



Influence of Blended NPSB Fertilizer Rates and Cattle Manure on Growth, Yield and Yield Components of Black Cumin (*Nigella Sativum* L.) in Guder, Ethiopia

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Abstract: Black cumin is a seed spice cultivated in Ethiopia for a long period of time. It is also cultivated in the Toke Kutaye district of West Shewa Zone by small-holder farmers. However, the expected benefit of this crop is not being obtained by farmers since they are using in-appropriate agronomic practices including in-appropriate fertilizer applications. A field experiment was conducted at Gudar campus, Toke Kutaye district to determine the influence of different rates of NPSB fertilizer and cattle manure on growth, yield, and yield components of black cumin. The treatments consisted of factorial combinations of four NPSB blended fertilizer levels (0, 50, 100, and 150 kg ha⁻¹) and four CM levels (0, 2.5, 5, and 7.5 t ha⁻¹). The experiment was laid out as a Randomized Complete Block Design in a factorial arrangement and replicated three times. The results indicated that interaction of NPSB and CM highly significantly ($P < 0.01$) influenced yield parameters except for growth and phenological parameters such as days to 50% flowering, days to 90% maturity, primary branches, and secondary branches. However, Days to 50% emergence was not affected by the combined application of NPSB blended fertilizer and cattle manure. The tallest plants (49.20 cm), the highest number of capsules per plant (25.00), the highest numbers of seeds per capsule (99.40) and, the highest harvest index (47.42%) was obtained from the treatment that received 100 kg NPSB ha⁻¹ and 7.5 t CM ha⁻¹. The highest seed yield (1113.33 kg ha⁻¹) was also obtained from the application of 100 kg NPSB ha⁻¹ and 7.5 t CM ha⁻¹. Similarly, the highest MRR (%) was obtained from the interaction effect of 100 kg NPSB ha⁻¹ and 7.5 t CM ha⁻¹ with a marginal rate of revenue (20576%) and net benefit of 86579.7 birr. Thus, the application of 100 kg NPSB ha⁻¹ and 7.5 t CM ha⁻¹ can be promoted for increased productivity of black cumin and economically feasible in the study area. Since the experiment was conducted at one place and one cropping season, the further trial will be needed for the final recommendation.

Keywords: Black Cumin, Capsule, Cattle Manure, NPSB, Seed Yield

1. Introduction

Black cumin (*Nigella sativa* L.) belongs to the family *Ranunculaceae*. Rarely it is known as black caraway, it is also known as “*Tikur azmud*” in Amharic and “*Abasuda guracha*” in Afan Oromo [23]. Black cumin is native to south and southwest Asia [14]. It is one of the most important species cultivated in various parts of the world namely Egypt, the

Middle East, Russia, Kenya, Sudan, Yemen, China, Turk, India, and middle Asian countries being the major producers [30].

Black cumin has a long history in the system of Ethiopian agriculture. It ranks second after ginger among the seed spices in terms of production and area coverage in Ethiopia [23]. It is mainly cultivated in the Amhara, Oromia, Tigray, and SNNPRS regions of Ethiopia; although for their household consumption, it is as well grown in various places. The national average productivity of black cumin was 0.79 t ha⁻¹ [35]. The demand

for black cumin seed and its oil has been increasing in both Ethiopian local and national markets. Black cumin has used for food flavors, perfumes, and medicinal values.

In Ethiopia, black cumin is one of the most important spice types which are mainly produced to flavor foods, preparation oil for perfumes and medicinal purpose, source of income, crop diversification, and export purposes [58]. It is commonly prepared as ingredient in mixture with "*Berber*" to reduce its hotness [28], for the preparation of curries, bread, "*Shamita*" [41], traditional Ethiopian stews, "*Wot*" and preservation of butter. Black cumin is used principally to flavor food, either as whole grain, in powdered form or as an oleoresin extract. More recently a great deal of attention has been given to the seed and oil yields of black cumin [56].

Black cumin has also a significant contribution to the export market. This shows that there is a wide room for black cumin production. Ethiopia has about a 12% share in the world market, however, 99% of the produce is consumed locally [56]. The utilization of black cumin for therapeutic purposes and trade depends on yield and its quality. Besides the importance of black cumin and the country's favorable environmental condition for its production, the black cumin cropping system has not been practiced in the West Shewa. Even though, production and land coverage of black cumin has been increasing the productivity is still less than 300 kg ha⁻¹ [16]. Several problems including limited availability of improved seed, poor soil fertility, lack of recommended fertilizer rate, lack of improved agricultural practices and extension system, marketing system, etc. are accountable for the continued low productivity and production of black cumin [63].

A higher yield of spices including black cumin could be attained through applying the optimum amount of nutrients. A quick and available supply of nutrients is possible from inorganic fertilizers. Previous works have also been reported for increased yield of black cumin from the application of inorganic fertilizers [5]. Farmers in most parts of the country in general and in Toke Kutaye district in particular however have limited information on the impact of different types and rates of fertilizers except blanket recommendation of nitrogen (60 kg N ha⁻¹) and phosphorus (40 kg TSP ha⁻¹) that is 100 kg urea and 100 kg DAP per ha⁻¹ [39]. Recently, the soil fertility mapping project in Ethiopia reported the deficiency of K, S, Zn, B and Cu in addition to N and P in major Ethiopian soils and N, P, S, and B particularly in the study area [18]. NPSB is a blended fertilizer containing 18.9% N, 37.7% P₂O₅, 6.95% S, and 0.1% B. Excessive use of inorganic fertilizers however could reduce crop yields and cause environmental pollution from high concentrations of mineral elements in the soil solutions [19].

Integrated use of inorganic fertilizer with organic fertilizer has been reported to improve soil fertility and crop yield sustainably than the sole application of inorganic fertilizer [7]. The application of organic fertilizers like cattle manure increases the accumulation of organic C in the soil, which in turn induces a change in the microbial community structure and stimulates the microbial biomass [47].

Although cattle manure is known to play an important role in plant production, only few experiments have been done on its effects on the growth and productivity of black cumin. Limited studies have been conducted so far on the effect of cattle manure integrated with inorganic NPSB fertilizer on black cumin plants. Thus, there is a need to develop site-specific recommendations on the fertilizer rates to increase the production and productivity of black cumin in the study area. General objective is to investigate the potential use of cattle manure, integrated with NPSB fertilizer for improved black cumin production in the Gudar area. Therefore the Specific objectives are to evaluate the main effects of NPSB and cattle manure on growth, yield and yield components of black cumin, evaluate the interaction effect of NPSB and cattle manure on growth, yield and yield components of black cumin under the agro-climatic conditions of the Gudar area and identify the economically feasible rates of NPSB blended fertilizer and cattle manure of black cumin production under the conditions of the Toke Kutaye district.

2. Materials and Methods

2.1. Description of the Experimental Site

The field experiment was conducted at Guder, Toke Kutaye district, West Shewa zone of Oromia during the 2019 cropping season. The district is located 126 km west of Addis Ababa and 12 km west of Ambo town, respectively (WSHZOSR Road and Transport Authority, 2017 unpublished). The total geographical area of the district is 78,887 km²; located 37°26'0" to 37°57'30" E longitude and 8°49'0" to 9°05'30" N latitude with an elevation range of 1600-3100 m.a.s.l (Woreda Agricultural Office Annual Report, 2017). The ecology of the district covers 23% of highland, 60% of mid-altitude and 17% is lowland. The mean annual rainfall recorded at the station is 1045 mm and the average annual minimum and maximum temperature are 8.9°C and 27.4°C, respectively.

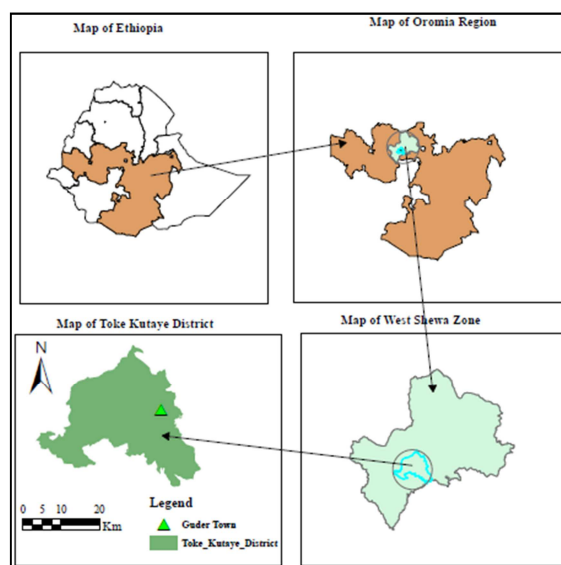


Figure 1. Area description of Toke Kutaye district.

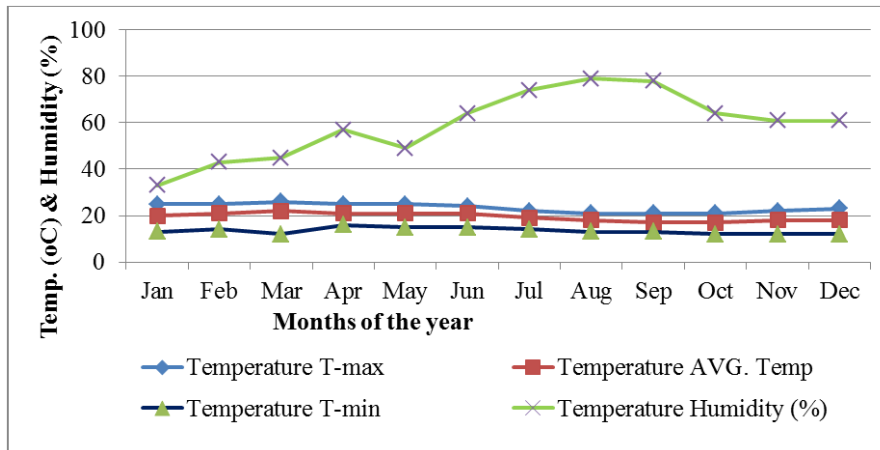
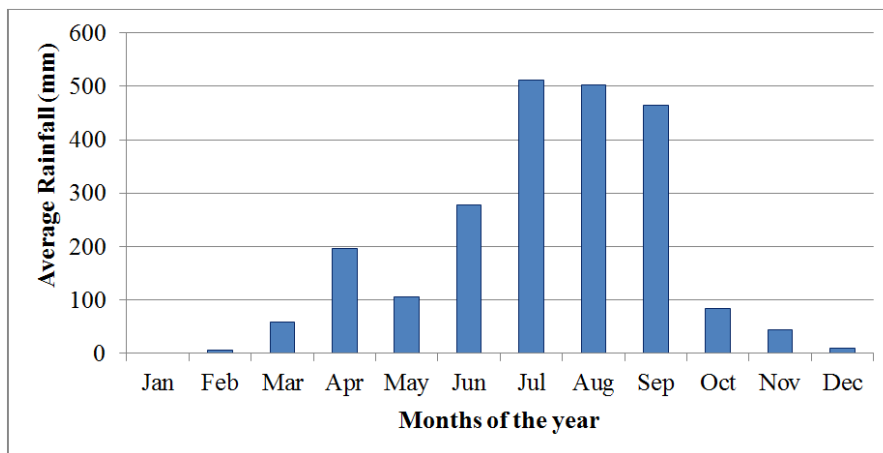


Figure 2. Temperature and humidity condition of the study area during 2019/20 season.



Source: world weather online.

Figure 3. Rainfall amount of the study area during 2019/20 cropping season.

2.2. Experimental Materials

Planting material: Seeds of black cumin variety *Dershaye* (223071) were obtained from Debriziet Agricultural Research Center (DZARC). This variety was selected as it is widely produced in the country [40]. *Dershaye* variety was released in 2009 from Melkassa Agricultural Research Center (MARC) and it is adapted to 1000-1200 mm rainfall and an altitude of 1800-2500 m.a.s.l. *Dershaye* variety matured within 134-154 days.

Fertilizer materials: NPSB fertilizer and cattle manure were used for experiments. Cattle manure was obtained from cattle farms at Ambo University.

2.3. Treatment and Experimental Design

The experiment consists of 16 treatments developed through factorial combinations of four rates (0, 2.5, 5, and 7.5 t ha⁻¹) of cattle manure and four levels (0, 50, 100 and 150 kg ha⁻¹) of NPSB blended fertilizer. The fertilizers were chosen based on fertilizer recommendation given for teff; since most of the time farmers produce black cumin by intercropping with teff [16] and Cattle manure also was

chosen based on [24] done on Evaluation of bio fertilizer and manure effects on quantitative yield of black cumin.

The treatments were arranged in Randomized Complete Block Design (RCBD) with the factorial arrangement in three replications. The detailed treatment combination is indicated in the Table 1.

Table 1. Detailed of treatment combinations.

Treatments	NPSB (kg)	Cattle manure (t)
T1	0	0
T2		2.5
T3		5
T4		7.5
T5	50	0
T6		2.5
T7		5
T8		7.5
T9	100	0
T10		2.5
T11		5
T12		7.5
T13	150	0
T14		2.5
T15		5
T16		7.5

2.4. Experimental Procedure and Field Layout

The selected experimental land was plowed using an oxen plough. Seedbed was harrowed using different hand tools to make fine tilth. Then the experimental site was partitioned into plots. The size of each plot was 1.8m^2 ($1.2\text{ m} \times 1.5\text{ m}$). The distances between plots and between blocks were 0.5 m and 1.0 m, respectively. The quantity of black cumin seed per plot was calculated based on the recommendations of [40], and [3]. Accordingly, two thousand eight hundred eighteen seed were required, which is equivalent to 12 plants per row and 60 plants per plot, respectively.

Seeds were drilled in rows at 30 cm distance between rows and 10 cm between plants at depth of 3 cm. When seedlings reached the 3-4 leaf stage, plants were thinned to obtain the required densities. NPSB was applied during sowing time and cattle manure was applied two weeks before sowing. All other cultural practices like weeding, pest control measures, pre and post-harvest handling etc., were kept uniform and normal for all the treatments as recommended for this crop. Weeds were controlled by hand weeding.

Harvesting was carried out by hand at 90% physiological maturity. First, the border row plants were harvested manually from all sides of each plot and subsequent plants of the net plot harvested excluding the earlier five randomly selected and tagged plants for recording various observations on yield components of parameters.

2.5. Soil Sampling and Analysis

Composite soil samples were collected from the experimental plots in a diagonal pattern from the depth of 0-20 cm before planting and after crop harvesting. Uniform slices and volumes of soil were obtained in each sub-sample by the vertical insertion of an auger to make a composite soil sample. Then, the composite soil samples were air dried, ground using a pestle and a mortar and allowed to pass through a 2 mm sieve and analyzed for the selected physico-chemical properties mainly Organic Matter (OM), Total Nitrogen (TN), soil pH, Cation exchange capacity (CEC), available phosphorus, sulfur and boron. The soil sample was taken after harvesting from each treatment of the experimental site and soil chemical properties were determined. The soil samples were analyzed for selected chemical properties using the appropriate laboratory procedures (Table 2). For experimenting organic fertilizer Cattle manure was used as a component of the treatments.

Soil textural Class was determined by the Bouyoucos Hydrometer Method [10]. Soil pH was determined in 1:2.5 soils: water ratio using a glass electrode attached to a digital PH meter [62]. Organic carbon was estimated by the wet digestion method [62]. CEC was determined turbid metrically by distillation of ammonia that was displaced by Na [48]. Total nitrogen (%) was determined using the Kjeldhal method [32]. Available phosphorus (ppm) was determined by the Olsen method [44]. Available sulfur (meq/l SO_4^{2-}) was determined by the mono-calcium phosphate extraction method [29], and available boron was determined using the hot water method [26].

2.6. Data Collected

2.6.1. Crop Phenology Parameters

Days to 50% seed emergence: The number of days from the date of sowing to the date at which about 50% of the plants in a plot emerge out was counted.

Days to 50% flowering: From the date of sowing, the day on which flowering was observed in five of the earlier tagged plants in each of the plots was recorded and expressed in the number of days taken to 50% flowering.

Days to maturity: The number of days required to reach full crop maturity from the date of sowing was computed on an individual plant basis for five tagged plants in each treatment.

2.6.2. Plant Growth Parameters

Plant height (cm): Plant height was measured from base of the plant to tip of the main shoot for the randomly tagged five plants at harvest stages. The average height was computed and expressed in centimeter (cm).

Root length (cm): Root length was measured from five randomly chosen normal seedlings between their collar regions to the tip of the primary taproot. The mean length of roots was expressed in centimeters.

Number of primary branches per plant: The number of primary branches per plant was recorded from the earlier tagged five plants at harvest stages. The average number of primary branches per plant was computed and expressed in number for respective stages of crop growth.

Number of secondary branches per plant: The number of secondary branches per plant was recorded from the earlier tagged five plants at harvest stages. The average number of secondary branches per plant was computed and expressed in number for respective stages of crop growth.

2.6.3. Seed Yield Parameters

Number of capsules per plant: The numbers of Capsules present in the five tagged plants were counted manually on an individual plant basis. The average was worked out and expressed as the number of capsules per plant at harvest for each treatment.

Number of seeds per capsule: Five well-matured, dried, and normal size pods were selected from each of the five tagged plants for recording the number of seeds per capsules. The seeds from each capsule were separated manually and their number was counted on individual capsules basis and average was expressed as the number of seeds per capsules.

Seed yield per hectare (kg): Seeds obtained from the corresponding net plot of each treatment were cleaned manually, dried to around 8.0% moisture and weighed on a sensitive balance. Seed yield per hectare was computed from net plot seed yield data and recorded as seed yield per hectare in kilograms.

1000 seed weight (g): About 1,000 seeds were chosen randomly from each treatment in three replications and their weight was measured on an Analytical balance as per the procedure given in the ISTA Rules and the average weight was expressed in grams.

Above ground Biomass yield (kg): The whole plant parts, including leaves, stems and seeds from the net plot area were harvested at maturity and dried for three days. Finally, the weights of dried plants were recorded.

Harvest index (%): The harvest index was calculated by dividing seed yield by the total above-ground biomass yield. Means expressed in percentage [1].

$$HI = \frac{\text{Seed Yield}}{\text{Total Biological Yield}} \times 100 \quad (1)$$

2.7. Data Analysis

The data were subjected to the analysis of variance (ANOVA) by using SAS 9.3 software [49]. The mean values were compared and separated using Duncan's multiple range tests at 5% level of significance [54].

2.8. Partial Budget Analysis

To determine the least cost and profitable treatments the partial budget technique was applied to the yield results. Economic analysis was done using the current market prices for inputs at planting and outputs at the time the crop was harvested. All costs and benefits were calculated on a hectare basis in Ethiopian Birr (ETB ha⁻¹). Potentially profitable treatments were selected from the range that was tested using the dominance analysis procedure as described by [12]. Non-dominated treatments were ranked from the lowest (farmers' practice) to the highest cost treatment. For each pair of ranked treatments, the Marginal Rate of Return (MRR) was calculated. The percentage of MRR between any pair of non-dominated treatments denotes the return per unit of investment in fertilizer expressed as a percentage.

3. Results and Discussion

3.1. Pre-Planting Physico-Chemical Properties of the Soil

The result of the laboratory analysis of the selected physico-chemical properties of the soil of the experimental site before planting is presented in Table 2. The result showed that the soil content of clay, silt and sand is 63.6%, 18% and 18.4%, respectively. As a result, the texture of the soil is clay according to [10] classification. The soil texture controls water contents,

water intake rates, aeration, root penetration, and soil fertility. The pH of the soil was 6.18 which is slightly acidic according to the rating of [57]. Black cumin requires a well-drained, aerated and porous sandy loam or loamy clay soils with the pH range for black cumin production of from 5.0-8.0 [38].

The CEC of the site was 36.4 meq/100 g soils. According to "Hazelton, p. and Murphy, B. [27], the experimental soil has high CEC". Most of the time, CEC of soil describes the potential fertility of soils and indicates the soil texture, organic matter content and the dominant types of clay minerals present. The organic carbon content (OC) of the experimental field was 1.6% which is low according to the rating of [57]. This indicates the medium potential of the soil to supply nitrogen to plants through the mineralization of organic carbon. The organic matter of the experimental site was 2.7% which is low according to the classification of [57].

The analysis revealed that the available P of the soil was 16.2 mg kg⁻¹ (Table 2). Indicative ranges of available phosphorus have been established by [44] as < 5 mg kg⁻¹ (very low), 5-15 mg kg⁻¹ (low), 15-25 mg kg⁻¹ (medium), and > 25 mg kg⁻¹ of soil (high). Black cumin needs a good supply of readily available phosphorus, since the root system is not extensive and does not readily utilize less available P forms. Because of the low efficiency of uptake by black cumin, phosphorus fertilizer application needs to be considerably higher than 30-40 kg ha⁻¹ of P taken up by the crop [38].

According to "Tekalign T. [57] classification the soil samples were found to have a low level of total N (0.14%) (Table 2), indicating that the nitrogen is potentially a limiting factor for optimum crop growth". Thus, the level of N in the soil showed that there is a need to apply N for black cumin crop to get optimum yield and quality.

The analysis revealed that the available sulfur of the soil was 34.6 mg kg⁻¹. Thus, the soil of the experimental site was considered as optimum in available sulfur content [33]. The result showed that, the mean B value of the soil was 0.38 mg kg⁻¹. This showed that soils of the study area are deficient in B indicated that need to apply B containing fertilizers. Intensive cultivation in the area might be responsible for the very low B content of the soil according to [33]. The result is in line with "Hailu *et al.* [25] who found B deficiency in soil samples taken around Addis Ababa".

Table 2. Soil physical and chemical properties of the experimental site before planting.

Soil properties	Values	Ratings	References
Physical properties			
Clay (%)	63.6		
Silt (%)	18		
Sand (%)	18.4		
Textural class	Clayey		[10]
Chemical Properties			
PH (1:2.5 H ₂ O)	6.58	Slightly acid	[57]
Organic carbon (%)	1.6	Low	[57]
Total nitrogen (%)	0.14	Low	[57]
Available P (ppm)	12.2	Medium	[44]
CEC (meq 100 ⁻¹ g soil)	36.4	High	[27]
Available sulfur (ppm)	34.6	Optimum	[33]
Available boron (ppm)	0.38	Very low	[33]

Table 3. Chemical properties of cattle manure.

Chemical properties	Values
PH (1:2.5 H ₂ O)	7.2
Organic carbon (%)	12.42
Total nitrogen (%)	0.46
Available P (ppm)	27.4
CEC (meq 100 ⁻¹ g soil)	63.7
EC (dS m ⁻¹)	0.15
Organic matter (%)	21.4

The cattle manure analysis results showed that the organic C and/or organic matter is high, implying that this organic fertilizer can be a good source of plant nutrients. Therefore, the application of inorganic NPSB fertilizers along with well-decomposed cattle manure with very high nutrient content is justified to produce a good yield of black cumin at the study site. The organic carbon, N, P, K, pH, and EC of cattle manure used in the experiment were determined and the results are illustrated in Table 3.

3.2. Soil Chemical Properties of the Experimental Site After Harvest

Soil analysis results before planting showed that the soil is clay in texture and it was found to be slightly acid with a pH of 6.58. Sole application of CM led to a slight increase in pH

level after harvesting from 6.1 to 6.8 which was different from the initial soil sample pH (7.2). The pH of soil after harvesting due to the application of inorganic fertilizer (NPSB) decreased from 6.0 to 5.2. Furthermore, “Kingery et al. [36] reported that the application of organic manure over many years had an average surface soil pH compared to fields receiving only chemical fertilizers”. Meanwhile, soil pH was observed to reduce with the application of organic or inorganic fertilizer compared to the initial soil condition before planting (Table 2). The reduction was more pronounced with plots that received inorganic fertilizer particularly NPSB. It is therefore advisable to apply chemical fertilizer to the experimental site to reduce the pH level.

Organic carbon before planting was 1.6% (Table 2). After harvesting, it ranged from 1.3 to 3.5% having highest value in 150 kg NPSB ha⁻¹ + 7.5 t CM ha⁻¹ followed by 2.7% in 150 kg NPSB ha⁻¹ + 5 t CM ha⁻¹. After harvesting, the soil organic carbon was reduced to 1.3% in the control. However, the organic carbon was in the range of 1.3 to 3.5% in the NPSB + CM treated plots. “Sing et al. [51] reported a drastic reduction in organic carbon concentration on the continuous application of chemical fertilizer, whereas the addition of 5 t ha⁻¹ farm yard manure in combination with N fertilizer helped in maintaining the original organic matter status of the soil”.

Table 4. Selected physico-chemical properties of soil after harvesting.

Treatment	NPSB Kg ha ⁻¹	CM t ha ⁻¹	PH- H ₂ O	EC (ds m ⁻¹)	%OM	%OC	%TN	Ava.P (ppm)
1	0	0	6.1	5.8	2.2	1.3	0.12	11.6
2	0	2.5	6.3	6.3	3.1	1.8	0.16	12.5
3	0	5	6.5	7.4	4.3	2.5	0.17	12.6
4	0	7.5	6.8	5.9	3.1	1.8	0.22	13.0
5	50	0	6.0	5.9	3.6	2.1	0.15	12.3
6	50	2.5	6.1	7.1	3.7	2.1	0.18	12.4
7	50	5	6.2	6.3	2.5	1.4	0.20	12.7
8	50	7.5	6.3	7.3	2.8	1.6	0.22	12.7
9	100	0	5.9	6.2	2.6	1.5	0.19	12.9
10	100	2.5	6.2	6.4	3.4	2.1	0.21	13.1
11	100	5	6.4	6.7	4.6	2.7	0.23	13.7
12	100	7.5	6.5	8.5	3.1	1.8	0.25	13.5
13	150	0	5.2	6.1	5.3	2.1	0.22	13.2
14	150	2.5	5.4	8.9	3.5	2.1	0.24	14.6
15	150	5	5.6	8.1	4.7	2.7	0.25	14.5
16	150	7.5	5.7	8.5	4.3	3.5	0.27	14.7

Where; CM=Cattle manure, TN=Total nitrogen, Av.p= Available phosphorus, PH= Hydrogen power, OC=Organic carbon, EC=Electric conductivity and OM=Organic matter.

The highest Nitrogen (0.27%) was found in 150kg NPSB + 7.5 t CM ha⁻¹ and the lowest was 0.12% observed in the control. Similarly, the amount of available phosphorus ranged from 11.6 ppm in the control to 14.7 ppm in 150 kg NPSB ha⁻¹ + 7.5 t CM ha⁻¹.

The change in total N and P after harvest (Table 4) revealed that incorporation of cattle manure and mineral N, P, S, B fertilizers could improve the fertility status of the soil. Improvement in the soil nutrient contents with the application of cattle manure might be a result of buildup in the organic carbon [50], solubilization of different organic nitrogenous compounds into a simple and available form,

conversion of unavailable P into available form at the time of decomposition of manure [17]. The application of organic or inorganic fertilizers is widely known to ameliorate soil N or P status [43]. This explains why plots that received CM or NPSB + CM had higher N and P contents after harvest.

3.3. Influence of NPSB and Cattle Manure on the Phenology of Black Cumin

3.3.1. Days to 50% Emergence

Days to 50% emergence of black cumin seeds was not

significantly ($P < 0.05$) influenced both by the main and interaction effects of cattle manure and NPSB fertilizer application (Table 5). This may be due to the reason that seed uses its own nutrient and left unused fertilizer applied to the soil before the root emerged [52].

3.3.2. Days to 50% Flowering

Highly significant ($P < 0.01$) differences in days to 50% flowering were observed due to the main effect of NPSB blended fertilizers and cattle manure (Table 5). The earliest days to 50% flowering (71.67 days) was recorded with a zero NPSB while late flowering (73.58 days) was observed from the application of 150 kg NPSB ha⁻¹ fertilizer (Table 5). Considering CM, the earliest days to 50% flowering (71.50 days) was recorded from 0 t ha⁻¹ while late flowering (74.75 days) was from application of 7.5 t CM ha⁻¹.

The delay in flowering with increased level of both mineral NPSB and CM could be because of increased level of nitrogen in NPSB and cattle manure which ultimately can increase nitrogen uptake and this increase contributes to having excessive haulm development for staying longer

duration [42]. Similarly, “Israel *et al.* [31] and Melkamu and Minwelet [37] reported that the application of nitrogen, phosphorous and sulfur fertilizer showed a significant effect on prolonging of time of flowering and maturity potato.

3.3.3. Days to 90% Maturity

The main effects of the fertilizer rate significantly ($P < 0.05$) influenced the days to 90% physiological maturity (Table 5). Early maturity (135.67 days) was observed from the application of 0 kg NPSB ha⁻¹ while late maturity (137.67 days) was from 150 kg NPSB ha⁻¹. Similarly application of 0 t CM ha⁻¹ resulted in early maturity (135.5 days) while late maturity (138.83 days) was observed from 7.5 t CM ha⁻¹ (Table 5).

The delay in days to physiological maturity from increased application of NPSB and CM might be attributed to the supplementation of nitrogen at an early stage of maturity which might enhance vegetative growth rather than physiological maturity as illustrated by [22]. This result agrees with the findings of “Kar *et al.* [34] who reported that nitrogen fertilizer has significantly affected days to 90% physiological maturity in black cumin”.

Table 5. The main effect of NPSB and cattle manure application on phenological parameters of black cumin.

	Days to 50% emergence	Days to 50% flowering	Days to 90% physiological maturity
NPSB rate (Kg ha ⁻¹)			
0	11.50	71.67 ^c	135.67 ^c
50	11.83	72.58 ^b	136.75 ^b
100	11.67	72.67 ^b	136.67 ^b
150	11.50	73.58 ^a	137.67 ^a
Mean	11.63	72.63	136.69
Cattle Manure rate (t ha ⁻¹)			
0	11.92	71.50 ^c	135.50 ^c
2.5	11.75	71.83 ^{bc}	136.83 ^{bc}
5	11.58	72.42 ^b	135.42 ^b
7.5	11.25	74.75 ^a	138.83 ^a
Mean	11.63	72.63	136.63
CR (5%)	0.48	0.63	0.68
CV (%)	4.97	1.04	0.60
Significance level			
NPSB	NS	**	**
CM	NS	**	**
NPSBxCM	NS	NS	NS

Means in a column followed by the same letter (s) are significantly different at the 5% probability level (DMRT); NS indicate non-significant, *, ** indicate significance different at $P < 0.05$ and 0.01, respectively. CR= critical range; CV= coefficient of variation; CM= cattle manure; NPSB= Nitrogen, Phosphorus, Sulfur, Boron; t ha⁻¹=ton per hectare; Kg ha⁻¹= Kilo gram per hectare.

3.4. Growth Parameters

3.4.1. Plant Height

The interaction effect of NPSB and cattle manure were highly significant ($P < 0.01$) on plant height of black cumin (Table 6). The longest plant height (49.20 cm) was obtained from the application of 100 kg NPSB ha⁻¹ + 7.5 t CM ha⁻¹. The shortest plant height (33.20 cm) was from the control treatment (no fertilizer) which is similar to the application of 50 kg NPSB ha⁻¹ + 0 t CM ha⁻¹. The probable reason for increment in plant height with the application of higher NPSB and Cattle manure might be due to more uptake of N₂ during the growth period increasing in cell size, elongation, and enhancement of cell division which ultimately increase

the plant growth [53].

Nitrogen and Phosphorus have enhancing effect on the vegetative growth of plants by increasing cell division, elongation and the varietal variability to absorb the nutrients from the soil. This also confirms the finding of “Gonzalez *et al.* [21] who reported that organic manure and inorganic fertilizer supplied most of the essential nutrients at growth stage resulting in increase of growth variables including plant height”. “Pariari *et al.* [46] also observed that combined application of boron and zinc particularly at lower doses promoted mostly the vegetative parameters of black cumin”. “Hadi *et al.* [24] also reported the highest plant height (78.11 cm) from the integrated application of 7.5 t manure ha⁻¹ and inoculation of seeds by Azotobacter + Azospirillum”.

Table 6. Interaction effect of NPSB and cattle manure on plant height (cm) of black cumin.

NPSB rate (Kg ha ⁻¹)	Cattle manure rate (t ha ⁻¹)				Mean
	0	2.5	5	7.5	
0	33.20 ^s	34.07 ^{fg}	47.07 ^{ab}	47.13 ^{ab}	40.37
50	33.53 ^s	35.13 ^{fg}	40.40 ^e	45.20 ^{bc}	38.56
100	36.87 ^c	39.80 ^c	45.27 ^{bc}	49.20 ^a	42.78
150	39.80 ^c	41.73 ^{de}	43.93 ^{cd}	46.60 ^{a-c}	43.02
Mean	35.87	37.68	44.17	47.03	41.19
CR (5%)	2.79				
CV (%)	4.06				
Significance level					
NPSB	**				
CM	**				
NPSB X CM	**				

Means in a column followed by the same letter (s) are significantly different at the 5% probability level (DMRT); NS indicate non-significant, *, ** indicate significance different at $P < 0.05$ and 0.01 , respectively. CR= critical range; CV= coefficient of variation; CM= cattle manure; NPSB= Nitrogen, Phosphorus, Sulfur, Boron; t ha⁻¹=ton per hectare; Kg ha⁻¹=Kilo gram per hectare.

3.4.2. Root Length

The interaction effects of NPSB and cattle manure were highly significant ($P < 0.01$) on root length of black cumin (Table 7). The longest root length (20.80 cm) was obtained from the application of 100 kg NPSB ha⁻¹ + 7.5 t CM ha⁻¹ which is statistically at par with the application of 150 kg NPSB ha⁻¹ + 7.5 t CM ha⁻¹ and 100 kg NPSB ha⁻¹ + 5 t CM ha⁻¹. The shortest

root length (8.80 cm) was from the control treatment (no fertilizer) which is similar to the application of 50 kg NPSB ha⁻¹ + 0 t CM ha⁻¹ and 50 kg NPSB ha⁻¹ + 2.5 t CM ha⁻¹. This could be the positive effects of nitrogen and phosphorous interaction combined with the physical and chemical properties of the soil condition enabling plants to form a deep taproot system. This result was close with, the finding of Ozguven et al. [45].

Table 7. Interaction effect of NPSB and cattle manure on root length (cm) of black cumin.

NPSB rate (Kg ha ⁻¹)	Cattle manure rate (t ha ⁻¹)				Mean
	0	2.5	5	7.5	
0	8.80 ^d	8.80 ^d	11.33 ^d	11.67 ^d	10.15
50	8.80 ^d	9.13 ^{cd}	9.60 ^{cd}	9.80 ^{cd}	9.33
100	8.90 ^{cd}	9.60 ^{cd}	19.33 ^a	20.80 ^a	14.66
150	10.13 ^{cd}	10.47 ^{cd}	15.20 ^b	20.00 ^a	13.95
Mean	9.16	9.50	13.86	15.57	12.02
CR (5%)		2.43			
CV (%)		12.11			
Significance level					
NPSB		**			
CM		**			
NPSBXCM		**			

Means in a column followed by the same letter (s) are significantly different at the 5% probability level (DMRT); NS indicate non-significant, *, ** indicate significance different at $P < 0.05$ and 0.01 , respectively. CR= critical range; CV= coefficient of variation; CM= cattle manure; NPSB= Nitrogen, Phosphorus, Sulfur, Boron; t ha⁻¹=ton per hectare; Kg ha⁻¹= Kilo gram per hectare.

3.4.3. Number of Primary and Secondary Branches

The main effect of NPSB and cattle manure showed a highly significant ($P < 0.01$) effect on the number of primary and secondary branches per plant of black cumin (Table 8). Increasing the NPSB fertilizer rate from 0 to 100 kg ha⁻¹ resulted in an increased number of both primary and secondary branches per plant. The maximum number of primary (6.03) and secondary (2.58) branches per plant was obtained with the

application of 100 kg NPSB ha⁻¹ which is statistically the same as the application of 150 kg NPSB ha⁻¹ in both case while, the minimum was obtained from the control plots (Table 8). The result is in agreement with the finding reported by "Tuncur et al. [61] from Turkey where the mean primary branch per plant obtained in response to the application of 80 kg N ha⁻¹ was greater than primary branches per plant obtained in response to the application of 92 kg N ha⁻¹".

Table 8. The main effect of NPSB and cattle manure application on growth parameters of black cumin.

NPSB rate (Kg ha ⁻¹)	Number of Primary branches (n°)	Number of Secondary branches (n°)
0	4.75 ^b	1.92 ^c
50	5.40 ^{ab}	2.22 ^b
100	6.03 ^a	2.58 ^a

	Number of Primary branches (n°)	Number of Secondary branches (n°)
150	5.98 ^a	2.47 ^a
Mean	5.54	2.30
Cattle manure rate (t ha ⁻¹)		
0	4.65 ^c	1.99 ^c
2.5	5.17 ^{bc}	2.21 ^b
5	5.87 ^{ab}	2.35 ^b
7.5	6.48 ^a	2.66 ^a
Mean	5.54	2.30
CR (5%)	0.75	0.20
CV (%)	16.21	10.12
Significance level		
NPSB	*	*
CM	**	**
NPSB×CM	NS	NS

Means in a column followed by the same letter (s) are significantly different at the 5% probability level (DMRT); NS indicate non-significant, *, ** indicate significance different at $P < 0.05$ and 0.01 , respectively. CR= critical range; CV= coefficient of variation; t ha⁻¹=ton per hectare; Kg ha⁻¹= Kilo gram per hectare; CM= cattle manure; NPSB= Nitrogen, Phosphorus, Sulfur, Boron; n°= number.

Application of 7.5 t ha⁻¹ CM resulted in the highest number of both primary (6.48) and secondary (2.66) branches (Table 8). This may due to the role of available nutrients in the cattle manure in the soil which is used for plant growth and development.

3.5. Yield and Yield Components

3.5.1. Number of Capsule Per Plants

The interaction effect of NPSB and cattle manure highly significantly ($P < 0.01$) influenced the capsules of black cumin (Table 9). The highest number of capsules per plant (25.00) was obtained from the combination of 100 kg NPSB ha⁻¹ and 7.5 t CM ha⁻¹ which is statistically the same with the application of 150 kg NPSB ha⁻¹ and 7.5 CM ha⁻¹ while the minimum (6.93) was obtained from the unfertilized treatment.

In different studies, researchers found that the number of

capsules for black cumin was in the ranges of 5.7-6.0 [11, 20]. “Datta, S. [15] found that the highest number of capsules (5.68-5.61) was determined in 20 and 40 kg ha⁻¹ phosphorus doses and the lowest number of capsules (4.68) was obtained from control plots”. The present result is far from these mentioned references. This could be the conducive environment of chemical and physical properties of the soil, support for soil microorganisms as well as increase availability of nitrogen and phosphorous. This condition could be the main factor for better plant height, for an increased number of primaries, secondary and tertiary branches; there could be a possibility of increasing the number of fruit-producing buds, which are the locations for capsules formation. This assumption also agreed with [60]. An adequate supply of nitrogen is associated with vigorous vegetative growth and more efficient use of other nutrients. Finally, lead to higher productivity.

Table 9. Interaction effect of NPSB and cattle manure on capsule per plants of black cumin.

NPSB rate (K g ha ⁻¹)	Cattle manure rate (t ha ⁻¹)				Mean
	0	2.5	5	7.5	
0	6.93 ^h	9.87 ^{fh}	18.27 ^{bc}	15.60 ^{b-d}	12.67
50	7.13 ^h	7.27 ^h	9.13 ^{gh}	12.40 ^{ef}	8.98
100	11.20 ^{fg}	14.60 ^{de}	18.60 ^b	25.00 ^a	17.35
150	11.73 ^{c-g}	15.73 ^{b-d}	15.37 ^{cd}	22.60 ^a	16.38
Mean	9.25	11.87	14.90	18.9	13.85
CR (5%)		2.80			
CV (%)		12.15			
Significance level					
NPSB		**			
CM		**			
NPSB×CM		**			

Means in a column followed by the same letter (s) are significantly different at the 5% probability level (DMRT); NS indicate non-significant, *, ** indicate significance different at $P < 0.05$ and 0.01 , respectively. CR= critical range; CV= coefficient of variation; CM= cattle manure; NPSB= Nitrogen, Phosphorus, Sulfur, Boron; t ha⁻¹=ton per hectare; Kg ha⁻¹= Kilo gram per hectare.

3.5.2. Number of Seeds Per Capsule

The interaction effects of NPSB with cattle manure fertilizer were highly significant ($P < 0.01$) on the number of seed per capsule of black cumin (Table 10). The maximum number of seed per capsule (99.40) was recorded on the plot which received 100 kg NPSB ha⁻¹ and 7.5t CM ha⁻¹ which is

followed by 150 kg NPSB ha⁻¹ + 7.5 t CM ha⁻¹ while the minimum (75.80) was recorded from the control treatment (Table 10).

The result from present finding is related to the findings of “Hadi et al. [24] who reported the highest seed number per capsule (95.38) from the application of 7.5 t manure ha⁻¹ integrated with inoculation of seeds by Azotobacter +

Azospirillum". However, this result disagrees with the finding reported by "Suleyman et al. [55] who reported that

phosphorus fertilizer rate had non- significant effects on the number of capsules per plant of black cumin".

Table 10. Interaction effect of NPSB and cattle manure on the number of seed per capsule of black cumin.

NPSB rate (K g ha ⁻¹)	Cattle manure rate (t ha ⁻¹)				Mean
	0	2.5	5	7.5	
0	75.80 ^h	82.47 ^{fg}	82.87 ^{c-g}	88.67 ^{cd}	82.45
50	80.20 ^{gh}	82.93 ^{c-g}	84.20 ^{d-g}	85.33 ^{d-g}	83.17
100	83.20 ^{c-g}	88.00 ^{c-e}	88.07 ^{c-e}	99.40 ^a	89.67
150	86.00 ^{d-f}	92.20 ^{bc}	93.07 ^{bc}	94.87 ^{ab}	91.53
Mean	82.50	85.20	87.33	91.78	86.70
CR (5%)		4.61			
CV (%)		3.19			
Significance level					
NPSB		**			
CM		**			
NPSBXCM		**			

Means in a column followed by the same letter (s) are significantly different at the 5% probability level (DMRT); NS indicate non-significant, *, ** indicate significance different at $P < 0.05$ and 0.01 , respectively. CR= critical range; CV= coefficient of variation; CM= cattle manure; NPSB= Nitrogen, Phosphorus, Sulfur, Boron; t ha⁻¹=ton per hectare; Kg ha⁻¹= Kilo gram per hectare.

3.5.3. Above Ground Biomass Yield

The result of the study showed that, the interaction effects of NPSB with cattle manure fertilizer were highly significant ($P < 0.01$) on the aboveground biomass yield of black cumin. The main effects of NPSB and cattle manure fertilizer were also significant ($P < 0.05$) on above-ground biomass of black cumin (Table 11). Aboveground biomass yield ranged from 1637.41 kg

ha⁻¹ to 2391.48 kg ha⁻¹. The highest above-ground biomass yield (2391.48 kg ha⁻¹) was recorded with the 150 kg NPSB ha⁻¹ combined with 7.5 t CM ha⁻¹ which is statistically at par with application of 150 kg NPSB ha⁻¹ + 5 t CM ha⁻¹ while the lowest (1637.41 kg ha⁻¹) was recorded from the control treatment. Total above-ground biomass yield indicated an increasing tendency in response to all higher interaction effects.

Table 11. Interaction effect of NPSB and cattle manure on above-ground biomass yield of black cumin.

NPSB rate (K g ha ⁻¹)	Cattle manure rate (t ha ⁻¹)				Mean
	0	2.5	5	7.5	
0	1637.41 ^g	1669.26 ^g	1774.07 ^f	1927.78 ^e	1752.13
50	1650.00 ^g	1805.93 ^f	1901.85 ^e	2008.00 ^d	1841.45
100	2140.74 ^c	2137.78 ^c	2297.63 ^b	2347.96 ^{ab}	2231.03
150	2045.19 ^d	2178.52 ^c	2382.59 ^a	2391.48 ^a	2249.44
Mean	1868.33	1947.87	2089.03	2168.80	2018.51
CR (%)		80.01			
CV (%)		2.38			
Significance level					
NPSB		**			
CM		**			
NPSB X CM		**			

Means in a column followed by the same letter (s) are significantly different at the 5% probability level (DMRT); NS indicate non-significant, *, ** indicate significance different at $p < 0.05$ and 0.01 , respectively; CR= critical range; CV= coefficient of variation; CM= cattle manure; NPSB= Nitrogen, Phosphorus, Sulfur, Boron; t ha⁻¹=ton per hectare; Kg ha⁻¹= Kilo gram per hectare.

The increase in above ground biomass yield of black cumin in response to the increased supply of combined NPSB and cattle manure fertilizer rate could be due to more luxurious plant growth due to the available nutrients from NPSB and CM expressed a more above ground biomass production. In addition to N and P, S is reported to enhance the formation of chlorophyll and encourage vegetative growth while B helps in N absorption. This result is in agreement with "Ashraf et al. [8] who reported that the highest biological yield (2758 kg ha⁻¹) was obtained from the application of 40 kg P ha⁻¹ and 30 kg N ha⁻¹". "Das et al. [13] also found a biological yield of 1967 kg ha⁻¹ with the application of 60/120 kg NP ha⁻¹".

3.5.4. Seed Yield

The interaction effect of NPSB and cattle manure significantly ($P < 0.01$) influenced seed yields of black cumin (Table 12). Maximum seed yield (1113.33 kg ha⁻¹) was recorded with the combined application of 100 kg NPSB ha⁻¹ and 7.5t CM ha⁻¹ while the minimum yield (545.11 kg ha⁻¹) was recorded from the control treatment (Table 12).

The result of this study is similar with the findings of "Hadi et al. [24] who reported a higher seed yield of 876.12 kg ha⁻¹ from the application of 5 t manure ha⁻¹ integrated with inoculation of seeds by Azotobacter + Azospirillum". "Tuncturk et al. [61] Reported increased seed yields of black cumin with increasing fertilizer levels and the highest values

were obtained from 40 kg P₂O₅ ha⁻¹”. Application of Boron 0.1% and Zinc 0.2% enhanced twice most of the yield attributes including seed yield (663 kg ha⁻¹) of black cumin reported by [46]. Manure application is also reported to

improve soil structure and soil moisture content; provide the plant with essential elements, increases growth, number of branches per plant and biological yield, and finally led to increasing seed yield [4].

Table 12. Interaction effect of NPSB and cattle manure on seed yield of black cumin.

NPSB rate (Kg ha ⁻¹)	Cattle manure rate (t ha ⁻¹)				Mean
	0	2.5	5	7.5	
0	545.11 ^l	572.22 ^{kl}	611.11 ^{jk}	727.78 ^{gh}	614.05
50	587.70 ^{kl}	644.44 ^{ij}	681.48 ^{hi}	736.78 ^{fg}	662.60
100	783.33 ^{ef}	868.04 ^d	949.56 ^c	1113.33 ^a	928.56
150	805.56 ^c	858.07 ^d	916.67 ^c	1047.89 ^b	907.05
Mean	680.42	735.69	789.70	906.44	778.06
CR (%)	46.85				
CV (%)	3.61				
Significance level					
NPSB	**				
CM	**				
NPSB X CM	**				

Means in a column followed by the same letter (s) are significantly different at the 5% probability level (DMRT); NS indicate non-significant, *, ** indicate significance different at p<0.05 and 0.01, respectively. CR= critical range; CV= coefficient of variation; CM= cattle manure; NPSB= Nitrogen, Phosphorus, Sulfur, Boron; t ha⁻¹=ton per hectare; Kg ha⁻¹= Kilo gram per hectare.

3.5.5. Thousand Seed Weight

The interaction effect of NPSB and cattle manure significantly ($P<0.01$) influenced thousand seed weights of black cumin (Table 13). Maximum thousand seed weight (3.56g) was recorded due to the combined effect of 100 kg

NPSB ha⁻¹ and 7.5t CM ha⁻¹ which is statistically the same with the application of 150 kg NPSB ha⁻¹ and 7.5t CM ha⁻¹ while the minimum yield (2.66g) was recorded from the control treatment (Table 13).

Table 13. Interaction effect of NPSB and cattle manure on thousand seed weight of black cumin.

NPSB rate (Kg ha ⁻¹)	Cattle manure rate (t ha ⁻¹)				Mean
	0	2.5	5	7.5	
0	2.66 ^d	2.93 ^{cd}	2.90 ^{cd}	3.01 ^{bc}	2.91
50	2.75 ^{cd}	2.79 ^{cd}	2.85 ^{cd}	3.03 ^{bc}	2.85
100	2.93 ^{cd}	3.01 ^{bc}	3.25 ^b	3.56 ^a	3.13
150	2.99 ^{bc}	2.87 ^{cd}	2.82 ^b	3.51 ^a	3.42
Mean	2.87	2.90	3.23	3.31	3.08
CR (%)	0.25				
CV (%)	4.97				
Significance level					
NPSB	**				
CM	**				
NPSB X CM	**				

Means in a column followed by the same letter (s) are significantly different at the 5% probability level (DMRT); NS indicate non-significant, *, ** indicate significance different at p<0.05 and 0.01, respectively. CR= critical range; CV= coefficient of variation; CM= cattle manure; NPSB= Nitrogen, Phosphorus, Sulfur, Boron; t ha⁻¹=ton per hectare; Kg ha⁻¹= Kilo gram per hectare.

This result agrees with “Ali et al. [6] who reported that application of cattle manure and biofertilizer increased the capsule number per plant, 1000 seeds weight and seed yield per plant compared to the control”. In different studies, thousand seed weight of black cumin was reported as 3.50 g [13], 2.15 g [11] and 2.15 g [45].

3.5.6. Harvest Index

Harvest index was found to be highly significantly ($P<0.01$) influenced by the interaction effect of NPSB and CM (Table 14). The highest harvest index (47.40%) was obtained from the treatment that received combined of 100 kg NPSB ha⁻¹ and 7.5t CM ha⁻¹ while the lowest (33.43%)

was recorded from the control treatment. The increased availability of nutrients both from NPSB and CM might have led to the increased harvest index of black cumin from increased application of NPSB and CM. Improved nutrient absorption increases the proportion of seed to dry mass by developing leaf area index and supplying more photosynthetic materials to seeds [13].

The present study is close with “Ebrie et al. [16] who reported 20.8% found from the application of 60/40 NP kg ha⁻¹”. This result was consistent with the idea of “Geren et al. [20] who indicated that grain crops are strongly forced in favor of seed yield and their harvest index can increase”.

Table 14. Interaction effect of NPSB and cattle manure on harvest index of black cumin.

NPSB rate (Kg ha ⁻¹)	Cattle manure rate (t ha ⁻¹)				Mean
	0	2.5	5	7.5	
0	33.43 ^h	34.49 ^{gh}	34.67 ^{gh}	37.94 ^{d-f}	35.13
50	35.88 ^h	35.69 ^h	36.00 ^h	36.83 ^g	36.10
100	36.71 ^g	40.62 ^{cd}	41.46 ^{bc}	47.40 ^a	41.55
150	39.42 ^{c-e}	39.41 ^{c-e}	38.59 ^{c-f}	43.75 ^b	40.29
Mean	36.36	37.56	37.68	41.48	38.27
CR (5%)		2.65			
CV (%)		4.15			
Significance level					
NPSB		**			
CM		**			
NPSB×CM		**			

Means in a column followed by the same letter (s) are significantly different at the 5% probability level (DMRT); NS indicate non-significant, *, ** indicate significance different at $P < 0.05$ and 0.01 , respectively. CR= critical range; CV= coefficient of variation; CM= cattle manure; NPSB= Nitrogen, Phosphorus, Sulfur, Boron; t ha⁻¹=ton per hectare; Kg ha⁻¹= Kilo gram per hectare.

3.6. Correlation Analysis

The correlation coefficient was calculated for the different variables which help to show how the yield components and growth characters affecting the yield of black cumin are related. Thus seed yield was significantly and positively correlated with plant height ($r = 0.65^{**}$), root length ($r = 0.82^{**}$), flowering date ($r = 0.63^{**}$), number of primary branches per plant ($r = 0.62^{**}$), number of secondary branches per plant ($r = 0.82^{**}$), number of capsules per plant ($r = 0.62^{**}$), number of seeds per capsule ($r = 0.86^{**}$), above-ground biomass yield ($r = 0.96^{**}$), thousand seed weight ($r = 0.73^{**}$), and harvest index ($r = 0.95^{**}$) (Table 15).

The observed relationship indicated that the combined use of cattle manure and NPSB fertilizer contributes for increasing vegetative growth and yield of black cumin. This result also agrees with the work of “Bradideh et al. [9] who reported positive correlation of yield with the number of capsules per plant, number of seeds per capsule, plant height, number of main branches and number of sub-branches”. Results also related with “Tewodros et al. [59] showed positive correlation of plant height and number of capsules per plant with seed yield of black cumin”. Positive and significant correlation of seed yield with days to maturity and plant height on black cumin were reported by [2].

Table 15. Correlations among growth yield and yield components of black cumin under NPSB and cattle manure application.

	DE	DF	DM	PH	PB	SB	RL	CPP	SPC	AGBY	SY	TSW	HI
DE	1.00												
DF	0.30*	1.00											
DM	0.29*	0.98**	1.00										
PH	0.32*	0.70**	0.68**	1.00									
PB	0.18ns	0.52**	0.57**	0.51**	1.00								
SB	0.17ns	0.60**	0.58**	0.57**	0.55**	1.00							
RL	0.17ns	0.53**	0.54**	0.65**	0.57**	0.74**	1.00						
CPP	0.29*	0.61**	0.59**	0.84**	0.56**	0.65**	0.84**	1.00					
SPC	0.33*	0.63**	0.63**	0.72**	0.67**	0.74**	0.73**	0.80**	1.00				
AGBY	0.25ns	0.62**	0.61**	0.63**	0.62**	0.75**	0.69**	0.75**	0.80**	1.00			
SY	0.25ns	0.63**	0.62**	0.65**	0.62**	0.82**	0.82**	0.83**	0.86**	0.96**	1.00		
TSW	0.24ns	0.62**	0.59**	0.57**	0.52**	0.68**	0.78**	0.74**	0.59**	0.61**	0.73**	1.00	
HI	0.25ns	0.60**	0.59**	0.62**	0.55**	0.81**	0.85**	0.83**	0.84**	0.83**	0.95**	0.79**	1.00

Where: *, ** and ns indicate that significant, highly significant and non-significant difference at probability levels of 5% and 1%, respectively. DE=Days to 50% emergency; DF=Days to 50% flowering; DM= Days to maturity; PH=Plant height; RL=Root length; PB= Primary branches; SB= Secondary branches; CPP= Capsule per plant; SPC= Seed per capsule; AGBY= above-ground biological yield; SY= Seed yield, TSW= Thousand seed weight; HI= Harvest index.

3.7. Partial Budget Analysis

The yield of black cumin was adjusted downwards by 10% to reflect the difference between the experimental yield and the expected yield of farmers from the same treatment. The actual price of black cumin was used to convert the adjusted yields into gross benefits (90 birr per kg). The cost of fertilizers (NPSB = 16.50 birr per Kg and for CM = 100 birr per ton) was taken from the study areas

(Table 16). The marginal rate of return (MRR%) analysis for seed yield indicated that the highest net benefit (86579.7 ETB ha⁻¹) was recorded from the combined application of 100 Kg NPSB ha⁻¹ and 7.5 t CM ha⁻¹ over the control treatment which resulted in the net benefit of 44153.9 ETB ha⁻¹. The highest marginal rate of return (20576.0%) was obtained from the interaction effect of 100 kg NPSB ha⁻¹ and 7.5 t CM ha⁻¹ over the control treatment (Table 16).

Table 16. Partial budget analysis for yield for all combinations of treatments of NPSB and cattle manure fertilizer on black cumin.

NPSB (kg ha ⁻¹)	CM (t ha ⁻¹)	UNAY (kg ha ⁻¹)	AY (kg ha ⁻¹)	BY (kg ha ⁻¹)	TVC (birr ha ⁻¹)	MTC (birr ha ⁻¹)	NB (birr ha ⁻¹)	MB (birr ha ⁻¹)	MRR (%)
0	0	545.11	490.6	44153.9			44153.9		
0	2.5	572.22	515.0	46349.8	550	550	45799.8	1645.9	299.25
50	0	587.70	528.9	47603.7	1050	500	46553.7	753.9	150.78
0	5	611.11	550.0	49499.9	1100	50	48399.9	1846.2	3692.40
50	2.5	644.44	580.0	52199.6	1500	400	50699.6	2299.7	574.92
0	7.5	727.78	655.0	58950.2	1650	150	57300.2	6600.6	4400.40
50	5	681.48	613.3	55199.9	2000	350	53199.9	-4100.3	--
100	0	783.33	705.0	63449.7	2050	50	61399.7	8199.8	16399.6
100	2.5	868.04	781.2	70311.2	2500	450	67811.2	6411.5	1424.78
50	7.5	736.78	663.1	59679.2	2600	100	57079.2	-10732	--
100	5	949.56	854.6	76914.4	3000	400	73914.4	16835.2	4208.80
150	0	805.56	725.00	65250.4	3050	50	62200.4	-11713	--
150	2.5	858.07	772.3	69503.7	3500	450	66003.7	3803.3	845.18
100	7.5	1113.33	1002.0	90179.7	3600	100	86579.7	20576	20576.0
150	5	916.67	825.0	74250.3	4000	400	70250.3	-16329.4	--
150	7.5	1047.89	943.1	84879.1	4600	600	80279.1	10028.8	1671.47

Where; UNAY= Unadjusted yield; AY= Adjusted yield; BY= Benefit Yield; TVC= Total variable cost; MTC= Marginal total cost; NB= Net benefit; MB= Marginal benefit; MRR= Marginal rate of return; CM= cattle manure; NPSB= Nitrogen, Phosphorus, Sulfur, Boron; t ha⁻¹= ton per hectare; Kg ha⁻¹= Kilo gram per hectare.

4. Conclusion

Black cumin seed is an expensive spice. The seeds are used as a seed spice as well as for medicinal purposes. A field study was conducted to determine the influence of NPSB and cattle manure on growth, yield and yield components of black cumin in the Toke Kutaye district West Shewa zone of Oromia. The results revealed that interaction of NPSB and CM significantly ($P < 0.01$) influenced the different growth and yield parameters except for growth parameters such; days to an emergence, days to 50% flowering, day to 90% maturity, primary and secondary branches. The highest number of capsules per plant (25.00); seeds per pod (99.40) and seed yield (1113.33 kg ha⁻¹) were obtained from the integrated application of 100 kg NPSB ha⁻¹ and 7.5t CM ha⁻¹. Similarly, the highest harvest index (47.42%) was recorded from the treatment that received 100 kg NPSB ha⁻¹ and 7.5 t CM ha⁻¹, followed by 150 kg NPSB ha⁻¹ + 7.5 t CM ha⁻¹ while the lowest harvest index (33.29%) was recorded from the control treatment.

The economic analysis revealed that the highest MRR was obtained with the interaction of 100 kg NPSB ha⁻¹ and 7.5t CM ha⁻¹ with a marginal rate of revenue (20,576%) for a net benefit of 86,579.7 birrs. In general, from the study result we can conclude that there is a tendency to increase yield and yield components; if both NPSB and cattle manure levels increased to the levels 100kg NPSB ha⁻¹ and 7.5t CM ha⁻¹. The highest and economical seed yield was obtained from integrated applications of 100kg NPSB ha⁻¹ and 7.5t CM ha⁻¹. This study was conducted at one location and for only one cropping season and it would be fallacious to provide growers with sound recommendations. However, a preliminary recommendation can be put forward by recommencing a repeated work to give conclusive recommendations.

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