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Effect of NPSB and N Fertilizer Rates on Yield and Yield Components of Black Cumin (*Nigella Sativa L.*) in the Midland Areas of Guji Zone, Southern Ethiopia

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Abstract

Black cumin (*Nigella sativa* L.) is one of the most important food security and cash crops in Ethiopia. However, its productivity is generally low. The low yields of the crop could be attributed to a number of factors, among which low soil fertility is an important constraint. There is little information on the types and rates of fertilizers to be applied, and the cropping system has been given attention to improve its production and productivity. Therefore, an experiment was conducted at the Kiltu Sorsa farmer field in Adola district during the 2021 and 2022 cropping seasons to determine the effect of blended NPSB and nitrogen fertilizer rates on black cumin and to assess the cost and benefit of different rates of blended NPSB and nitrogen fertilizers on black cumin. The treatments consisted of four rates of blended NPSB (0, 50, 100, and 150 kg NPSB/ha) and four rates of nitrogen (0, 23, 46, and 69 kg N/ha) fertilizers. The experiment was laid out as a Randomized Complete Block Design (RCBD) in a 4*4 factorial arrangement replicated three times. An improved black cumin variety called Silingo was used as a test crop. The two-year analysis of the data revealed that the interaction effects of blended NPSB and nitrogen fertilizers influenced significantly ($P<0.05$) days to 50% flowering, days to 90% maturity, plant height, number of capsules per plant, and seed yield. However, the two fertilizers did not interact to influence the number of seeds per capsule parameter of the crop. The highest seed yields were obtained with the application of 100 kg of blended NPSB/ha and 46 kg of N/ha (9.75 qt/ha), while the lowest seed yield (3.71 qt/ha) was obtained with both nil-received plots of the two fertilizers. The partial budget analysis revealed that the application of 100 kg ha of blended NPSB and 46 kg N/ha resulted in net benefits of 122,425 ETB/ha with an acceptable 2148.478.00% marginal rate of return. Therefore, the application of 100 kg blended NPSB with 46 kg N/ha (64.9 kg N + 37.7 kg P_2O_5 + 6.95 kg S + 0.1 kg B/ha) fertilizer rates led to optimum black cumin seed yield production and economic returns and was recommended for black cumin growers in the midland areas of the Guji zone.

Keywords: NPSB fertilizer; Seed yield; Silingo; Partial budget analysis

Introduction

Black Cumin (*Nigella sativa* L.) originated in Egypt and East Mediterranean, but is widely cultivated in Iran, Japan, China, and Turkey [61]. Hence, Black cumin is confirming to be a medicinal plant rich in phytochemicals [70]. In Ethiopia, It is mainly cultivated in Amhara, Oromia, Tigray and SNNPRS and other various places, for household consumption (Habtewold *et al*., 2007). Nigella sativa is widely cultivated in the Amhara Region, Northern Gondar, and Oromia. It is highly cultivated in Kaffa and Keficho Zones and districts of the Southern Nations, Nationalities People's Region [37]. It is also particularly growing in Western Arsi (Kofele and Dodola districts) and Arsi Zone (Shirka, Tena and Silitana districts).

Black cumin is commonly used in Amharic "*Berbere*" in

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which it tends to reduce its hotness [46], for preparation of curries, bread, katikala [49]," to induce an abortion [48]. Besides its medicinal importance, Black cumin seed is also used for the production of soap, perfumes and lotions, food flavorings, food preservation, nutraceuticals and cosmeceuticals from the Black cumin oil [32].

In Ethiopia, black cumin is one of the most important spice types which are mainly produced to favor foods, preparation of oil for perfumes and medicinal purpose, source of income, crop diversification, and export purposes [30,69]. It is also used for reducing the hotness of pepper powder in the country [36]. The demand for black cumin seed and its oil has also been increasing both in Ethiopian local and national markets for consumption purpose. It is also the second most important cash crop that is exported to the international market next to ginger [69]. Currently, a great deal of attention has been given to the seed and oil-yields of black cumin. Their consumption is increasing [63].

According to Inga and Sebsebe (2000), *Nigella sativa* is found in an altitudinal range between 1500-2500m. A rainfall of 120-400mm during its growing season could be enough for its optimum production. It grows in temperature ranges of 5-25^{O}C, with 12-14^{O}C being the optimum. Although it is known to be a low water demanding plant typical of semi-arid areas, the availability of water supply over the growing season is very crucial to the timeliness of flower emergence and seed setting. It grows best on well drained sandy loam to loamy soils with a pH range of 6.8 to 8.3. Acidic soils and alkaline soil reduce yield [75]. The sloppy soils of heavy rainfall areas and leveled and well drained soils of moderate rainfall areas are quite suitable for its cultivation. Soil pH of 7.0 to 7.5 is favorable for its production [57,75].

Ethiopia has favorable environmental condition for black cumin production but the national average productivity of black cumin was 0.79 tonnes/ha [45]. Black cumin cropping system has been given a little attention to improve its production and productivity of the crop. Several problems including lack of improved seed, recommended fertilizer rate, lack of knowhow on postharvest handling; improved agriculture practices and extension system, marketing system, etc. are accountable for the continued low productivity and production of black cumin [77].

Adequate use of chemical fertilizer improves the yield and quality of aromatic plants. The appropriate use of fertilizers increases the growth and quality of medicinal plants [54]. Nitrogen nutrient has the largest effect on plant physiology and is probably the single most important limiting nutrient for crop growth [56]. The Availability of nitrogen is of prime importance for growing plants as it is a major and indispensable constituent of protein and nucleic acid molecules [71]. Agricultural soils are often deficient in N and hence, to ensure adequate N supply to crops and to prevent-nutrient deficiencies, large amounts of inorganic N are applied [60]. In phosphorus in the soil has developmental activity in the plant's root growth. Phosphorus applications, the contact area of the root expands with the growth of the root which, in turn, gives values in the range of 30.7 cm and 35.3 cm in black cumin [42].

Many experiments have been conducted to investigate the effect of different amounts of nitrogen [31,73] and phosphate [52] fertilizers on different agronomic characteristics, yield and yield components of black cumin. According to Rana *et al*. (2012), the maximum values of agronomic characteristic such as plant height and number of branches and the highest yield of seed were observed at a ratio of 60:120 kg NP ha^{-1}. According to Ebrie *et al*. (2015) they reported that combination of 45/40 kg NP ha^{-1} for black cumin production in Konta district. Tuncturk *et al*. (2012) also reported that 60 kg N ha^{-1} produce the highest seed yield in Turkey.

Despite its importance, little attention has been given to improving its production and productivity of the crop. Developing and using an improved variety alone is not enough to realize optimum production of the crop unless fertilizers are properly supplied [68]. Moreover, today there is little available information pertaining to agronomic practices including the optimum dose of blended NPSB and nitrogen fertilizers. Applying at a rate to match crop requirement at an economic and sustainable level is therefore desirable. This requires knowledge of the specific crop requirement in a given environments and of the amount being applied. The farmer needs to adjust these rates according to yield potential affected by soil, crop history and variety and anticipated weather.

Even though much of at Adola district has a potential for black cumin production, almost no research work has so far been conducted to determine the rates of blended NPSB and nitrogen fertilizers. Fertilization rates are insufficient to sustain high yields and to replenish nutrient removal by the crop [47]. Black cumin of different genotypes requires a good combination of fertilizers for optimum growth and yield [29]. Since soil test based and site specific nutrient management has been a major tool for increasing the productivity of agricultural soils. According to the Ethio-SIS studies, the soils of the experimental areas are deficient in nitrogen, phosphorous, and sulfur nutrients [38], but the levels of applications were not identified, and there was no information about recommended rates for blended NPSB and N fertilizer application in the study area. Therefore, this research was conducted and answers the farmers question with the objectives of determining optimum rates of blended NPSB and nitrogen fertilizer rates and assessing the cost and benefit of blended NPSB and nitrogen fertilizer rates for Black cumin production in the study areas.

Materials and Methods

Description of the Experimental Site

The experiment was conducted in the midland (Adola district) areas of Guji Zone at one location during the 2021 and 2022 cropping seasons. Adola district is located at about 470 to the south of Addis Ababa. Adola district is characterized by three agro-climatic zones, namely Dega (high land), Weinadega (mid land), and Kola (low land) with different coverage. The mean annual rain falls and temperature of the district is are about 900mm and 12-34 ^{0}c respectively. Based on this condition two-time cropping season was commonly practiced i.e. Arfasa (main cropping season) which starts from March to April especially for maize, haricot bean, sweet potato and Irish potato. The second cropping season is called Gena (short cropping season) which was practiced as double cropping using small-size cereal crops like tef, potato, Pepper, and barley after harvesting the main cropping season crops. This study was also conducted during the short cropping season in midland areas of Guji zone.

Experimental Materials

An improved Black cumin variety called 'Silingo' which was released by Kulumsa Agricultural Research Center (KARC) in 2017 [53], was used as a planting material. The variety was selected on the based on its high yield, and wider adaptation in the midlands of Guji Zone. Blended NPSB ((18.9% N, 37.7% P_2O_5, 6.95% S and 0.1% B) and Urea (CO $[NH_2]_2$) (46% N) were used as a source of nitrogen, phosphorus, Sulfur, and Boron respectively.

Treatments and Experimental Design

The treatments consisted of four levels of NPSB (0, 50, 100, and 150 kg NPSB ha^{-1}) and four levels of nitrogen (0, 23, 46, and 69 kg N ha^{-1}) fertilizer rates

The experiment was laid out as a Randomized Complete Block Design (RCBD) in a factorial arrangement and replicated three times per treatment. There are 16 treatment combinations, which were assigned to each plot randomly. The total number of plots was 48 and each plot was 2.4m in length and 2.4m in width = 5.76 m^2 in size consisting of six rows, 0.40 m between rows. While the net harvested area is 2.4m (4 rows × 0.4 m) =3.84m^2 (the four central rows). The spacing between plots and adjacent blocks was 0.5 m and 0.75m, respectively. Urea was applied in the split. All pertinent management practices were carried out following the recommendation of the crop.

Soil Sampling and Analysis

The composite soil samples were collected by using Auger (Soil sampler) from 0-20 cm depth based on the procedure outlined by Taye (2000) and using the zigzag method [33]. The surface soil samples collected from the experimental field were air dried and grinded and allowed to pass through a 2mm sieve and for further analysis for total nitrogen and organic carbon were allowed to pass through a 0.5 mm sieve [40]. Pre-planting soil samples were analyzed for particle size distribution (soil texture), soil pH, Cation Exchange Capacity (CEC) (Meq/100g soil), organic carbon (%), available potassium (ppm), phosphorus (ppm), and available sulfur (ppm), boron(ppm), total nitrogen (%), exchangeable magnesium, sodium, and calcium (Cmol (+) kg^{-1}) at Horti coop Ethiopia soil and water analysis laboratory.

Data collection

Phenology, Growth, yield and yield components were collected:- Days to 50% flowering, Days to 90% maturity, Plant height (cm), Number of branches per plant), Number of capsules per plant, Number of seeds per capsule, Seed yield (qt ha^{-1})

Partial Budget Analysis

The partial economic analysis was carried out by using the methodology described in CIMMYT (1988). Only the cost that varied among different treatments was taken into account. The yield of the crop was adjusted downward by 10% to reflect the difference between the experimental yield and the yield farmers expect from the same treatments. The treatment which gives the highest NB and a MRR greater than the minimum is considered acceptable to farmers (>1 or 100%). To compare the costs that varied with the net benefits, the marginal rate of return was calculated as NB = TR – TVC

$$\text{MRR\%} = \frac{\text{Change } 6 \text{ Net Benefit } (\Delta \text{NB})}{\text{Change } 6 \text{ Total Varaible Cost } (\Delta \text{TVC})} \times 100$$

Data Analysis

Field data were analyzed by using SAS software for the data following the standard procedures outlined by Gomez and Gomez (1984). Comparisons among the treatment means were done using Duncan's Multiple Range Test (DMRT) tests at 0.05 level of significant.

Results and Discussion

Physico-Chemical Soil Properties of the Experimental Site

The laboratory results of the selected physico-chemical properties of the soil sample taken pre-planting and post-harvesting are presented in Table 3. The results of pre-planting indicate that the soil has 32, 24, and 44% sand, silt, and clay, respectively, as well as post-harvesting soil having 30, 22, and 48% sand, silt, and clay, respectively, and could be categorized as clay soil on the basis of the 1987 USDA textural soil classification system. According to Murphy (2007), the experimental soil has medium CEC (23.79 and 24.13 meq/100g soil) pre-planting and post-harvest, respectively. The rating made by FAO (2006) indicates that the contents of exchangeable potassium are high (1.10 and 0.71 Cmol (+) kg^{-1}soil), exchangeable Mg is high (3.48 and 2.87 Cmol (+) kg^{-1}soil), exchangeable Ca is high (15.53 and 13.71 Cmol (+)) kg^{-1}soil), and exchangeable Na is low to very low (0.11 and 0.07 Cmol (+) kg^{-1}soil) pre-planting and post-harvesting, respectively. According to the rating of Tekalign (1991), the organic carbon (OC) content of 1.68 and 3.36 percent could be categorized as low to medium pre-planting and post-harvesting, respectively.

Furthermore, according to EthioSIS (2014), the soil of the experimental site is moderately acidic in reaction (pH of 5.97 and 6.08), medium in total N (0.29 and 28%), low in available S (14.08 and 10.52 ppm), low in available B (0.97 and 0.81 ppm), and low in available phosphorus (9.20 and 7.21 ppm) pre-planting and post-harvest, respectively. At increased soil acidity (pH reduces value), phosphorus is fixed to surfaces of Fe and Al oxides and hydrous oxide, which are not readily available to plants [62]. Black cumin can grow in well-drained sandy loam to loamy soils with a pH range of 6.8 to 8.3 [48]. However, the low content of available phosphorus, sulfur, and organic matter calls for the application of mineral and/or organic fertilizers containing these nutrients.

Mean Squares of Black Cumin Parameters

The overall year's analysis of variance showed that the interaction effect of blended NPSB and nitrogen fertilizers signifi-

Table 1: List of experimental treatments, fertilizer compositions and their descriptions.

No.	Treatments		Total composition of fertilizer in the treatment (kg ha^{-1})			
	Blended NPSB rate (kg ha^{-1})	Nitrogen rate (kg ha^{-1})	N	P_2O_5	S	B
1	0	0	0	0	0	0
2	0	23	23	0	0	0
3	0	46	46	0	0	0
4	0	69	69	0	0	0
5	50	0	9.45	18.85	3.475	0.05
6	50	23	32.45	18.85	3.475	0.05
7	50	46	55.5	18.85	3.475	0.05
8	50	69	78.5	18.85	3.475	0.05
9	100	0	18.9	37.7	6.95	0.1
10	100	23	41.9	37.7	6.95	0.1
11	100	46	64.9	37.7	6.95	0.1
12	100	69	87.9	37.7	6.95	0.1
13	150	0	28.35	56.55	10.425	0.15
14	150	23	51.35	56.55	10.425	0.15
15	150	46	74.35	56.55	10.425	0.15
16	150	69	97.35	56.55	10.425	0.15

Table 2: Physical and chemical properties of pre-planting and post-harvesting at Adola Kiltu Sorsa on the farm during 2021 and 22 main cropping season.

	Physical and Chemical Property	Value	Rating	Reference
Pre planting	Sand	32%	-	-
	Clay	44%	-	-
	Silt	24%	-	-
	Textural class	Clay	-	USDA ,1987
	pH (1: 2.5 soil H_2O ratio)	5.97	moderately Acidic	EthioSIS, 2014
	Organic matter (%)	2.89	low	EthioSIS, 2014
	Organic carbon (%)	1.68	low	Tekalign, 1991
	Total N (%)	0.29	medium	EthioSIS, 2014
	CEC (meq/100 g soil)	23.79	medium	Murphy, 2007
	Available P (ppm)	9.20	low	EthioSIS, 2014
	Available S (ppm)	14.08	low	EthioSIS, 2014
	Available B (ppm)	0.97	low	EthioSIS, 2014
	Ex. K [$Cmol_{(+)}kg^{-1}$soil]	1.10	high	FAO, 2006
	Ex.Mg [$Cmol_{(+)}$ kg^{-1}soil]	3.48	high	FAO, 2006
	Ex.Ca [$Cmol_{(+)}kg^{-1}$soil]	15.53	high	FAO, 2006
	Ex.Na [$Cmol_{(+)}kg^{-1}$soil]	0.11	low	FAO, 2006
Post harvesting	Sand	30%	-	-
	Clay	48%	-	-
	Silt	22%	-	-
	Textural class	Clay	-	USDA, 1987
	pH (1: 2.5 soil H_2O ratio)	6.07	moderately Acidic	EthioSIS, 2014
	Organic matter (%)	5.79	Medium	EthioSIS, 2014
	Organic carbon (%)	3.36	high	Tekalign, 1991
	Total N (%)	0.28	medium	EthioSIS, 2014
	CEC (meq/100 g soil)	24.13	medium	Murphy, 2007
	Available P (ppm)	7.21	low	EthioSIS, 2014
	Available S (ppm)	10.52	low	EthioSIS, 2014
	Available B (ppm)	0.81	low	EthioSIS, 2014
	Ex. K [$Cmol_{(+)}kg^{-1}$soil]	0.71	high	FAO, 2006
	Ex.Mg [$Cmol_{(+)}$ kg^{-1}soil]	2.87	medium	FAO, 2006
	Ex.Ca [$Cmol_{(+)}kg^{-1}$soil]	13.71	high	FAO, 2006
	Ex.Na [$Cmol_{(+)}kg^{-1}$soil]	0.07	very low	FAO, 2006

cant difference (P<0.05) were observed on days to 50% flowering, days to 90% physiological maturity, plant height, number of capsules per plant, and seed yield (Table 3). However, the non-significant differences at (*P*>0.05) was observed among their interaction of blended NPSB and nitrogen fertilizers on the number of seeds per capsule (Table 3). Moreover, overall years analysis of variance showed that the interaction effect of blended NPSB, nitrogen, and years showed statistically significant differences (P<0.05) observed on days to 50% flowering, and seed yield. However, non-significant differences at (*P*>0.05) were observed among their interaction of blended NPSB, nitrogen, and years on days to 50% flowering, plant height, number of capsules, and number of seeds per capsule (Table 3).

Days to 50% Flowering

Increasing the application rate of NPSB/N 150/69 kg ha^{-1} prolonged the time required to attain 50% flowering (73.67 days). The earliest days to reach 50% flowering (67.5 days) were observed from nil-treated plots of NPSB and nitrogen (Table 4). This is due to excessive nitrogen and phosphorous, which re-

Table 3: Mean squares of ANOVA for Black Cumin Phenology, growth, yield and yield component effects of blended NPSB and N fertilizer rates at Adola, Southern Ethiopia in 2021 and 2022 growing season.

Source of Variables	Parameters					
	DF	DM	PH(cm)	NCPP	NSPC	Syld qt/ha
Rep.	5.32Ns	72.80Ns	49.68*	2.51Ns	122.99Ns	6.91*
Year	32.66**	600.00**	27.22Ns	4.86Ns	1565.58*	942.32***
NPSB	35.66***	48.26Ns	46.04*	7.59*	853.05*	12.45***
N	37.55***	78.82*	38.91*	20.38***	387.94Ns	11.27***
NPSB*Year	14.11*	Ns	11.9Ns	Ns	400.83Ns	3.11Ns
N*Year	6.67Ns	Ns	5.63Ns	Ns	95.66Ns	9.45*
NPSB*N	3.88**	162.15***	53.13*	4.06*	189.75Ns	7.28***
NPSB*N*Year	6.78*	Ns	20.53Ns	Ns	59.19Ns	3.16*

Significant'***' 0.001, '**' 0.01, '*' 0.05 and Non-Significant (NS) at P>0.05.DF= Days to 50% Flowering, DM= Days to 90% Maturity, PH= Plant height(cm),NCPP= No. capsule per plant, NSPC=No. of Seed per capsule, and Syld= Seed yield qt/ha

sult in prolonged vegetative growth of the plant. This result is in agreement with the findings of Ozguven and Sekeroglu (2007).

Days to 90% Physiological Maturity

Late maturing (125.8 days) was observed from the application of 50 and 100 kg NPSB and 23 kg N ha-1, while early maturing (112.5 days) was observed from 150 and 23 kg NPSB/N per hectare. The delay in days to physiological maturity from increased application of NPSB and nitrogen might be enhancing vegetative growth rather than physiological maturity. This result agrees with the findings of Kar *et al*. (2012) who reported that nitrogen fertilizer has significantly affected the days to 90% physiological maturity of black cumin. This suggestion is also in agreement with that of Tantowijoyo and Van de Fliert (2006) that the application of nitrogen fertilizer at higher rates enhances vegetative growth by helping the plant absorb sunlight and produce carbohydrates but delays the production of reproductive parts and thereby maturity.

Plant Height

The tallest plant height (39.48cm) was obtained from the application of 50 kg NPSB ha^{-1} and 69 kg N ha^{-1}. The shortest plant height (29.24cm) was obtained from the application of 150 kg NPSB ha^{-1} and 23 kg N ha^{-1}. Plant heights might be controlled genetically and/or by environmental factors. The reason may be due to higher doses of nitrogen applied which itself increases plant growth by promoting processes such as cell division, cell enlargement, and metabolic processes. Nitrogen and phosphorus enhance the vegetative growth of plants by increasing cell division, elongation, and varietal variability to absorb the nutrients from the soil [63].

Number of Capsules per Plants

The highest number of capsules per plant (8.55) was obtained from the combination of 50 kg NPSB ha^{-1} and 69 kg nitrogen ha^{-1}, while the lowest (4.05) was obtained from 50 kg NPSB ha^{-1} and the unfertilized treatment nitrogen. This could be the conducive environment of chemical and physical properties of the soil, support for soil microorganisms, as well as increased availability of nitrogen and phosphorous. The main factor for better plant height is an increased number of primary, secondary, and tertiary branches. There could be a possibility of increasing the number of fruit-producing buds, which are the locations for capsule formation. Increased application of nutrients might result in more vigorous plant growth with greater plant height, number of branches, number of leaves, and number of capsules, producing a greater total plant biomass, thereby resulting in a higher biological yield [29].

Table 4: Over year Pooled mean interaction effects of NPSB and N fertilizer rates on days to 50% flowering and days to 90% physiological maturity of black cumin.

NPSB Rates (kg ha-1)	Days to 50% flowering				Days to 90% physiological maturity			
	Nitrogen (kg ha-1)				Nitrogen rates (kg ha-1)			
	0	23	46	69	0	23	46	69
0	67.5d	67.67d	69cd	70cd	114.2de	117.5b-e	115.8cde	115.8cde
50	67.67d	69.33cd	69.67cd	70.67c	117.5b-e	125.8a	114.2de	115.8cde
100	68.67cd	69.33cd	69.33cd	70cd	122.5abc	114.2de	114.2de	125.8a
150	69.17cd	69.83cd	73ab	73.67a	114.2de	112.5e	114.2de	124.2ab
Mean = 69.66					Mean = 117.8			
LSD (0.05) = 0.9					LSD (0.05) =3.06			
CV (%) = 2.4					CV (%) = 4.5			

Table 5: Over location and year Pooled mean interaction effects of NPSB and N fertilizer rates on plant height and Number of capsules per plant of black cumin.

NPSB Rates (kg ha-1)	Plant height(cm)				Number of capsules per plant			
	Nitrogen (kg ha-1)				Nitrogen rates (kg ha-1)			
	0	23	46	69	0	23	46	69
0	31.11e-i	36.62a-d	30.32f-i	31.97d-i	5.17cde	5.5b-e	4.38de	6.44bc
50	33.90b-h	32.64c-i	36.51a-d	39.48a	4.05e	6.55bc	7.11ab	8.55a
100	34.49b-f	29.90gi	37.08abc	35.22a-e	4.33e	5.39cde	6.11bcd	6.44bc
150	36.35a-d	29.24gi	35.61a-e	37.61ab	5.11cd	4.99cde	5.33cde	6.22bc
Mean =34.5					Mean = 5.73			
LSD (0.05) = 1.98					LSD (0.05) = 0.83			
CV (%) = 9.99					CV (%) = 24.9			

In addition, an adequate supply of nitrogen is associated with vigorous vegetative growth and more efficient use of other nutrients. Rana *et al*. (2012) and Tuncturk *et al.* (2012) also reported an increased capsule number per plant of black cumin with increased fertilizer levels. This result is also in agreement with the findings of Ozguven and Sekeroglu (2007).

Number of Seeds Per Capsule

The highest number of seeds per capsule (65.82) was obtained at the application of 50 kg of NPSB per hectare, while the lowest (51.39) was obtained from the unfertilized treatment. The highest number of seeds per capsule (62) was obtained at the application of 23 kg N ha^{-1}, while the lowest (53.04) was obtained from the unfertilized treatment, which is statistically the same but numerically different.

Seed Yield

The highest seed yield (9.75qtha-1) was recorded with the combined application of 100 kg NPSB ha-1 and 46 kg N ha-1, while the lowest yield (3.71qtha-1) was recorded from the control treatment (Table 7). Similar results concerning the positive response of the nigella crop to inorganic fertilization were also recorded by another researcher, Yiman et al. (2015). Valabadi and Aliabadi (2011) found yields of up to 1.43 t/ha. Tuncturk et al. (2012) reported that increasing phosphorus doses positively influenced seed yields in black cumin. Moreover, the agronomic parameters contributed directly or indirectly to the total seed yield for black cumin. This result is in agreement with the findings of Girma et al. (2016) and Fufa (2016) who reported black cumin seed yield is positively correlated with plant height, number of capsules per plant, number of primary branches per plant, and number of seeds per capsule. Moreover, in agreement results with that of Tuncturk et al. (2012) who reported that increasing phosphorus doses positively influenced seed yields in black cumin.

Table 6: Over year Pooled mean main effects of NPSB and N fertilizer rates on the number of seeds per capsule of black cumin.

Treatments	Yield related parameter
NPSB rate (kg ha-1)	**Number of seed per capsule**
0	51.39b
50	65.82a
100	60.07ab
150	57.92ab
Nitrogen rate (kg ha-1)	
0	53.04
23	62.1
46	59.21
69	60.84
Mean = 58.8	
LSD (5%) = 17.58	
CV (%) = 26	

Table 7: Over year Pooled mean interaction effects of NPSB and N fertilizer rates on Seed yield of black cumin.

NPSB Rates (kg ha-1)	Seed Yield(qt/ha)			
	Nitrogen (kg ha-1)			
	0	23	46	69
0	3.71b	7.41ab	5.78ab	7.05ab
50	6.37ab	7.27ab	7.55ab	7.59ab
100	7.14ab	7.68ab	9.75a	6.26ab
150	6.37ab	7.28ab	7.23ab	6.34ab
Mean = 6.96				
LSD (0.05) = 0.68				
CV (%) = 17.16				

Table 8: Correlation analysis on phenology, growth, yield, yield components Characters/traits of Black Cumin at Adola on-farm in 2021 and 2022 cropping season.

Characters/Traits	Characters/Traits					
	DF	DM	PH	NCPP	NSPC	SYLD
DF	1					
DM	0.116	1				
PH	0.24	0.134	1			
NCPP	0.177	0.079	0.304	1		
NSPC	0.113	0.129	0.263	0.23	1	
SYLD	-0.137	0.311	0.049	0.194	0.399	1

Table 9: Partial budgets and marginal rate of return analysis effect of blended NPSB and Nitrogen fertilizer rates to Black cumin variety at Adola on-farm in 2021 and 2022 cropping season.

Treatments		Un Adjusted Seed Yield (kgha^{-1})	Adjusted Seed yield (kgha^{-1})	Total variable cost (ETB)	Total Revenue (ETB)	Net benefit (ETB)	MRR%
NPSB rate (kg ha^{-1})	Nitrogen rate (kg ha^{-1})						
0	0	371	333.9	0	50085	50085	-
0	23	741	666.9	2300	100035	97735	D
50	0	637	573.3	2300	85995	83695	D
0	46	578	520.2	4600	78030	73430	D
50	23	727	654.3	4600	98145	93545	D
100	0	714	642.6	4600	96390	91790	D
0	69	705	634.5	6900	95175	88275	D
100	23	768	691.2	6900	103680	96780	D
150	0	637	573.3	6900	85995	79095	D
50	46	755	679.5	6900	101925	95025	692.61
50	69	759	683.1	9200	102465	93265	D
150	23	728	655.2	9200	98280	89080	D
100	46	975	877.5	9200	131625	122425	2148.478
100	69	626	563.4	11500	84510	73010	D
150	46	723	650.7	11500	97605	86105	622.39
150	69	634	570.6	13800	85590	71790	D

Where, blended NPSB cost = Birr 20 kg-1of blended NPB, N cost = Birr 20 kg^{-1}, blended NPSB and N fertilizers application cost=Birr 6 kg^{-1} of blended NPSB and N, Application cost of blended NPSB and N fertilizers 6 persons 100 kg ha^{-1}, each 75 ETB day^{-1}, Field price of black cumin during harvesting= Birr 150 birr kg^{-1}, MRR (%) = Marginal rate of return and D= Dominated treatment.

Correlation Analysis

The correlation analysis was performed to determine simple correlation coefficient between Phenology, growth, yield and yield component parameters as affected by NPSB and Nitrogen fertilizers application. The present finding has indicated that the number of capsules per pod was positively correlated with plant height (r=0.304). Seed yield was significantly and positively correlated with Days to maturity (r=0.399), and Number of seeds per capsule (r=399). Seed yield was inversely (negatively correlated) related with days to 50% flowering (r=-0.137) (Table 8). Correlation coefficients close to +1 or –1 indicate a close fit to a straight line (strong correlation) and values closer to zero indicate a very poor fit to a straight line or no correlation. According to [66] correlation coefficient analysis attempts to measure the strength of relationships between two variables using of a single number.

Partial Budget Analysis

The results of the study indicated that blended NPSB and N fertilizers had a greater promotion benefit than the control. Partial budget analysis was done based on the view of the CIMMYT Economics Program (1988) recommendations, which stated that the application of fertilizer with a marginal rate of return above the minimum level (100%) is economical. As a result of this study, partial budget analysis revealed that the maximum net benefit of 122,425 ETB with an acceptable Marginal Rate of Return (MRR) of 2148.478.00% was recorded in the treatment that received the application of 100 kg blended NPSB ha^{-1} and 46 kg N ha^{-1} fertilizer rates, respectively (Table 9). However, the lowest net benefits of Birr 50085 ha^{-1} and non-acceptable Marginal Rates of Return (MRR) were obtained in both nil-received plots of blended NPSB and N fertilizers, respectively. The application of 100 kg of blended NPSB ha^{-1} and 46 kg of N ha^{-1} generated 122,425 ETB ha^{-1} more compared to both nil-received plots of blended NPSB and N fertilizers, respectively. The application of 100/46 kg blended NPSB and N per hectare gives the highest net benefit and a marginal rate of return greater than the minimum considered acceptable to farmers (>1 or 100%).

Conclusions and Recommendations

Black cumin is one of the most important food security and cash crops for farmers in mid-land parts of southern Ethiopia, particularly in the Guji zone. Nowadays, black seed plays a vital role throughout the world because of its importance in health, pharmaceuticals, spices, and income-earning. Even though black cumin is important, the production and productivity obtained from the hectares are very low compared to other countries. The main reasons for the lower productivity are mainly attributed to a lack of improved variety, a lack of fertilizer management, a lack of knowledge of cultural practices, and insect pest management.

The overall year's analysis of variance showed that the interaction effect of blended NPSB, nitrogen, and years showed statistically significant differences were observed on days to 50% flowering and seed yield. However, non-significant differences were observed among their interactions of blended NPSB, nitrogen, and years on days to 50% flowering, plant height, number of capsules, and number of seeds per capsule. The highest seed yields were obtained with the application of 100 kg of blended NPSB/ha and 46 kg of N/ha (9.75 qt/ha), while the lowest seed yields (3.71 qt/ha) were obtained with both nil-received plots of the two fertilizers.

The partial budget analysis revealed that the application of 100 kg/ha blended NPSB and 46 kg/ha resulted in net benefits of 122,425 ETB/ha with an acceptable 2148.478.00% marginal rate of return. Therefore, combined application of 100 kg NPSB with 46 kg N ha^{-1} (64.9 kg N+37.7 kg P_2O_5+6.95 kg S+0.1 kg B/ha) produces the highest seed yield, is economically feasible, and is recommended for black cumin growers in the midland areas of the Guji zone.

Author Statements

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