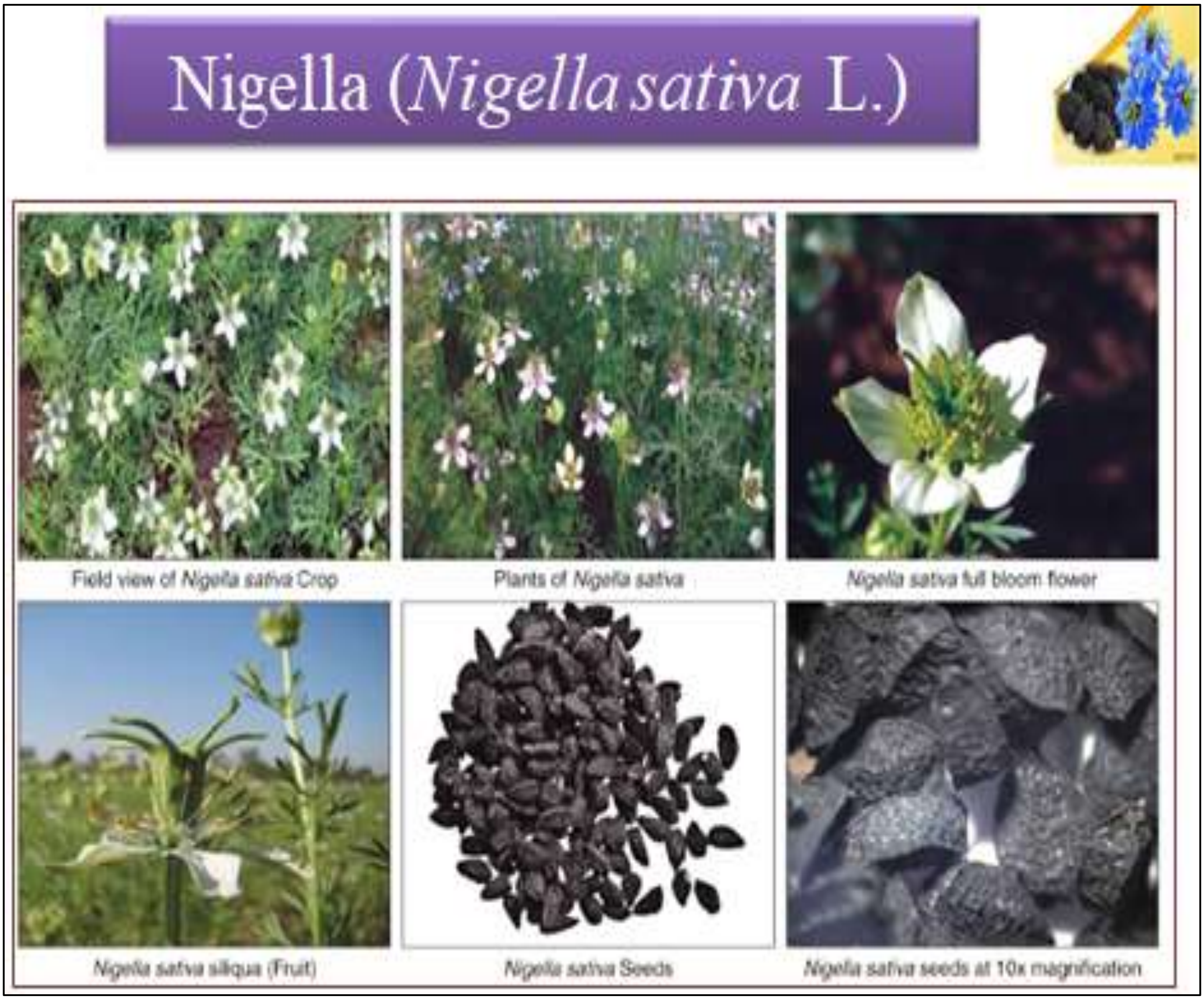


Plate 1: *Nigella sativa* plant and the seeds

Nigella (*Nigella sativa* L.) is commonly known by the kalonji or kalajira in Hindi, black cumin in English. It is an annual and seasonal (winter) herbaceous plant grown for its economic part i.e. seed.

Origin: South and South west Asia

Distribution: Due to their transient nature, these crops are commonly planted in intercropping and crop rotation with annual food crops in both rainfed and irrigated environments. Many Indian states, including Rajasthan, Gujarat, Madhya Pradesh, Haryana, Punjab, Uttar Pradesh, Andhra Pradesh, Karnataka, and others, cultivate seed spices. Although 17 seed spices are produced in the country, the main economic drivers are coriander, cumin, fennel, and fenugreek. The seeds of ajwain, dill, celery, nigella, and poppy all play supporting roles.

Importance

As a Spice/ food

- It is a valuable spice, having distinctive aroma and taste; its seeds were used in pickles, bread preparations and condiments, culinary and savoury dishes.
- It can also be used as food preservative.
- Nutritional value:

Protein: 20-27%
Carbohydrates: 23.5-33.2%
Minerals: 1.79-3.74%
Crude fibre: 5.5%
Fixed oil: 32-53%

Agricultural Importance

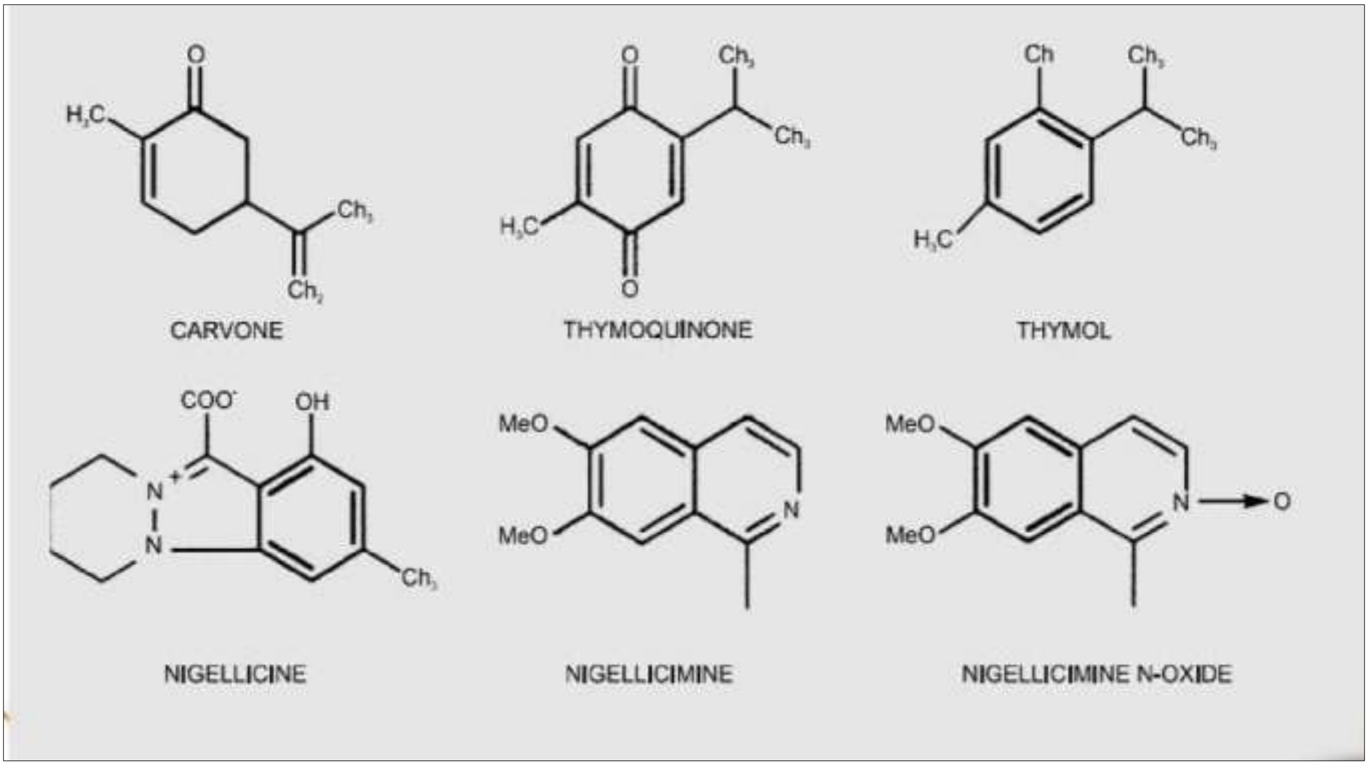
- Nigella is annual crop grown in *rabi* season In agriculture or plant science it is cytogenetically. Used to illustrate the connection between genes and chromosomes in plants.
- Most suited for semi-arid and arid climate
- It can be grown under low to medium fertile soil
- Well suited for intercropping/cropping system
- Incidence of pest and diseases are less compare to other *rabi* season crops
- Easy to manage, harvest and threshing
- Seed oil good repellent action-used against storage pest
- Attracts more honey bees
- Less incidence of storage pest
- Yields better and good economic returns

In recent years fetching highest prices. Rs. 120-300 per kg.

Medicinal Importance

It is also referred as 'Miracle herb'. Both seed and the oil are used as medicine. In Ayurveda, it is also called kalonji, upakuncika, karavi and krishnajiraka. It is known to balance both Vata and Kapha. In holy Quran and Bible the medicinal importance of nigella has been mentioned. Prophet Mohammad said: "It has a cure for every disease except death".

Chemical composition seed oil



Health benefits of Nigella: Multiple medicinal value of the nigella crop has been mentioned in many of the medicinal journals (Sharma *et al.*, 2009) [16]

1. **Antidiabetic activity:** Clinical trials supporting these findings also imply that the plant extract has an anti-diabetic effect. Black seed, when consumed at a daily dose of 2 grammes, has the potential to lower fasting blood sugar levels, lower insulin resistance, and improve beta-cell activity in the pancreas.
2. **Anticancer activity:** The anti-cancer properties of nigella seed include their ability to inhibit cell proliferation, cell cycle progression, angiogenesis, and metastasis.
3. **Liver health:** Nigella seed oil has been shown to improve liver function and protect against disease and injury. Nigella seed oil may hasten recovery from impaired liver function caused by drugs' adverse effects, alcohol, disease, and other causes.
4. **Protection against heart attack damage:** Heart attacks and their related damage can be mitigated, and general cardiovascular health can be improved, thanks to an extract from nigella seeds.
5. **Weight loss:** Nigella seed oil benefits the function of the liver and helps prevent both damage and disease. *Nigella sativa* is a marvellous anti-inflammatory agent that is known to help people lose weight by decreasing these weight gain triggers.
6. **Anti-infertility:** It is concluded that daily intake of 5 milli liters nigella oil for two months improves fertility and without any adverse effects.
7. **Antimicrobial activity:** Among the many harmful microorganisms that the seed oil can eradicate is methicillin-resistant staphylococcus aureus (MRSA).
8. **Effective against insomnia:** Nigella seed oil's natural balancing and harmonising effects lead to improved sleep, decreased stress, and increased energy, all of which contribute to us looking our best.
9. **Skin:** Black seed oil has profoundly restorative effects on the skin and other cells because of its ability to both stimulate and suppress melanogenesis (melanin synthesis).
10. **Hair:** The seed oil has been shown to fortify hair by thickening the follicles.

Plant Description

Scientific classification

Kingdom: Plantae
Division: Magnoliophyta
Order: Ranunculales
Family: Ranunculaceae
Genus: *Nigella*
Species: *sativa*

Plate 2: Plant description

- It is a bushy, branching plant and grows to about 50 to 60 cm in height.
- Leaves are divided into linear segment 2 to 3 cm long; they are opposite in pairs on either side of the stem.
- Its lower leaves are small, and petiolate and upper leaves are long. The plant has finely divided foliage.
- Flowers are pale bluish or whitish in colour, grow terminally on its branches. Often cross pollinated by insects and wind.
- Fruit is capsule which consist of many white trigonal seeds, once the fruit capsule matures the seed colour changes to black.
- Seeds are black, triangular in shape, possess a pungent smell, contains considerable amount of oil.

Research activities on nigella in India

NRC on Seed Spices, Ajmer, Rajasthan is involved in various research activities pertaining to nigella.

- Crop improvement
- Crop production
- Crop protection

Research studies

Sowing window and plant density

According to Meena *et al.* (2012) [12], seed production (8.13 q ha^{-1}), number of capsules per plant (50.76), and number of seeds per capsule (91.67) were all considerably higher for sowing on October 15th than for any other date (Table 2). In terms of cropping geometry, 25 cm x 10 cm spacing resulted in the highest seed production (6.80 q ha^{-1}). But it was on par with spacings of 20 by 10 centimetres and 30 by 10 centimetres. There was also a notable increase in the growth parameters (Table 2), such as plant height and the number of branches per plant, as compared to the other planting dates.

Table 1: Effect of sowing dates and crop geometry on growth parameters of nigella (pooled two years).

Treatment	Plant height (cm)			No. of days taken to branching	No. of branches plant^{-1}		No. of days taken to flower initiation
	45 DAS	90 DAS	At harvest		90 DAS	At harvest	
Date of sowing							
1st October	10.40	34.80	50.13	61.11	11.22	11.07	73.33
15th October	10.52	46.76	59.47	65.00	12.04	11.98	75.00
30th October	10.44	40.27	56.27	65.00	11.63	11.53	73.89
15th November	5.10	35.91	42.36	59.44	10.04	10.31	69.00
30th November	5.30	23.83	28.27	60.00	7.48	8.33	70.00
CD (P = 0.05)	0.47	2.53	2.10	1.93	1.13	0.60	2.00
Crop geometry							
20 × 10 cm	8.22	35.70	47.16	62.00	10.16	10.36	72.00
25 × 10 cm	8.45	37.52	47.55	62.33	10.70	10.84	72.67
30 × 10 cm	8.35	35.74	47.19	62.00	10.60	10.73	72.07
CD (P = 0.05)	0.37	1.96	1.63	1.50	0.87	0.46	1.55

Table 2: Effect of sowing dates and crop geometry on seed yield and quality parameters of nigella (pooled data of two years).

Treatment	No. of capsules plant^{-1}	No. of seeds capsule^{-1}	Capsule weight (mg)	1000 seed weight (g)	Seed yield (q ha^{-1})	Essential oil content (%)
Date of sowing						
1st October	32.07	79.16	25.13	1.86	5.79	0.32
15th October	50.76	91.67	27.11	2.30	8.13	0.34
30th October	45.29	83.09	26.71	2.10	5.80	0.32
15th November	25.42	76.47	17.98	1.86	1.44	0.29
30th November	12.31	64.69	14.91	1.67	0.96	0.28
CD (P = 0.05)	4.41	5.92	3.21	0.16	1.25	0.02
Crop geometry						
20 × 10 cm	31.87	75.55	20.99	1.91	6.10	0.30
25 × 10 cm	35.23	82.17	23.45	1.99	6.80	0.32
30 × 10 cm	32.41	79.32	22.67	1.96	6.42	0.31
CD (P = 0.05)	3.41	4.59	2.49	0.12	0.97	0.02

Giridhar *et al.* (2017) [5] reported that, sowing of nigella in October II fortnight (Table 4) recorded significantly higher seed yield of 789 kg ha^{-1}. However, it is found on par with October I fortnight sowing. Among the different plant densities, the plant density of 50 plants m^{-2} has recorded the significantly higher seed yield of 848 kg ha^{-1} compared to other planting densities. The growth parameters (Table 3) *viz*., plant height, number of leaves and branches per plant were found to be higher for sowing on first fortnight of October, second fortnight of October and first fortnight of November compare to other sowing time in nigella. Among the plant densities the 25 plants m^{-2} recorded significantly higher number of leaves and branches per plant however it was on par with the 33.3 plants m^{-2}.

Table 3: Influence of dates of sowing and plant densities on growth parameters of nigella

Treatment	Plant height (cm)				Number of leaves $plant^{-1}$			Number of branches $plant^{-1}$			
	30 DAS	60 DAS	90 DAS	Harvest	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	Harvest
Date of sowing											
S1 (1st FN of Oct)	16.2	34.6	42.4	42.8	10.5	42.6	43.8	0.68	7.5	8.4	8.8
S2 (2nd FN of Oct)	15.8	33.5	42.3	42.0	10.4	43.1	44.8	0.62	7.5	8.5	8.9
S3 (1st FN of Nov)	16.0	33.4	42.2	41.8	10.6	42.9	45.6	0.60	7.4	8.3	8.7
S4 (2nd FN of Nov)	14.7	32.1	35.0	36.3	8.9	38.6	39.3	0.55	6.7	7.6	7.6
S5 (1st FN of Dec)	14.0	31.9	35.0	36.4	8.7	38.0	37.6	0.55	6.4	7.3	7.7
CD (p=0.05)	1.13	NS	2.26	NS	0.75	1.48	2.87	NS	0.54	NS	0.7
Plant densities											
D1 (50 plants m^{-2})	15.2	33.1	39.5	40.2	9.0	36.4	36.6	0.55	6.7	7.6	7.8
D2 (33.3 plants m^{-2})	15.3	33.2	39.2	39.5	10.2	43.0	44.7	0.61	7.3	8.2	8.6
D3 (25 plants m^{-2})	15.4	33.1	39.4	39.9	10.3	43.8	45.4	0.64	7.3	8.2	8.6
CD (p=0.05)	NS	NS	NS	NS	0.4	1.18	1.26	NS	0.3	0.35	0.36

Table 4: Influence of dates of sowing and plant densities on yield and yield parameters

Treatments	Number of seeds $capsule^{-1}$	1000 seed weight (g)	Capsule yield (g $plant^{-1}$)	Seed yield (g $plant^{-1}$)	Seed yield (kg ha^{-1})	Stalk yield (g m^{-2})
Date of Sowing						
S1 (1st FN of Oct)	63.2	1.68	3.8	22	777.0	161.1
S2 (2nd FN of Oct)	64.3	1.71	3.9	22	789.0	166.5
S3 (1st FN of Nov)	63.5	1.67	3.8	22	761.5	161.4
S4 (2nd FN of Nov)	59.1	1.57	3.4	20	703.5	147.8
S5 (1st FN of Dec)	59.2	1.54	3.3	19	683.5	146.8
CD (P=0.05)	1.06	0.05	0.14	0.09	23.8	5.74
Plant densities						
D1 (50 plants m^{-2})	60.4	1.56	29	17	848.0	197.1
D2 (33.3 plants m^{-2})	62.5	1.66	40	23	778.0	155.3
D3 (25 plants m^{-2})	62.7	1.68	41	24	602.0	117.8
CD (P=0.05)	0.97	0.03	0.11	0.06	24.4	3.67

Goutam *et al.* (2016) [6] conducted an experiment at the Horticultural experimental farm, College of Horticulture, Mandsaur during the rabi season of 2015-16 to analyse the impact of row spacing and nitrogen levels on the development, production, and quality of Nigella. Plant height, number of branches per plant, fresh and dried weight of plant (Table 5), number of capsules per plant (25.94), number of seed per capsule (72.71), test weight (2.29 g), and seed yield (12.18 q ha^{-1}) were all considerably increased when row spacing was raised to 30 cm (Table 6).

Table 5: Effect of row spacing on growth attributes of nigella

Row spacing (cm)	Plant height (cm)			No. of branches $plant^{-1}$			Fresh weight of plant (g)			Dry weight of plant (g)		
	45 DAS	90 DAS	At harvest	45 DAS	90 DAS	At harvest	45 DAS	90 DAS	At harvest	45 DAS	90 DAS	At harvest
15	16.08	64.43	72.58	6.08	6.98	7.95	8.64	27.65	60.65	0.367	5.32	16.92
22.5	18.50	67.31	75.21	6.75	7.85	8.23	9.59	34.55	68.20	0.501	7.62	18.78
30	20.81	73.71	80.61	8.13	8.43	9.00	12.35	41.19	85.00	0.682	8.80	20.06
S. Em±	0.52	1.63	1.17	0.15	0.14	0.18	0.39	1.60	2.67	0.047	0.265	0.371
CD(P=0.05)	1.80	5.64	4.06	0.54	0.51	0.64	1.35	5.56	9.25	0.16	0.91	1.28

Table 6: Effect of row spacing on yield and yield attributes of nigella

Row spacing (cm)	No. of capsule/plant	No of seed/ capsule	1000 seed weight (g)	Seed yield (q ha^{-1})	Straw yield (q ha^{-1})	Biological yield (q ha^{-1})	Harvest index (%)
15	19.83	61.15	1.72	8.57	15.13	23.70	36.25
22.5	22.75	67.88	1.89	9.95	17.22	27.18	36.78
30	25.94	72.71	2.29	12.18	22.98	35.16	34.69
S. Em ±	0.740	1.041	0.07	0.38	0.944	1.303	0.616
CD(P=0.05)	2.56	3.60	0.24	1.34	3.26	4.51	NS

Koli (2013) [8] observed that there was a large amount of variance in the number of capsules per plant due to the effect of row spacing (Fig. 3). 15 cm 10 cm spacing yielded the fewest capsules per plant (19.5), though 15 cm 15 cm spacing yielded a statistically indistinguishable amount of capsules per plant (20.41). Figure 4 displays statistically significant variance across the four spacing treatments, with the 25 cm 15 cm spacing producing the maximum seed output (1458 kg/ha). 20 cm 15 cm spacing resulted in the highest seed output (1,346.57 kg/ha), followed by 25 cm 15 cm spacing (1,245.22 kg/ha). The number of capsules per plant at 15 cm 10 cm spacing was 26.53, whereas at 20 cm 15 cm spacing it was only 24.26. This resulted in a seed yield of 1017.56 kg/ha.

The interaction effect of variety and spacing (Table 7) showed that the statistically the maximum seed yield (1458.19 kg/ha) was recorded by BARI Kalozira-1 variety with a spacing of 20 cm x 15 cm and it was closely followed by BARI Kalozira-1 with a spacing of 25 cm x 15 cm.

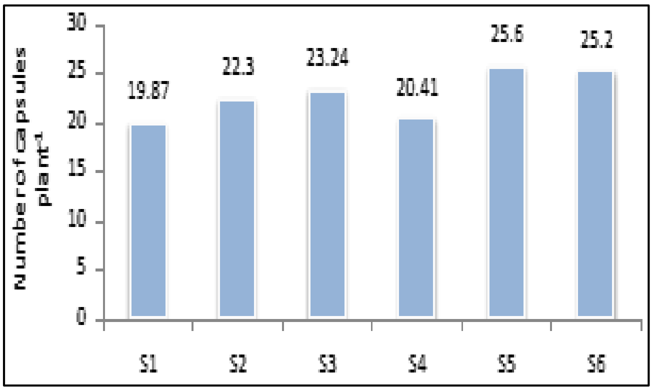


Fig 3: Effect of spacing on number of capsules plant^{-1}

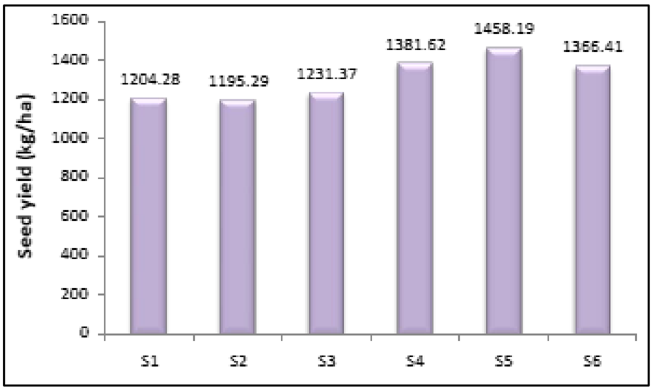


Fig 4: Effect of spacing on seed yield of nigella (kg ha^{-1})

Table 7: Response of variety and spacing for seed yield and yield attributes of nigella

Treatments	Weight of seeds plant^{-1} (g)	Number of capsules plant-^{1}	Number of seeds capsule^{-1}	1000-seed weight (g)	Seed yield (kg ha^{-1})
V1S1	2.767 e	17.87 e	84.67 f	2.230 c	1107.11 f
V1S2	2.840 e	22.20 d	87.33 ef	2.340 a-c	1108.23 f
V1S3	3.140 de	23.07 cd	87.67 d-f	2.390 ab	1169.07 e
V1S4	3.960 bcd	18.02 e	90.67 c-f	2.310 bc	1346.59 c
V1S5	4.510 abc	23.73 bcd	91.00 c-f	2.397 ab	1416.67 b
V1S6	4.753 ab	24.80 bc	95.00 b-e	2.357 ab	1288.37 d
V2S1	3.110 de	21.87 d	95.00 b-e	2.360 ab	1300.19 d
V2S2	3.270 de	22.40 cd	97.00 b-d	2.410 ab	1282.17 d
V2S3	3.590 cde	23.40 b-d	98.00 a-c	2.430 ab	1294.78 d
V2S4	4.253 abc	22.80 cd	100.0 a-c	2.427 ab	1416.21 b
V2S5	4.793 ab	27.47 a	103.3 ab	2.440 a	1458.19 a
V2S6	5.180 a	25.60 ab	107.0 a	2.420 ab	1445.79 b
LSD	0.9363	2.141	8.464	0.1071	37.19
CV%	8.26	5.55	5.28	4.72	5.01
Level of sign.	**	*	*	*	**

Where,
V1 = Local, V2 = BARI Kalozira-1,
S1 = 15 cm x 10 cm, S2 = 20 cm x 10 cm, S3 = 25 cm x 10 cm, S4 = 15 cm x 15 cm, S5 = 20 cm x 15 cm and S6= 25 cm x 15 cm

The highest grain production (1583.3 kg/ha) was recorded by Akbarian *et al.* (2013) [1] under a planting density of 25 plants m^{-2}, as shown in Fig. 5. The largest grain output was seen at the highest plant density (25 plants m^{-2}).

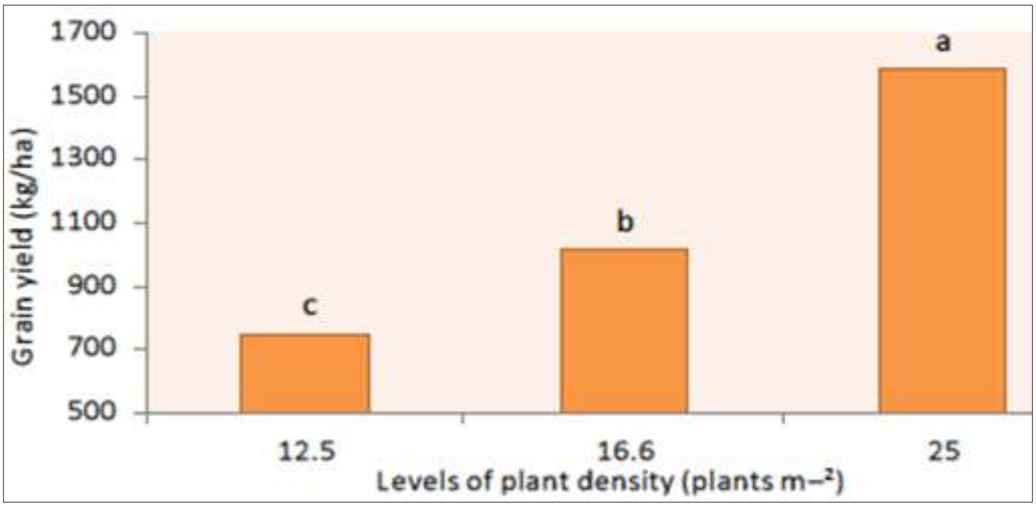


Fig 5: Effect of plant density on seed yield of nigella (kg ha^{-1})

According to Table 8 from Tuncturk *et al.* (2005) [19], when compared to the other treatments, the seed rate of 15 kg/ha produced the maximum seed yield of 701.2 kg/ha. It has been determined that a seed rate of 15 kg/ha is optimal for obtaining a high seed yield of nigella.

Table 8: Effect of seed rate on growth and yield of Nigella (Pooled data of 2001 & 2002)

Seed rates (kg ha^{-1})	Plant height (cm)	No. of Branches plant^{-1}	No. of capsules plant^{-1}	No. of seeds capsule^{-1}	1000 seed weight (g)	Seed yield (kg ha^{-1})	Essential oil content (%)	Essential oil yield (kg ha^{-1})
5	37.11ab	9.56a	14.65a	68.31ab	2.53	364.3d	0.51	1.8c
10	34.68b	8.66ab	12.30b	71.12a	2.65	494.1c	0.48	2.4b
15	40.68a	7.85bc	12.51b	70.38b	2.63	701.2a	0.50	3.5a
20	39.08ab	6.46c	9.48c	66.45b	2.40	588.0b	0.55	3.3b
CV (%)	4.59	1.44	1.60	2.90	2.9	2.90	-	0.03
Seed rate (s)	*	**	**	*	NS	**	NS	**

Nutrient management practices

Goutam *et al.* (2016) [6] reported that (Table 9), application of nitrogen @ 60 kg ha^{-1} recorded significantly higher seed yield (11.72 q ha^{-1}) and yield attributing characters compare to other levels of nitrogen doses.

Table 9: Effect of nitrogen levels on yield and yield attributes of nigella

Nitrogen levels (kg ha^{-1})	No. of capsule plant^{-1}	No. of seeds capsule^{-1}	1000 seed weight (g)	Seed yield (q ha^{-1})	Straw yield (q ha^{-1})	Biological yield (q ha^{-1})	Harvest index (%)
20	21.69	63.90	1.75	8.76	15.70	24.47	35.97
40	22.52	67.45	1.90	10.22	18.77	28.99	35.60
60	24.31	70.40	2.24	11.72	20.87	32.59	36.15
S. Em ±	0.422	0.825	0.08	0.48	0.891	1.304	0.858
CD (P=0.05)	1.25	2.45	0.26	1.44	2.65	3.87	NS

Black cumin yield and yield components were investigated by Tuncturk *et al.* (2012) [21] in the Van ecological conditions of Eastern Anatolia, Turkey, between 2006 and 2007. Results from a two-year study show that changing the nitrogen dose has an effect on black cumin's development (Table 10), yield, and yield components (Table 11). Application of 60 kg N ha^{-1} resulted in the maximum seed yield. The seed harvest suffered when too much fertiliser was used. As a result, in both years of the experiment, nitrogen fertilisation had a significant impact on black cumin yield and yield components.

Table 10: Growth attributes of nigella for varied levels of nitrogen doses

Nitrogen doses kg ha^{-1}	Plant height (cm)			Number of branch plant-^{1}			Number of capsule plant^{-1}		
	2006	2007	Mean	2006	2007	Mean	2006	2007	Mean
0	30.7 c	28.3 b	29.5 c	2.93 c	3.43 b	3.18 b	5.3 c	5.7 b	5.5 d
20	31.9 bc	30.6 ab	31.3 b	3.33 bc	3.80 ab	3.56 b	5.6 c	6.5 ab	6.1 cd
40	33.7 ab	28.7 ab	31.2 b	4.16 a	4.50 ab	4.33 a	6.6 b	6.6 ab	6.6 bc
60	33.5 ab	29.2 ab	31.3 b	4.16 a	4.86 a	4.51 a	7.5 a	7.5 a	7.5 a
80	34.9 a	30.9 a	32.9 a	4.00 ab	5.00 a	4.50 a	6.4 b	7.2 a	6.8 b
Mean	32.9 A	29.6 B		3.72 B	4.32 A		6.3 B	6.7 A	
CD (P=0.05)	2.31	2.32	1.43	0.67	1.19	0.60	0.48	1.25	0.65

Table 11: Yield and yield attributes of nigella for varied levels of nitrogen doses

Nitrogen doses kg ha^{-1}	Number of seeds capsule-1			1000 seed weight (g)			Seed yield (kg ha^{-1})		
	2006	2007	Mean	2006	2007	Mean	2006	2007	Mean
0	51.3 bc	53.5	52.4	2.20	2.33	2.26	493 b	527 e	509 d
20	50.1 c	55.5	52.8	2.33	2.20	2.31	515 ab	548 d	532 c
40	57.2 a	52.9	55.0	2.23	2.33	2.28	554 a	570 b	562 ab
60	56.4 ab	53.7	55.1	2.30	2.30	2.30	555 a	594 a	575 a
80	54.8 a-c	53.0	53.9	2.20	2.20	2.20	549 a	561 c	555 b
Mean	53.9	53.7		2.25	2.29		533 B	560 A	
CD (P=0.05)	5.46	NS	NS	NS	NS	NS	4.05	0.68	1.80

Ali *et al*., (2015) [2] reported that, the exotic variety of nigella (Table 12) with application of NPK fertilizer @ 120:40:60 kg ha^{-1} recorded the highest seed yield (2.30 t ha^{-1}) and yield attributing characters.

Table 12: Effect of fertilizer doses on nigella genotypes for seed yield and yield components.

Genotypes	Fertilizer levels N:P:K (kg ha^{-1})	No. of capsule plant^{-1}	No. of seeds capsule^{-1}	1000 seed weight (g)	Seed yield (t ha^{-1})
Exotic variety (Iran)	40:20:30	15.45 bc	74.53 d	2.17	1.90 cd
	80:30:45	17.00 ab	80.87 bcd	2.30	2.10 b
	120:40:60	18.28 a	99.13 a	2.35	2.30 a
BARI kalozira-1	40:20:30	10.58 e	77.13 cd	2.10	1.45 g
	80:30:45	14.38 cd	82.00 bcd	2.34	1.95 bc
	120:40:60	13.06 d	80.60 bcd	2.28	1.75 de
Faridpur local	40:20:30	10.10 e	77.93 cd	2.09	1.50 fg
	80:30:45	14.28 cd	88.67 b	2.38	1.90 cd
	120:40:60	13.67 d	87.84 b	2.32	1.80 cde
Natore local	40:20:30	10.26 e	74.07 d	2.02	1.40 cde
	80:30:45	13.21 d	84.87 bc	2.27	1.80 cde
	120:40:60	11.34 e	83.07 bcd	2.25	1.65 ef
CV (%)		5.28	4.59	3.30	3.78
Level of significance		**	**	NS	**

Tuncturk *et al.* (2011) [20] increasing phosphorus doses positively affected the number of capsule, thousand-seed weight and seed yield in black cumin. According to the data obtained from the two-year study, varying phosphorus levels increased the yield of (Table 14) black cumin. The highest seed yield was obtained from 40 kg P_2O_5/ha fertilizer applications, however, it was found to be at par with the application of P_2O_5 @ 20 kg/ha. The effect of increasing fertilizer levels on plant height, the number of branches and the number of seeds in the capsule were not significant (Table 13). As a result, phosphorus fertilization considerably affects yield of black cumin. Further agricultural and technological studies should be developed for obtaining black cumin with high yield and quality.

Table 13: Effect of phosphorus doses on nigella for growth components

Phosphorus doses (kg ha^{-1})	Plant height (cm)			Number of branches plant^{-1}			Number of capsules plant^{-1}		
	2006	2007	Mean	2006	2007	Mean	2006	2007	Mean
0	33.4	30.9	32.1	3.46	4.06	3.76	4.33 a	5.03 b	4.68 b
20	34.3	32.2	33.3	3.56	4.20	3.88	3.93 b	7.43 a	5.68 a
40	35.3	30.7	32.9	3.76	4.43	4.10	4.16 ab	7.06 a	5.61 a
Mean	34.3	31.3		3.60 B	4.23 A		4.14 B	6.51 A	
CD (P=0.05)	NS	NS	NS	NS	NS	NS	0.39	0.59	0.26

Table 14: Effect of phosphorus doses on nigella for seed yield and yield components

Phosphorus doses (kg ha^{-1})	Number of seeds capsule^{-1}			1000-seed weight (g)			Seed yield (kg ha^{-1})		
	2006	2007	Mean	2006	2007	Mean	2006	2007	Mean
0	52.4	51.9	52.2	2.30 b	2.26 b	2.28 b	507 c	549 b	528 b
20	52.3	60.0	56.2	2.40 ab	2.43 a	2.41 a	536 b	580 b	558 b
40	52.5	52.6	52.6	2.50 a	2.46 a	2.48 a	568 a	626 a	597 a
Mean	52.4	54.8		2.40	2.38		537 B	585 A	
CD (P=0.05)	NS	NS	NS	0.13	0.15	0.08	1.43	3.46	2.27

Sen *et al.* (2019)15 [] reported that the results showed (Table 15 & Table 16) that 100% RDF recorded maximum plant height (52.37 cm), seed per capsule (89.62) and yield per plant (2.06 g). 100% FYM showed positive influence resulting higher values for plant height (49.38 cm), yield per plant (1.95 g). 100% biofertilizer showed higher seed per capsule (88.72) and yield per plant (1.67 g).

The interaction effect of chemical fertilizer, FYM and bio fertilizer (Table 17 & Table 18) showed that that application of 100% RDF (30:40:45 NPK kg/ha) + with FYM 100% (15 t ha-1) + biofertilozers 100% (Azophos @ 25 g/kg of seed) has recorded significantly highest seed yield (961 kg ha^{-1}) and other yield parameters compared to other treatment combinations.

Table 15: Effect of inorganic fertilizers, organic manure and bio-fertilizers on growth attributes of nigella

Treatment	Plant height (cm)			No. of primary branches plant^{-1}			No. of secondary branches plant^{-1}		
	2005	2006	Pooled	2005	2006	Pooled	2005	2006	Pooled
Inorganic fertilizers									
No	54.63	37.82	46.23	6.88	4.98	5.93	11.35	8.92	10.14
75% RDF	58.68	42.92	50.80	7.80	5.37	6.59	13.98	9.47	11.73
100% RDF	60.31	44.42	52.37	7.82	5.42	6.62	14.07	10.00	12.04
S. Em ±	0.74	0.80	0.45	0.22	0.18	0.18	0.40	0.32	0.33
C. D. (0.05)	2.17	2.35	1.39	0.64	NS	0.544	1.16	NS	1.02
Organic manure (Farmyard manure)									
No	55.18	40.44	47.81	7.23	5.18	6.21	12.57	9.17	10.87
100%	55.77	42.99	49.38	7.77	5.24	6.51	13.70	9.76	11.73
S. Em.±	0.60	0.65	0.37	0.18	0.14	0.14	0.32	0.26	0.27
C. D. (0.05)	1.77	1.92	1.14	0.52	NS	NS	0.95	NS	0.83
Bio fertilizer (Azophos)									
No	56.42	40.32	48.37	7.04	5.16	6.10	12.18	9.16	10.67
100%	59.32	43.11	51.22	7.96	5.36	6.66	14.09	9.77	11.93
S. Em±	0.60	0.65	0.37	0.18	0.14	0.14	0.32	0.26	0.27
C. D. (0.05)	1.77	NS	1.14	0.52	NS	0.44	0.95	NS	0.83

Table 16: Effect of inorganic fertilizers, organic manure and bio-fertilizers on yield attributes of nigella

Treatment	No of capsule plant^{-1}			No. of seeds capsule^{-1}			Yield plant^{-1} (g)		
	2005	2006	Pooled	2005	2006	Pooled	2005	2006	Pooled
Inorganic fertilizers									
No	14.24	12.55	13.40	83.13	83.63	83.38	0.95	0.86	0.90
75% RDF	17.03	16.32	16.68	84.62	85.15	84.89	1.83	1.72	1.77
100% RDF	18.15	17.20	17.68	89.74	89.50	89.62	2.10	2.01	2.06
S. Em ±	0.47	1.55	0.26	0.98	1.23	0.89	0.28	0.23	0.29
C. D. (0.05)	1.39	NS	0.81	2.88	3.61	2.77	0.81	0.64	0.83
Organic manure (Farmyard manure)									
No	15.57	14.77	15.17	82.55	84.26	83.41	1.25	1.19	1.22
100%	17.38	15.94	16.66	85.12	87.93	86.53	2.00	1.90	1.95
S. Em.±	0.39	1.27	0.21	0.80	1.00	0.73	0.19	0.21	0.23
C. D. (0.05)	1.14	NS	0.66	NS	2.94	2.26	0.54	0.61	0.66
Bio fertilizer (Azophos)									
No	14.61	13.83	14.22	82.41	84.01	83.21	1.55	1.45	1.50
100%	18.34	16.88	17.61	89.26	88.18	88.72	1.70	1.65	1.67
S. Em±	0.39	1.27	0.21	0.80	1.00	0.73	0.28	0.32	0.34
C. D. (0.05)	1.14	NS	0.66	2.35	2.94	2.26	0.80	0.64	0.97

Table 17: Response of nigella for integrated nutrient management practices

Treatment	Plant height (cm)	No. of primary branches plant^{-1}	No. of secondary branches plant^{-1}	Plant dry weight (g)	No. of capsules plant^{-1}
T1-C0F0B0	44.57	5.70	10.40	09.25	12.92
T2-C0F0B1	46.07	5.93	11.07	09.40	14.12
T3-C0F1B0	46.53	5.80	11.00	09.31	13.20
T4-C0F1B1	47.73	6.30	12.93	09.93	13.35
T5-C1F0B0	46.60	6.47	13.93	10.15	13.19
T6-C1F0B1	51.57	6.97	14.87	12.73	22.09
T7-C1F1B0	52.47	6.15	12.27	11.72	13.79
T8-C1F1B1	53.40	6.77	14.87	12.63	17.63
T9-C2F0B0	47.03	5.74	10.20	11.61	12.99
T10-C2F0B1	54.27	6.75	14.93	12.55	15.70
T11-C2F1B0	57.20	6.77	15.27	13.76	19.25
T12-C2F1B1	54.28	7.23	15.87	14.78	22.77
S. Em±	1.07	0.35	0.79	0.27	0.47
CD (P=0.05)	03.33	NS	02.32	00.85	01.46

Table 18: Response of nigella for integrated nutrient management practices

Treatment	No. of seeds plant^{-1}	1000 seed weight (g)	Yield plot^{-1} (g)	Yield (kg ha^{-1})	Seed oil content (mg g^{-1})
T1-C0F0B0	80.50	2.747	138.19	345.47	0.22
T2-C0F0B1	86.22	3.043	183.31	458.27	0.29
T3-C0F1B0	81.90	2.709	142.39	355.97	0.28
T4-C0F1B1	84.90	2.739	162.61	404.87	0.30
T5-C1F0B0	83.37	2.803	133.41	333.55	0.30
T6-C1F0B1	91.10	2.996	288.22	720.55	0.32
T7-C1F1B0	79.00	3.053	161.82	404.54	0.31
T8-C1F1B1	86.07	3.238	230.05	575.13	0.35
T9-C2F0B0	84.60	2.642	141.54	353.84	0.25
T10-C2F0B1	86.60	3.146	205.53	466.99	0.31
T11-C2F1B0	89.89	2.796	236.44	591.1	0.32
T12-C2F1B1	97.40	3.604	384.79	961.98	0.34
S. Em±	2.75	0.177	8.10	20.83	0.003
CD (P=0.05)	NS	NS	025.21	64.82	0.01

III. Irrigation Management

Mohammad *et al.* (2012) [14] reported that the irrigation treatment (Table 19) of normal irrigation from emergence to harvest + *Azospirillum* as seed inoculated and soil application recorded the highest seed yield. However, it was on par with normal irrigation from emergence to harvest + *Azospirillum* seed inoculated.

The interaction between various levels of irrigation treatment and *Azospirillum* inoculation, the normal irrigation from emergence to harvest (control) & seed inoculated + soil application (W1A4) and the normal irrigation from emergence to harvest (control) & seed inoculated (W1A2) resulted in the highest seed yield (Fig. 6).

Table 19: Response of nigella for irrigation levels and *Azospirillum* inoculation

Treatment	Plant height (cm)	1000 seed weight (g)	Biological yield (kg ha^{-1})	Seed yield (kg ha^{-1})
Irrigation treatments				
W1	31.7^{a}	1.98^{a}	2562.64^{a}	722.85^{a}
W2	28.2^{a}	1.93^{a}	1477.06^{c}	377.32^{c}
W3	28.3^{a}	1.91^{a}	1890.76^{b}	532.88^{b}
A. lipoferum				
A1	27.4^{c}	1.45^{b}	1724.13^{c}	430.71^{d}
A2	30.2^{ab}	1.67^{ab}	2107.14^{ab}	583.45^{b}
A3	28.3^{bc}	1.62^{ab}	1928.51^{b}	551.63^{c}
A4	30.7^{a}	2.14^{a}	2147.49^{a}	611.59^{a}

Where,
I. Irrigation levels
W1 = normal irrigation from emergence to harvest (control),
W2 = irrigation terminated at the start of budding
W3 = irrigation terminated at the start of flowering

II. *Azospirillum* inoculation
A1 = non-inoculated
A2 = seed inoculated
A3 = soil application
A4 = seed inoculated + soil application

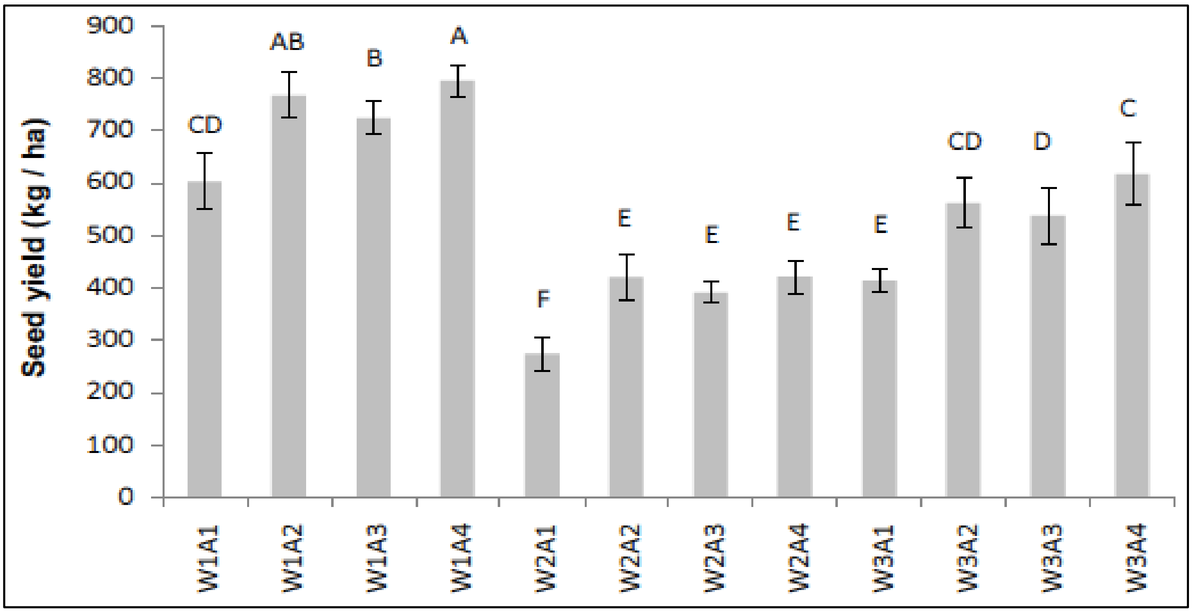


Fig 6: Interaction of irrigation levels and *Azospirillum* inoculation on seed yield of nigella

Ghamarnia *et al.* (2010) [4] conducted an irrigation experiment involving three modes of surface drip tape (SDT) irrigation with 50, 75, and 100% evapotranspiration (Et) and one mode of surface furrow (SF) irrigation with 100% Et requirement. The highest water use efficiency was achieved for the drip tape 50% (Et) treatment, while the lowest was for the furrow irrigation treatment 100% (Et). The results showed significant effects on seed yield, harvest index, pod number per plant, and total yield. No significant effects were found on plant height, seed per pod, seed weight, number of plants per m^2, or oil content. The study suggests that drip tape irrigation 50% (Et) is suitable for producing black cumin in areas with water deficits, with high water use efficiency and significant oil content.

Table 20: Effect of irrigation treatments growth and yield attributes of nigella

Irrigation Treatment	Plant height (cm)	No. of pods plant^{-1}	No. of seeds pod^{-1}	1000 seed weight (g)	Seed yield kg ha^{-1}	WUE based on seed yield (kg/ha-mm)
T1(50%ET) SD	29.67 b	17.52 b	52.46 a	2.33 a	575.6 c	1.39 a
T2(75%ET) SD	35.2 ab	19.28 b	59.92 a	2.35 a	697.2 b	1.123 b
T3(100 ET)SD	38.53 a	24.24 a	64.42 a	2.24 a	906.5 a	1.097 b
T4(100%ET)SF	31.93 ab	23.29 ab	55.75 a	2.267a	719.1 b	0.492 c

Bannayan *et al.* (2008) [3] reported that from the study conducted for two years (Table 21) that the significantly higher seed and straw yield of nigella was observed in the treatment I_4 (weekly irrigation) compared to other irrigation treatments. The high seed yield of nigella under I_4 compared to the I_2 and I_3 treatments might be due to a higher number of pods per plant and also a higher number of seeds per pod (Table 21). Plants grown under the I_4 treatment also showed a higher straw yield compared to plants grown under the I_2 and I_3 treatments. This was consistent with higher plant height too. Higher stored biomass during vegetative growth was shown as higher straw yield under the I_4 treatment compared to the other water deficit levels.

Table 21: Effect of irrigation regimes on nigella

Irrigation regimes	Plant height (cm)	No. of seeds pod^{-1}	1000 seed weight (g)	Seed yield (g m^{-2})	Straw yield (g m^{-2})	Seed oil (%)
Year 2003						
I_1	27.00ab	56.30a	1.10	71.67a	113.30a	29.05
I_2	22.60b	34.40b	1.15	17.30c	43.10c	28.70
I_3	29.70a	53.40a	1.30	36.00b	55.00c	28.60
I_4	25.90ab	53.40a	1.50	60.00a	81.60b	25.90
Year 2004						
I_1	37.03ab	72.30a	1.90	93.90a	122.90a	32.30
I_2	31.60b	53.20b	1.70	27.50b	49.80b	29.20
I_3	34.30ab	53.60b	2.10	39.40b	70.70ab	28.00
I_4	37.60a	71.30a	1.96	74.30ab	117.60ab	31.00

I_1-weekly irrigation (control); **I_2**-irrigation terminated at blooming; **I_3**-irrigation terminated at flowering; **I_4**-irrigation terminated at seed formation

Karim *et al.* (2017) [7] reported that the seed yield per hectare varied significantly due to influence of irrigation (Fig. 7). The highest seed yield (1.77 t/ha) was found in I6 (Ten irrigation) which was statistically different from others. The minimum seed yield (1.31 t/ha) was observed in I1 (No irrigation). Reduced yield as impact of stress mainly is due to shortening of plant growth stages. Yield of black cumin per hectare increased with increase of irrigation.

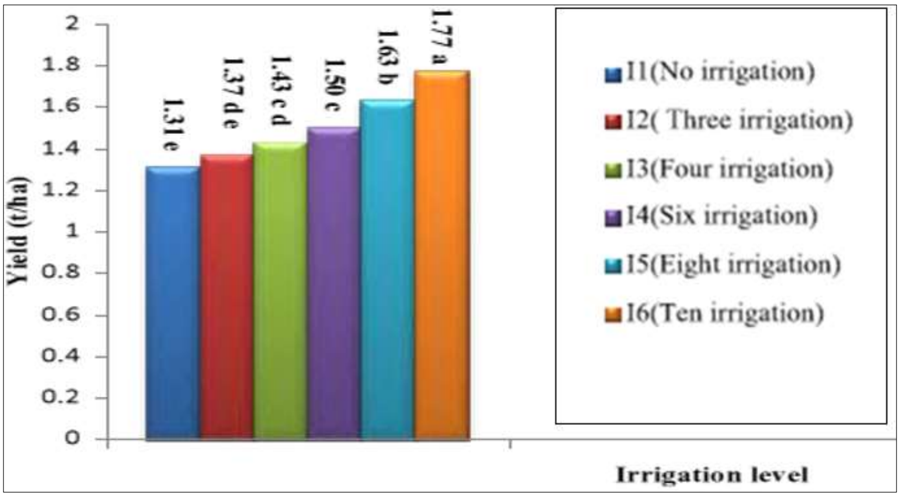


Fig 7: Effect of irrigation levels on seed yield of nigella

Where,
I 1-No irrigation, I 2-Three irrigation, I 3-Four irrigation, I 4-Six irrigation, I 5-Eight irrigation, I 6-Ten irrigation

Malhotra *et al*. (2009) [10] reported that among the different methods of irrigation drip (Fig. 8) irrigation recorded higher seed yield due to increased water use efficiency.

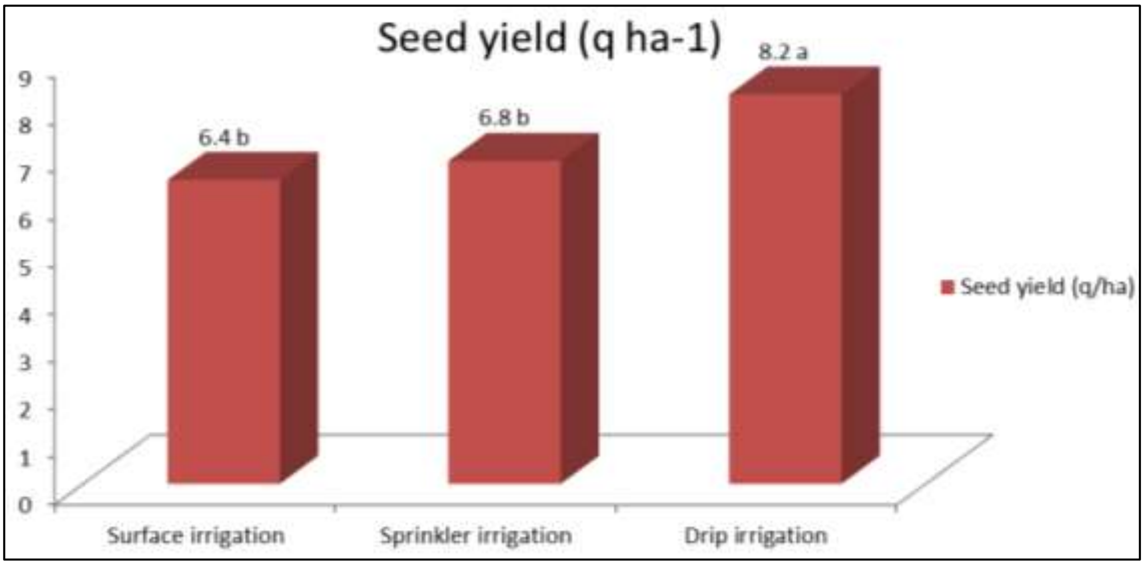


Fig 8: Methods of irrigation on seed yield of nigella Weed Management

According to the study by Ved Kant *et al*. (2018) [22], the average number of pods per plant was 22.6, the average pod size was 0.92 cm, and the average number of seeds per pod was 76.7. This was determined by analysing the interaction effect of different treatments, including sowing dates, fertiliser doses, and weedicides application. Similarly, the treatment combination D1xF3xW1 produced the highest nigella seed production (922.2 kg/ha), which was statistically equivalent to the yield (840 kg/ha) produced by the treatment combination D1xF2xW2.

Table 22: Effect of sowing dates, fertilizers levels and weedicides effect on growth and yield of nigella

Treatments	Plant height (cm)	No. of Pri. branches plant^{-1}	No. of Sec. branches plant^{-1}	No. of weed m^{-2}	No. of pods plant^{-1}	No. of seeds pod^{-1}	Seed yield (kg ha^{-1})
D1F1W1	39.1	5.9	6.4	116.3	13.0	63.3	647.7
D1F1W2	39.0	6.5	8.2	35.3	17.8	71.9	811.1
D1F2W1	46.1	6.4	9.4	60.6	11.9	77.4	674.4
D1F2W2	46.4	7.2	10.3	40.0	22.6	77.7	840.0
D1F3W1	42.7	7.0	8.9	53.6	18.0	65.4	922.2
D1F3W2	46.0	7.0	8.2	32.0	17.4	75.4	777.7
D2F1W1	43.1	5.2	5.3	77.0	10.6	69.4	446.6
D2F1W2	45.4	4.6	6.4	41.6	13.7	69.2	502.2
D2F2W1	44.9	6.5	7.0	22.3	16.6	63.8	849.9
D2F2W2	42.1	6.8	5.9	12.0	18.9	75.4	806.6
D2F3W1	43.9	7.1	7.6	47.3	15.8	68.2	575.5
D2F3W2	44.6	5.8	7.6	28.6	15.5	73.1	778.8
D3F1W1	34.4	4.2	4.0	110.6	10.0	60.4	166.6
D3F1W2	41.6	4.6	5.0	2.0	11.9	64.1	370.0
D3F2W1	44.6	5.0	6.4	63.3	12.8	73.8	365.5
D3F2W2	45.4	4.2	5.4	26.6	11.4	72.0	526.6
D3F3W1	36.6	5.0	8.2	105.0	9.7	60.3	254.3
D3F3W2	37.2	4.5	4.0	1.0	12.8	68.0	288.8
SEm±	3.19	0.59	1.26	20.55	0.90	0.94	58.6
CD (P=0.05)	NS	1.78	3.76	61.67	2.58	2.70	168.5

Fertilizers: F1(NPK: 30:30:15 kg ha^1),	**Sowing date:** D1-1st (1st November)	**Weedicides:** W1-pendimethalin @ 1.0 kg ha-1
F2(NPK: 40:40:20 kg ha^1)	D2-2nd (15th November),	W2-oxadiargyl @ 0.75 g ha-1
F3(NPKs: 50:50:25 kg ha^1)	D3-3rd (30th November);	

Meena *et al*. (2019) [11] noted that the study found that the dry weight of weeds, weed control efficiency, and weed index were all significantly altered by the application of different treatments (Table 23). Pre-emergence application of oxadiargyl @ 75 g + one hand weeding at 45 DAS (T2) resulted in the lowest dry weight of weeds (3.97 q ha^{-1}), weed index (7.6%), and maximum weed control efficiency (95.48%) besides the weed-free treatment. Effective weed control from the field and weeds that escaped herbicidal control were removed by hand weeding at 45 DAS (T2), leading to a higher weed control efficiency, lower weed index, and lower dry weight of weeds. At 45 DAS (T2), when herbicides and hand weeding were used together, the dry weight of weeds was drastically reduced.

Table 24 also shows that pre-emergence application of oxadiargyl @ 75 g + one hand weeding at 45 days after sowing (T2) and post-emergence application of oxadiargyl @ 75 g at 20 days after sowing (T4) both resulted in the highest seed yield (8.81 q ha^{-1}) and straw yield (23.10 q ha^{-1}) among the weed-free treatments.

Table 23: Effect of weed management practices on weed control efficiency and weed index in nigella

Treatments	Dry weight of weeds at harvest (q ha^{-1})	Weed control efficiency (%)	Weed index (%)
T1-Manual weeding at 30 & 60 DAS	10.09	88.57	28.56
T2-Oxadiargyl @ 75 g ha^{-1} (PE) + HW at 45 DAS	3.97	95.48	7.16
T3-Oxadiargyl @ 75 g ha^{-1} (Pt.E) at 20 DAS	7.39	91.57	21.31
T4-Oxadiargyl @ 75 g ha^{-1} (Pt.E) at 20 DAS + HW at 50 DAS	5.14	94.28	9.66
T5-Oxadiargyl @ 75 g ha^{-1} (PE) & Oxadiargyl @ 75 g ha^{-1} (PtE) at 45 DAS	6.03	93.08	17.42
T6-Pendimethalin @ 0.75 kg ha^{-1} (PE)	8.99	89.97	21.98
T7-Pendimethalin @ 0.75 kg ha^{-1} (PE) + HW at 45 DAS	9.25	90.06	29.07
T8-Pendimethalin @ 0.75 kg ha^{-1} (PE) + Oxadiargyl @ 75 g ha^{-1} (Pt.E)at 45 DAS	12.21	86.38	33.52
T9-Weed free	0.00	100.00	0.00
T10-Weedy check	93.20	0.00	54.43
S.Em ±	2.06	3.23	1.22
CD (P=0.05)	6.13	9.58	3.61

Where, Pt.E-Post emergent, PE-Pre emergent

Table 24: Effect of weed management practices for yield and yield attributes of nigella

Treatments	No. of pods $plan^{-1}$	No. of seeds pod^{-1}	Seed yield (q ha^{-1})	Straw yield (q ha^{-1})
T1-Manual weeding at 30 & 60 DAS	13.80	76.93	6.83	21.89
T2-Oxadiargyl @ 75 g ha^{-1} (PE) + HW at 45 DAS	17.67	83.83	8.81	23.1
T3-Oxadiargyl @ 75 g ha^{-1} (Pt.E) at 20 DAS	15.00	78.33	6.44	22.1
T4-Oxadiargyl @ 75 g ha^{-1} (Pt.E) at 20 DAS + HW at 50 DAS	17.07	80.27	7.79	22.9
T5-Oxadiargyl @ 75 g ha^{-1} (PE) & Oxadiargyl @ 75 g ha^{-1} (PtE) at 45 DAS	15.27	79.27	7.49	22.65
T6-Pendimethalin @ 0.75 kg ha^{-1} (PE)	11.33	70.40	6.00	20.5
T7-Pendimethalin @ 0.75 kg ha^{-1} (PE) + HW at 45 DAS	14.23	77.07	6.98	22.0
T8-Pendimethalin @ 0.75 kg ha^{-1} (PE) + Oxadiargyl @ 75 g ha^{-1} (Pt.E)at 45 DAS	12.53	75.53	6.03	21.69
T9-Weed free	20.07	85.47	9.84	23.5
T10-Weedy check	2.60	47.07	2.84	15.7
S.Em ±	0.60	3.34	0.28	0.96
CD (P=0.05)	1.78	9.94	0.83	2.85

Cropping systems and economics

According to Meena *et al*. (2017) [12], all cropping sequences exhibited greater financial return when intercropped with ber, then with aonla. Heavy ber fruiting and favourable market pricing account for the highest return of any cropping sequence (Table 25). Aonla had sufficient fruit production, but poor pricing overall. The fenugreek-okra cropping sequence with ber had the highest gross return (982275), net return (809215), and BCR (4.68), followed by the nigella-cowpea cropping sequence with ber, with returns of Rs.873750/ha and Rs.705450/-ha., respectively for the two crops.

Table 25: Economics of seed spice based intercropping systems

Treatments	Cost of cultivation (Rs.)	Gross returns (Rs.)	Net returns (Rs.)	BCR
Ber + Nigella+ Cowpea	168300	873750	705450	4.19
Ber + Anise+ Cluster bean	159432	797835	638403	4.00
Ber + Rai+ Black gram	151800	724600	572800	3.77
Ber +Ajwain+ Tinda	173300	895375	722075	4.17
Ber +Fenugreek+ Okra	173060	982275	809215	4.68
Ber + coriander+ Green gram	156060	754000	597940	3.83
Aonla +Nigella + Cowpea	173000	721330	548330	3.17
Aonla +Anise + Cluster bean	164132	637740	473608	2.89
Aonla +Rai + Black gram	156500	558950	402450	2.57
Aonla + Ajwain +Tinda	178000	742980	564980	3.17
Aonla +Fenugreek + Okra	177760	804780	627020	3.53
Aonla +Coriander + Green gram	160760	593600	432840	2.69
Ber	110300	614500	504200	4.57
Aonla	115000	484250	369250	3.21
SEm±	-	23669.00	18729.24	0.06
CD (P=0.05)	-	67762.59	53620.43	0.18
CV (%)	-	7.06	7.15	7.52

Ved Kant *et al.* (2018) [22] reported that (Table 26) most suitable date of sowing for nigella crop was 1st November for getting maximum seed yield (922.2 kg/ha), net returns of Rs. 122900.7 ha^{-1} and B:C ratio (3.75). It was also observed that the appropriate dose of fertilizer (NPK level) was 40:40:20 kg/ha, whereas the application of weedicide oxadiargyl 75 g a.i. /ha has also given minimum weed count in nigella

Table 26: Effect of sowing dates, fertilizers levels and weedicides effect on yield and economics of nigella

Treatments	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Gross returns (Rs. ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
D1F1W1	647.7	1463.3	119512.6	42632.9	76879.7	2.80
D1F1W2	811.1	1366.6	148731.2	43445.4	105285.8	3.42
D1F2W1	674.4	1547.7	124487.4	43793.6	80693.8	2.84
D1F2W2	840.0	2137.8	155475.6	44606.1	110869.5	3.48
D1F3W1	922.2	722.2	167440.4	44539.7	122900.7	3.76
D1F3W2	777.7	1666.6	143319.3	45352.2	97967.1	3.16
D2F1W1	446.6	886.6	82161.2	42632.9	39528.3	1.93
D2F1W2	502.2	1408.9	93213.8	43445.4	49768.4	2.15
D2F2W1	849.9	1016.7	155015.4	43793.6	111221.8	3.54
D2F2W2	806.6	1393.2	147974.4	44606.1	103368.3	3.32
D2F3W1	575.5	1413.3	106416.6	44539.7	61876.9	2.39
D2F3W2	778.8	1376.6	141560.6	45352.2	96208.4	3.12
D3F1W1	166.6	1077.7	32143.4	42632.9	-10489.5	0.75
D3F1W2	370.0	1118.9	68837.8	43445.4	25392.4	1.58
D3F2W1	365.5	1078.9	67947.8	43793.6	24154.2	1.55
D3F2W2	526.6	1028.8	96845.6	44606.1	52239.5	2.17
D3F3W1	254.3	790.0	47354	44539.7	2814.3	1.06
D3F3W2	288.8	977.8	53939.6	45352.2	8587.4	1.19

Fertilizers: F1 (NPK: 30:30:15 kg ha^1),	**Weedicides:** W1-pendimethalin @ 1.0 kg ha-1	**Sowing date:** D1-1st (1st November)
F2 (NPK: 40:40:20 kg ha^1)	W2-oxadiargyl @ 0.75 g ha-1	D2-2nd (15th November)
F3 (NPK: 50:50:25 kg ha^1)		D3-3rd (30th November)

Sultana *et al.* (2018) [18] the black cumin sown during mid-October recorded highest yield of 3.65 q/ha and the crop sown during early November recorded 3.05 q/ha, which are higher than the crop sown during the month of September (2.40 q/ha). The yield of black cumin sown in mid-October (B: C ratio 1.96) and sown during early November (B: C ratio 1.64) are 73.8% and 45.2% higher than farmers practice (2.10 q/ha) particularly in the old alluvial zone of West Bengal.

Table 27: Effect of sowing dates on growth, yield and economics of nigella

Treatments	Plant height (cm)	No. of branch $plant^{-1}$	Yield (q ha^{-1})	Cost of cultivation (Rs.ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	BC ratio
T1-Mid Sept.	21.07	2.9	1.98	55600	59400	3800	0.68
T2-End Sept.	24.37	3.1	2.40	55600	72000	16400	1.29
T3-Mid Oct.	32.12	4.8	3.65	55600	109500	53900	1.96
T4-Early Nov.	27.24	3.8	3.05	55600	915000	35900	1.64
T5-Farmers practice (Oct-Nov)	25.69	3.2	2.10	55600	63000	7400	1.13

Meena *et al.* (2019) [11] reported that gross return, net return and B: C ratio were significantly influenced by the application of different weed control treatments. The highest gross return of Rs. 87950 ha^{-1} was obtained in weed free treatment (T9) followed by pre-emergence application of oxadiargyl @ 75 g ha^{-1} + one hand weeding at 45 DAS (T2) (Rs. 83910 ha^{-1}). However, the highest net return (Rs. 60727 ha^{-1}) and B:C ratio (2.62) was recorded with the application of oxadiargyl @ 75 g ha^{-1} (PE) + one hand weeding at 45 DAS. Hence it is inferred from the investigation that the pre-emergence application of oxadiargyl @ 75 g ha^{-1} + one hand weeding at 45 DAS is the best economically feasible weed control treatment resulting in efficient weed and ultimately higher yields.

Table 28: Effect of weed management practices for seed yield and economics

Treatments	Seed yield (q ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C
T1-Manual weeding at 30 & 60 DAS	6.83	65848	39066	1.46
T2-Oxadiargyl @ 75 g ha^{-1} (PE) + HW at 45 DAS	8.81	83910	60728	2.62
T3-Oxadiargyl @ 75 g ha^{-1} (Pt.E) at 20 DAS	6.44	62380	42198	2.09
T4-Oxadiargyl @ 75 g ha^{-1} (Pt.E) at 20 DAS + HW at 50 DAS	7.79	74690	51508	2.22
T5-Oxadiargyl @ 75 g ha^{-1} (PE) & Oxadiargyl @ 75 g ha^{-1} (PtE) at 45 DAS	7.49	71940	50858	2.41
T6-Pendimethalin @ 0.75 kg ha^{-1} (PE)	6.00	58100	37755	1.86
T7-Pendimethalin @ 0.75 kg ha^{-1} (PE) + HW at 45 DAS	6.98	67220	43875	1.88
T8-Pendimethalin @ 0.75 kg ha^{-1} (PE) + Oxadiargyl @ 75 g ha^{-1} (Pt.E)at 45 DAS	6.03	58608	37363	1.76
T9-Weed free	9.84	87950	58168	1.95
T10-Weedy check	2.84	28700	9418	0.49
S.Em ±	0.28	-	-	-
CD (P=0.05)	0.83	-	-	-

Conclusion

- Nigella is becoming a most popular crop due to its wide range of importance and awareness.
- The optimum time for sowing of nigella is mid-October to first week of November, the optimum inter row spacing of 25 to 30 cm and intra row spacing of 10 to 15 cm founds to be better for getting higher seed yield.
- The nutrient level of 30:40:45 kg NPK ha-1 + FYM @ 15 t ha^{-1} + Azophos 25 g kg^{-1} seeds found better for getting the highest seed yield of 922 kg ha^{-1}.
- Herbicide oxadiargyl @ 75 g ha^{-1} (PE) + HW at 45 DAS recorded the highest seed yield of 881 kg ha^{-1} with net returns of Rs. 60,728 ha^{-1}.

Future line of work

- Need to develop the basic cultivation practices *viz*., sowing time, spacing and seed rate to under different agro-climatic regions of our state.
- Scope for inclusion of the crop in different intercropping and cropping sequences.
- Need to develop the suitable weed and water management practices to achieve the higher yield.

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