Effects of N and NPS fertilizer on yield components and seed yield of black cumin (*Nigella Sativa* L.) at Bale, south-eastern Ethiopia

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Abstract

Black cumin is one of the most widely grown seed spices crops in the highlands and mid altitude of Bale. However, the productivity is low due to poor agronomic practices, diseases, insect pests and other botic and abiotic factors. Therefore, experiment was conducted in field to determine the effects of N and NPS fertilizer rates on yield and yield attributes of black cumin and to recommend the most economically feasible rate of N and NPS fertilizer for black cumin production. Days to flowering, days to physiological maturity, number of secondary branches per plant, number of capsules per plant, and number of seeds per capsule were all significantly impacted by N and NPS fertilizer. The interaction between N and NPS fertilizers had a significant impact on plant height and seed yield. The number of days to 50% flowering was increased by increasing the nitrogen fertilizer from 0 N kg ha^{-1} to 90 N kg ha^{-1} and the NPS fertilizer from 0 kg NPS ha^{-1} to 105 kg NPS ha^{-1}. In contrast, physiological maturity was extended by increasing the nitrogen fertilizer from 0 N kg ha^{-1} to 90 N kg ha^{-1} and the NPS fertilizer from 0 NPS kg ha^{-1} to 105 kg NPS ha^{-1}. The highest plant height (79.93 cm) was observed with 90 kg UREA ha^{-1} and 70 kilogram NPS ha^{-1}, which was statistically equivalent to 90 Kg UREA and 105 kg NPS ha^{-1}. The highest number of capsule per plant (9.583) was obtained from 90 kg UREA which is statistically at par with 60 kg UREA ha^{-1}. The application of 60 and 90 Kg UREA ha^{-1} resulted in maximum numbers of seeds per capsule. Maximum seed production (1669 kg ha^{-1}) and net benefit/return with the highest marginal rate of return was observed with application of 60 kg UREA and 70 kg NPS ha^{-1}. Thus, based on the yield and yield characteristics, and partial budget analysis results the use of 60 kg UREA and 70 kg NPS ha^{-1} can be suggested for the production of black cumin in South-eastern Ethiopia.

Keywords: Black cumin, capsule, NPS fertilizer, UREA, seed yield

Introduction

Black cumin or nigella (*Nigella sativa* L.) is a member of the Ranunculaceae family (Weiss, 2002) and it is one of the important medicinal and spice crops native to West Asia and North Africa where the maximum diversity of crops is found (Ramadan, 2021). Ethiopia is a country with different and favorable agro ecological zones for the production of various spices including black cumin (Dessie *et al*., 2019). Black cumin can grow successfully on light (sandy), medium (loamy), and heavy (clay) soils (Kifelew *et al*., 2017). The crop needs well prepared seed beds which are ploughed at least 3 times and free of clogging for easy emergence of seedlings (Abuziad, 2015, Ebrie *et al*., 2015). The crop requires a soil pH range of 6.5 to 7.5 with optimum organic matter and phosphorus contents (Datta *et al*., 2018).

The black cumin is used for traditional medical purposes or for human consumption. Black cumin is a significant source of revenue for smallholder farmers in Ethiopia, both domestically and internationally. Among spices, black cumin is Ethiopia's second-most-exported crop after ginger. This demonstrates the broad potential for producing black cumin (Ebrie Yimam *et al*., 2015). Approximately 98% of Ethiopia's exports of black cumin are to Arab nations, including Saudi Arabia, Sudan, and others (Ermias *et al.,* 2015, Teshome and Anshiso, 2019).

Nitrogen and phosphorus are crucial nutrients that significantly impact both the quantity and quality of agricultural produce. Nitrogen plays a vital role in photosynthesis, respiration, and protein synthesis, all of which are essential for plant growth and development. Phosphorus is equally important, serving as a structural and regulatory element. It is involved in numerous physiological processes, including photosynthesis, root development, energy transfer, carbon metabolism, redox reactions, and nucleic acid synthesis (Patel *et al*., 2022). Sulfur is also plays a crucial role in plant growth, development and quality of oil seeds. It is a constituent of proteins, amino acids, vitamins, and coenzymes. Most of the soil's sulfur is present in organic matter, making it unavailable to plants. The primary source of plant-available sulfur is the sulfate ion (SO_4^{2-}), which is often present in limited quantities in the soil (Narayan *et al*., 2023; Walker and Booth, 2023). In Bale mid-altitudes, black cumin is extensively cultivated as common seed spice crop. However, its productivity is low due to poor agronomic practices, nutrient management, diseases and insect pests. Despite its potential and profitability, the crop has been traditionally grown on marginal lands without fertilizers. The effects of NPS fertilizers, other than nitrogen and phosphorous, on black cumin yield and other characteristics are either unknown or poorly understood. As there is no comprehensive study on N and NPS fertilizer rates for this crop, this study was proposed to assess the effect of N and NPS fertilizer rates on growth and yield of black cumin; and to identify economically feasible rates of N and NPS fertilizer for black cumin production.

Materials and methods

Description of Study Area

The experiment was conducted at Sinana (on-station), Goro and Ginir of Bale and East Bale Zones, Oromia Regional State, and South eastern Ethiopia during the main cropping season of 2021 to 2023. Sinana is located 07o 07'10.837" N latitude and 040o 13'32.933" E longitude; and 2400m a.s.l.) and it is found 463 km south east of Finfinnee and 33 km East of Robe, the capital of Bale zone. Goro is located at 6º59'N latitude; 40º30'E longitude, and at an altitude of 1650 meters above sea level. It has an average temperature of 19º C and humidity of about 70%. The average rainfall is relatively high ranging from 1500-2000 mm per year. On the other hand Ginir is situated 86 kilometers from Robe, the zonal capital, and 519 kilometers from Addis Ababa in the southeast. It is situated 1972 meters above sea level at latitude 07° 15 N and longitude 40° 66 E. The rainfall patterns in this area are bimodal. Theses area has bimodal rainfall patterns. Based on this there are two separate crop growing seasons locally called *bona* and *gana*. The main season *bona* extends from September to November and *gana* from March to May. The soil type of area is *Vertiso*ls. The major crops grown widely in the area are cereals, pulses, vegetables under rain fed and irrigation.

Treatments and Experimental Design

The experiment was consists of factorial combinations of four rates of N (0, 30, 60 and 90 kg ha^{-1}) and four rates of NPS (0, 35, 70 and 105 kg ha^{-1}) and was laid out as a Randomized complete block designs (RCBD) in three replications. The Soressa variety was used as planting material. The UREA and blended NPS (19% N, 38% $P_2O_5$and 7% S) will be used as the sources of fertilizer.

Experimental Procedure and Field Management

Tractors were used to plough and disk the experimental field, then hand digging was used to grind it to a fine texture. The cultivar was planted with a 30 cm and 10 cm gap between rows and plants, respectively, in a gross plot measuring 1.8 m x 2.5 m (4.5 m2) with six rows. Data was gathered using the four center rows. The crop's suggestions for land preparation, planting, and other management techniques were followed.

Agronomic parameters and yield-related data

Agronomic parameters and yield-related data, encompassing the duration until 50% flowering, the time required to achieve 90% physiological maturity, plant height, the count of primary branches per plant, the number of secondary branches per plant, the total number of capsules per plant, and the resultant seed yield, were systematically gathered.

Soil Sampling and Analysis

Prior to planting, soil specimens (0-30 cm depth) were gathered from five diagonal locations across the whole experimental area and blended to create a single composite sample. This composite sample was air-dried, crushed with a pestle and mortar, and allowed to pass through a 2-mm sieve. Working samples were obtained from submitted bulk samples and taken to Sinana Agricultural Research Centre Soil Testing Laboratory for analysis of major physicochemical properties - soil PH, soil texture, organic carbon, total N, available P and organic matter.

Economic Analysis

Yield from experimental plots was adjusted downward by 10% for management difference, to reflect the difference between the experimental yield and the yield that farmers could expect from the same treatment. Accordingly, the mean seed yields for NPS treatment combinations were subjected to a discrete economic analysis using the procedure recommended by CIMMYT (1988).

Average yield (AY) (kg ha^{-1}): It is an average yield of each treatment converted to kg ha^{-1}.

Adjusted yield (AJY): The adjusted yield for a treatment is the average yield adjusted downward by 10% to reflect the difference between the experimental yield and the yield farmers could expect from the same treatment. **AJY** = **AY** - (**AY × 0.10**).

Gross field benefit (GFB): The gross field benefit for each treatment was calculated by multiplying field/farm gate price that farmers receive for the crop when they sale it as adjusted yield. **GFB = AJY x field/farm gate price of a crop.**

Total variable costs (TVC): This is the sum of all the costs that vary for a particular treatment. The total costs that varied included the cost of N and NPS fertilizer and the application cost of the fertilizer to the crop. To estimate economic parameters, black cumin yield was valued at average open price of 200 kg^{-1} and the mean current prices of N and NPS and wages were 40.00 N Birr kg^{-1} and 45.00 NPS Birr kg^{-1} and 300 Birr/ person/ day, respectively.

Net benefit (NB): This was calculated by subtracting the total variable costs from the gross field benefit for each treatment. **NB = GFB – TVC**

Dominance analysis (D): This was carried out by first listing the treatments in order of increasing costs that vary. Any treatment that has net benefit that are less or equal to those of a treatment with lower costs that vary were considered as dominated.

Marginal rate of return (MRR): This was computed by dividing the marginal net benefit (*i.e.*, the change in net benefits) with the marginal cost (*i.e.*, the change in costs) multiplied by hundred and expressed as a percentage.

$$MRR = \frac{\text{Change in NB}}{\text{Change TVC}} \times 100$$

Where, NB= change in net benefit, TVC= change in total variable cost, MRR= Marginal rate of return. Thus, MRR of 100% implies a return of one Birr on every Birr of expenditure in the given variable input.

Finally, within the non-dominated approaches, the strategy that yielded the greatest net profit and a marginal return rate surpassing the minimum threshold deemed satisfactory by farmers (100%) was selected for endorsement.

Statistical data analysis

The collected data were subjected to analysis of variance (ANOVA) procedure using GenStat 16th edition software. Comparisons among treatment means with significant difference for measured characters were done by using Fisher's protected Least Significant Difference (LSD) test at 5% level of significance.

Results and discussion

Soil Physico-chemical Properties of the Experimental Sites

The chosen physical and chemical characteristics of the soil were analyzed for composite soil samples (0-30 cm depth) gathered prior to planting (Table 1). As a result, the soil texture at the experimental site is primarily composed of clay, and the pH across all locations was found to be neutral.

Days to 50% of flowering

Effect of N and NPS had a highly significant ($p<0.01$) impact on the number of days to attain 50% flowering, although the interaction of N and NPS had no discernible effect on this number (Table 2). Days to 50% flowering were considerably and regularly improved by increasing the nitrogen fertilizer from 0 kg ha^{-1} to 90 kg urea ha^{-1}. Days to 50% flowering also increased when NPS fertilizer was increased from 0 kg NPS ha^{-1} to 105 kg NPS ha^{-1}. The application of the highest rates of both urea and NPS fertilizers resulted in the longest time in days to reach 50% blooming. The shortest period (85.33 and 85.42 days) required to reach days to 50% flowering were observed from no application of UREA while the longest days (87.33 and 87.17 days) required to reach days to 50% flowering were observed with 90 kg UREA ha^{-1} and 105 kg NPS ha^{-1} respectively.

This may be due to rapid physiological and metabolic activities of plant enhanced by adequate nitrogen and phosphorus availability in the soil, which may have resulted rapid cell division, vegetative growth, rapid photosynthesis and accumulation of dry matter during early growth stage. This result is in agreement with Ashraf *et al*. (2005) and Ali *et al*. (2015) who stated that increased nitrogen application stimulated plant flowering and hastened days to flowering in black cumin. Ali *et al*. (2015) also reported that application of increased level of phosphorus hasten days to 50% flowering in black cumin.

Days to 90% of physiological maturity

Physiological maturity was significantly ($p<0.05$) and highly significantly ($p<0.01$) affected by the effect of N and NPS fertilizers, respectively while the interaction of N and NPS had non- significant effect (Table 2). Increasing nitrogen fertilizer from 0 kg ha^{-1} to 90 kg UREA ha^{-1} significantly prolonged the duration to reach physiological maturity. Similarly, increasing the NPS fertilizer from 0 to 105 kg NPS ha^{-1} prolonged the duration required to reach physiological maturity. Thus, shortest duration to reach physiological maturity was recorded for black cumin plants grown in the control treatment (Table 3). The prolonged duration to reach physiological maturity in response to the increasing application rates of nitrogen and NPS fertilizer may be due to the fact that adequate supply of both nitrogen and phosphorus in the soil would lead to increased uptake of both nutrients, which lead to increased photosynthesis and accumulation of more carbohydrate in the plant. This result is in accordance with the findings of, Ebrie *et al*., (2015); who reported that increased nitrogen application led to prolonged luxurious vegetative growth of black cumin and resulted into prolonged duration in days to reach

Table 1. Selected soil physico-chemical properties of the experimental sites before planting

	Sinana		Goro		Ginir		
Properties	**Result**	**Rating**	**Result**	**Rating**	**Result**	**rating**	**References**
1. Physical properties							-
Sand (%)	20		22		21		-
Silt (%)	26		27		27		-
Clay (%)	54		51		52		-
Textural Class	Clay		clay		Clay		-
2.Chemical Properties							
pH (1: 2.5 H_2O)	6.82	Neutral	6.01	Neutral	6.82	Neutral	Tekalign (1991)
Organic Carbon /OC/ (%)	1.18	Low	1.32	Medium	1.18	Low	Tekalign (1991)
Total nitrogen /TN/ (%)	0.16	Medium	0.12	Low	0.14	medium	Tekalign (1991))
Available phosphorus /P/ (ppm)	10.23	Medium	4.2	Low	0.16	Medium	Roy *et al* (2006)

Table 2. Mean squares of ANOVA for phonological parameters and yield of black cumin as affected by N and NPS fertilizer

Source	df	Mean squares							
		DF	DM	PH	NPBPP	NSBPP	NCPP	NSPC	SY
Block	2	0.15	1.19	2.01	0.32	0.40	0.81	7.02	1738
N	3	9.52 **	20.08 *	21.68 **	0.11 ns	0.10 ns	2.19 *	19.89 *	26720 **
NPS	3	8.69 **	23.63 **	9.67 **	0.24 ns	0.26 *	0.22 ns	64.06 *	44885 **
N× NPS	9	0.52 ns	5.45	3.24 *	0.13 ns	0.07 ns	0.43 ns	1.28 ns	964 *
Error	30	0.21	3.88	1.44	0.17	0.08	0.88	1.51	1264
CV (%)		**0.5**	**1.2**	**1.5**	**11.4**	**10.1**	**10.0**	**1.6**	**2.3**

Where; V=Varieties; df=degree of freedom; DF=date of flowering; DM=date to maturity; PH=plant height; NPBPP=number of primary branch per plant; NSPP=number of secondary branches per plant; NCPP= number of capsule per plant; NSPC=Number of seed per capsule; SY=Seed Yield *= significant; ** = highly significant

Table 3. Mean effects of N and NPS fertilizer on days of flowering and maturity of black cumin

Plant Height

Treatment	Days to 50% flowering	Days to 90% physiological maturity
Rate of N (kg ha^{-1})		
0	85.42 c	158.8 c
30	86.08 b	159.3 bc
60	87.08 a	160.5 ab
90	87.33 a	161.7 a
Rate of NPS (kg ha^{-1})		
0	85.33 c	158.2 b
35	86.33 b	159.8 a
70	87.08 a	161.1 a
105	87.17 a	161.2 a
LSD (0.05)	**0.3843**	**1.642**
CV (%)	**0.5**	**1.2**

Values sharing identical letter(s) in the table indicate no significant difference at the 5% significance level; LSD=Least significant difference at a 5% probability threshold; CV=Coefficient of variation.

physiological maturity. The main effects of the N and NPS fertilizer highly significantly ($P \leq 0.01$) influenced plant height. In addition, the interaction of N and NPS fertilizer significantly ($P \leq 0.05$) affected this variable (Table 2). The maximum plant height (79.93 cm) was obtained from 90 UREA kg $ha^{-1}$and 70 kg NPS ha^{-1}which is statistically at par with 90 UREA and 105 kg NPS ha^{-1}whereas the minimum plant height (73.0 cm) was obtained from no application of UREA and NPS on black cumin (Table 4). This could be probably due to positive effect of nitrogen on vegetative growth, metabolic and physiological functions of plants.

That nitrogen and phosphorus increased plant height may be attributed to the role the two nutrients play enhancing vegetative growth of plants through their effect on photosynthesis, cell division, leaf expansion, and internodes growth (Shirmohammadi *et al.*, 2014). Similar with the results of this study, Tuncturk *et al.* (2012) reported that the plant height of black cumin increased in response to increasing the rate of N fertilizer. On the other hand, Ali *et al.*, (2015) reported tallest plant in response to combined effects of 120 kg of nitrogen, 40 kg of phosphorus fertilizer and 60 kg of potassium fertilizers.

Number of primary branches per plant

The difference in number of primary branches per plant was observed to be non-significant for main effects of N and NPS. Similarly, significant variation was also not observed by the interactions of the two factors (Table 2).

Number of Secondary branches per plant

The difference in number of secondary branches per plant was observed to be significant ($P \leq 0.05$) for main effects of NPS while the main effects of N and the interaction of N and NPS was non-significant for this parameter (Table 2). The highest number of secondary branches per plant (2.933) was observed from the application of 105 kg NPS ha^{-1} while the lowest number of secondary branches per plant was observed from no application of NPS to black cumin (Table 5). This may due to available nutrients in the soil for plant growth and development. This result is in agreement with Tuncturk *et al.* (2012).

Number of capsule per plant

The number of capsules per plant was significantly ($P \leq 0.05$) affected by main effect of N fertilizer while the main effect of NPS and the interaction between the two factors did not show any significant variation for this parameter (Table 2). The highest number of capsule per plant (9.583) was obtained from 90 kg UREA ha^{-1}which is statistically at par with 60 kg UREA ha^{-1} while the lowest number of capsule per plant (8.683) was obtained from no application of N fertilizer (Table 5).

The observed results might be due to physiological function of nitrogen in cytokinin synthesis, which stimulates cell division, expansion, and enhanced capsule formation during the mid-growth stage, and its roles in plant metabolism may be the cause of this (Rahayu *et al.,* 2005). Similar results were reported by Ali *et al*. (2015) who found that applying 120–40–60 kg of N–P–K fertilizers produced maximum numbers of capsules per plant of black cumin.

Number Seed per capsule

The significant ($P \leq 0.01$) impact of N and NPS fertilizers were observed in number of seeds per capsule. However, the interaction of N and NPS was non-significant for the number of seeds per capsule (Table 2). The highest number of seeds per capsule was produced in response to the application of 60 and 90 kg UREA ha^{-1}. Similarly, the maximum number of seeds per capsule was also obtained from 70 NPS kg ha^{-1} which is statistically at par with the application of 105 NPS kg ha^{-1} while the minimum number of seeds per pod was produced without applying of UREA and NPS fertilizers (Table 5).

Seed Yield

The black cumin seed yield was significantly ($P \leq 0.01$) effected by the main effects of the N and NPS fertilizer. The interaction effect of N and NPS fertilizer also significant ($P \leq 0.05$) for seed yield (Table 2).

The crop attained its maximum seed yield (1669 kg ha^{-1}) by applying 60 kg UREA and 70 kg NPS ha^{-1}. However, the minimum seed yield was noticed without use of UREA and NPS fertilizer on black cumin (Table 6). This result is statistically similar with the seed yield obtained in response to the application of 90 UREA and 105 kg NPS ha^{-1}.

In the current study, the seed yield of black cumin highly responded to the moderate rate of N and NPS. This could probably be due to N and P, important plant nutrients, having complementary metabolic and physiological functions, thereby affecting cell division and elongation of plant. It might be also due to the essential role Sulfur in NPS fertilizer plays in the process of DNA formation and nuclear division, which leads to higher capsule formation which led to higher seed yield. In line with the results of this study, Yemisrach *et al*. (2008) reported the highest seed yield of black cumin in response to a combined application of 45 kg nitrogen ha^{-1} and 30 Kg NPS ha^{-1}. In present study, the moderate rate of N and NPS had a significant impact on black cumin seed yield. This may be because N and P, two essential plant nutrients, have complementary physiological and metabolic roles that influence plant elongation and cell division. It may possibly be because NPS fertilizer contains sulfur, which is crucial for nuclear division and DNA synthesis. increased capsule formation results in increased seed production. Yemisrach *et al*. (2008) observed the maximum black cumin seed yield in response to a combined application of 45 kg N ha^{-1} and 30 kg NPS ha^{-1}, which is consistent with the findings of this study. Similar results were observed by Yosef (2008); Tuncturk *et al*. (2012); Ali *et al*. (2015).

Economic evaluation

A partial budget analysis identified the optimal nutrient application rate of 60 kg UREA ha^{-1} and 70 kg NPS ha^{-1} for yielding the highest net benefit of 293,670 ETB/ha and a substantial marginal rate of return (MRR) of 3164%. (Table 7). The treatments deemed less favorable as per the dominance analysis were removed from subsequent financial assessment. To pinpoint treatments that yield the best return on the farmer's investment, a marginal analysis was conducted on the non-dominated treatments. For a treatment to be deemed a viable option for farmers, the marginal rates of return (MRR) must fall within the range of 50% to 100% (CIMMYT, 1988).

In this study, the farmer's recommendations deduced from marginal analysis suggest that a 100% return on investment serves as a reasonable baseline for an acceptable rate of return. Consequently, the usage of 60 kg ha^{-1} UREA and 70 kg ha^{-1} NPS, yielding a marginal return rate of 3164% for garlic cultivation, significantly exceeds the minimum threshold for acceptable returns. Thus, the application of 60 kg ha^{-1} UREA and 70 kg ha^{-1} NPS emerges as particularly advantageous treatments, making these fertilizer rates advisable for black cumin cultivation in Sinana, Goro, and Ginir, as well as in other regions sharing similar agro-ecological characteristics.

Table 4. The interaction effect of N and NPS fertilizer on plant height of black cumin

N rates (kg ha^{-1})	**NPS rates (kg ha^{-1})**			
	0	**35**	**70**	**105**
0	73.0 c	77.93 bc	78.27 ab	79.00 ab
30	76.4 bc	78.20 bc	78.40 ab	79.13 ab
60	76.5 bc	78.20 bc	78.53 ab	79.33 ab
90	77.7 bc	78.53 ab	79.93 a	79.60 a
LSD 0.05= 2.0		**CV (%) =1.5**		

Means followed by the same letter(s) in the table are not significantly different at 5% level of significance; N= Urea; NPS=NPS fertilizer rate; LSD=Least significance difference at 5% probability level and CV=Coefficient of variation.

Table 5. Mean effects of N and NPS fertilizer on Number of Primary Branches per plant, Number of Secondary Branches per plant, Number of capsule per plant and Number Seed per capsule of black cumin

Treatment	Number of Primary Branches per plant	Number of Secondary Branches per plant	Number of capsule per plant	Number Seed per capsule
Rate of N (kg ha^{-1})				
0	3.450	2.817	8.683 c	73.92 c
30	3.550	2.733	9.383 ab	76.25 b
60	3.583	2.717	9.583 a	76.84 a
90	3.683	2.600	9.583 a	76.58 ab
LSD (0.05)	**NS**	**NS**	**0.78**	**1.03**
Rate of NPS (kg ha^{-1})				
0	3.700	2.600 c	9.183	72.67 c
35	3.667	2.650 b	9.200	75.58 b
70	3.500	2.683 b	9.417	77.75 a
105	3.400	2.933 a	9.433	77.33 a
LSD (0.05)	NS	0.23	NS	1.024
CV (%)	**4.5**	**5.1**	5.0	**1.6**

Values sharing identical letter(s) in the table indicate no significant difference at the 5% significance level; LSD=Least significant difference at a 5% probability threshold; CV=Coefficient of variation.

Table 6. The interaction effect of N and NPS fertilizer on Seed Yield of black cumin

N rates (kg ha^{-1})	**NPS rates (kg ha^{-1})**			
	0	**35**	**70**	**105**
0	1449 g	1526 ef	1544 def	1551 cde
30	1453 fg	1541 def	1558 bcd	1610 abc
60	1483 fg	1543 def	1669 a	1662 ab
90	1541 def	1601 abc	1649 ab	1649 ab
LSD$_{0.05}$= 59.28		**CV (%) = 2.3**		

Means followed by the same letter(s) in the table are not significantly different at 5% level of significance; N= Urea; NPS= NPS fertilizer rate; LSD=Least significance difference at 5% probability level and CV=Coefficient of variation.

Table 7. Partial budget analysis result for N and NPS fertilizer rate on black cumin production

N (Kg ha^{-1})	NPS (Kg ha^{-1})	Aver yield (kg ha^{-1})	Adjusted yield by 10% down (kg ha^{-1})	GFB (ETB ha^{-1})	TVC (ETB ha^{-1})	NB (ETB ha^{-1})	MRR (%)
0	0	1449	1304.1	260820	0	260820	
30	0	1453	1307.7	261540	1500	260040	-52
60	0	1483	1334.7	266940	3000	263940	260
90	0	1541	1386.9	277380	4500	272880	596
0	35	1526	1373.4	274680	1875	272805	D
30	35	1541	1386.9	277380	3375	274005	-100
60	35	1543	1388.7	277740	4875	272865	D
90	35	1601	1440.9	288180	6375	281805	260
0	70	1544	1389.6	277920	3750	274170	D
30	70	1558	1402.2	280440	5250	275190	D
60	70	1669	1502.1	300420	6750	293670	3164
90	70	1649	1484.1	296820	8250	288570	D
0	105	1551	1395.9	279180	5625	273555	1788
30	105	1610	1449	289800	7125	282675	608
60	105	1662	1495.8	299160	8625	290535	524
90	105	1649	1484.1	296820	10125	286695	D

Where GFB = gross field benefit; TVC = total variable costs; NB = net benefit, MRR = marginal rate of return; ETB ha^{-1} = Ethiopian Birr per hectare; D = dominated treatments; Cost of N and NPS 4000.00 Birr and 4500 Birr, 100 kg^{-1} respectively; Labour cost for N fertilizer 1, 2, 3 persons to apply N 30, 60, 90 kg at 300 ha^{-1} day^{-1} respectively and Labour cost for NPS fertilizer 1,2,3 persons to apply NPS 35,70,105 kg ha^{-1} day^{-1} at 300 ETB per day respectively; sale price of black cumin 200 Birr per kg^{-1} during harvest on farm.

Conclusions

The study demonstrated that the application of NPS fertilizers significantly influenced various growth, yield, and yield-related parameters of black cumin. Increasing N and NPS rates (N: 0 to 90 and NPS: 0 to 105 kg ha^{-1}) positively affected plant height, number of secondary branches, number of capsules per plant, and number of seeds per capsule. However, excessive fertilization led to delayed flowering and maturity. The optimal nutrient application rate was determined to be 60 kg UREA ha^{-1} and 70 kg NPS ha^{-1}, resulting in the highest seed yield (1669 kg/ha) and net economic benefit. This treatment combination was found to be the most cost-effective, providing a substantial return on investment. In conclusion, the findings of this study provide valuable insights into the optimal fertilization practices for black cumin cultivation in the Bale region of Ethiopia. This recommendation can contribute to sustainable and efficient agricultural practices for black cumin production.

Conflicts of interest: There are no conflicts of interest.

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