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Effect of NP and Blended NPSB Mineral Fertilizer on Black Cumin Yield in Central Highlands of Ethiopia

Eticha Shiberu [1*], Nigussie Dachassa[2], Temesgen Desalegn[3] and Tesfaye Balami[4]

[1]School of Plant Sciences, Haramaya University, Ethiopia.
[2]School of Plant Sciences, Haramaya University, Ethiopia.
[3]Ethiopian Institute of Agricultural Research, Addis Ababa, Ethiopia.
[4]Ethiopian Institute of Agricultural Research, Addis Ababa, Ethiopia

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ABSTRACT

Black cumin (Nigella sativa L) is an important spice and medicinal plant cultivated in Ethiopia. However, the seed yield of the crop is low due to low soil fertility and poor soil fertility management. A field experiment was conducted to determine the effect of nitrogen and phosphorus (NP) and blended nitrogen, phosphorus, sulfur, and boron (NPSB) fertilizers on seed yield and yield components of black cumin. The experiment consists of three levels of N/P2O5 (20/15, 40/30, and 60/45 kg N/P2O5 ha–1 in the form of UREA and tri-super phosphate); and four levels of blended NPSB (0, 50, 100 and 150 kg ha–1) laid in RCBD design arranged in a factorial and replicated three time. The research was conducted during the 2017/18 primary season in the central highlands of Ethiopia. The interaction of NP and blended NPSB significantly influenced yield and yield components ($P \leq 0.01$). The application of 40/30 kg N/P2O5 and 150 kg blended NPSB ha–1 resulted in the highest seed yield (1.85 t ha–1) and the highest net benefit of (78,137 ETB ha–1). Therefore, the application of 40/30 kg N/P2O5 and 150 kg NPSB ha–1 resulted in more than double the current national average yield and benefits black cumin-producing farmers in the central highlands of Ethiopia.

Keywords: Biomass yield, Inorganic fertilizers, Growth parameters, Plant nutrients, Soil physical properties, Soil chemical properties.

INTRODUCTION

Black cumin 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). The crop belongs to the family Ranunculaceae (buttercup family) (Weiss, 2002). The crop is grown under a wide range of environments but flourishes in cooler and dry regions. A temperature range of 5 to 25^{0}C with an optimum of 12 to 14^{0}C is the most suitable for the crop (Weiss, 2002).

Ethiopia is a country with different and favorable agroecological zones for the production of various spices including black cumin (Dessie *et al*., 2019). The country grows an enormous number of spices particularly black cumin, white cumin, pepper, paprika, turmeric, fenugreek, coriander, ginger, cardamom, and basil some to mention out of many spices and herbs produced for consumption and commercial purposes (*Girma et al.*,

* Corresponding author.E-mail: eticha23@gmail.com

2015, *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, 2000, Ebrie *et al.,* 2015). The crop requires a soil pH range of 6.5 to 7.5 with optimum organic matter and phosphorus contents (Orgut, 2007, Datta *et al*., 2018).

The utilization of black cumin in medicinal and healthy caring industries has gained enormous importance in recent years due to the great increase in population that needs the substitution of the chemical therapy side-effects of drugs on human health through the use of these medicinal plants (Al-Naqeeb *et al*., 2009, Hassan *et al.,* 2013). The seed of black cumin contains active compounds including thymoquinone (TQ), thymohydroquinone, thymol, carvacrol, nigellidine, nigellicine, and α-hederin which are expected to have pharmacological effects and therapeutic benefits in human healthy (Zaoui *et al*., 2000, Kabir *et al*., 2019). In Ethiopia, the crop is also an important cash earner for smallholder farmers in the local as well as international markets. Ethiopian black cumin is often exported to Sudan, Saudi Arabia, and other Arab countries, which account for more than 98% of the nation's exports of the crop (Ermias *et al*., 2015, Teshome & Anshiso, 2019).

However, the yield of black cumin in opia is low due to different factors. The major challenging factors that limit the production and productivity of the crop in the country include the absence of improved varieties, lack of properly recommended seed rate, proper planting distance, and fertilizer types and rates are some to mention (Dessie *et al*., 2020). Low soil fertility and poor soil fertility management practices like producing the crop without organic and chemical fertilizer application are major causes of the low yield of black cumin in the country (Teshome & Anshiso, 2019; Dessie *et al.,* 2020). Therefore, proper soil fertility management through adequate use of fertilizers is a paramount aspect of exploiting the potential yield and maintaining the quality of aromatic plants (Ashraf *et al.,* 2005). Nitrogen and phosphorus nutrients are the most important limiting nutrients for crop growth and productivity. Nitrogen and phosphorus fertilizers also have positive effects on plant physiology during vegetative growth and partitioning of dry matter at a late stage of development (Oren *et al*., 2001). In addition to the macronutrients essential micronutrient deficiency become common in Ethiopia soil in recent years (ATA, 2016). The application of micronutrients like boron and zinc fertilizer helps to enhance the uptake of nitrogen and phosphorus in the soil and enables the full exploitation of the genetic potential of crops (Rietra *et al.,* 2017, Teshome & Anshiso, 2019).

Various efforts have been made in previous years to improve black cumin productivity and quality. In this regard, Ebrie *et al*. (2015) conducted research to investigate the effects of nitrogen and phosphorus fertilizers on growth, yield, and yield components of black cumin (Nigella sativa L.) at Kaffa zone, South West Ethiopia and found the highest number of pods per plant (45.9), the highest number of branches (46.1), the highest numbers of seeds per capsule (91.6) and the highest seed yields 1.34 t ha^{-1} in response to the application of 60 kg N and 40 kg P ha^{-1}. Samuel *et al*. (2022) undertook a field experiment to explore the influence of blended NPSB fertilizer rates and cattle manure on growth, yield, and yield components of black cumin (Nigella Sativum L.) in Guder, central Ethiopia, and found the highest number of capsules per plant (25.00), the highest number of seed per capsule (99.40) and the highest seed yield of (1113.33 kg ha^{-1}) in response to combined application of 100 kg NPSB ha^{-1} and 7.5 t CM ha^{-1}. Adam (2011) reported the highest black cumin seed yield of 1.87 t ha^{-1} in response to applying 60 kg ha^{-1} of UREA in north Ethiopia.

In another study, Ali *et al*. (2015) undertook a field experiment to investigate the influence of NPK fertilizer levels on the growth, yield, and yield components of black cumin (Nigella sativa L.) at Dinajpur, Bangladesh, and found the highest primary branch plant^{-1} (6.87), highest number of capsule plant^{-1} (18.28), number of seed capsule^{-1} (99.13) and seed yield (2.30 t ha^{-1}) of black in response to application of 120:40:60 N:P: K ha^{-1}. Gedik (2021) also undertook a field experiment to determine the effect of different phosphorus doses on seed yield and quality parameters of black cumin (Nigella sativa L.) in Kahramanmaras, Turkey, and found the highest number of seeds per capsule (128.23 seed capsule^{-1}) in response to the application of highest (120 kg P ha^{-1}) fertilizer. However, the author reported that the highest seed yield of black cumin (1.36 t ha^{-1}) was in response to the application of 60 kg ha^{-1} of phosphorus.

The national average yield of black cumin in Ethiopia is only about 0.89 t ha^{-1} (MoARD, 2019) which is low and below the potential productivity of the crop, for example, Earlier, Kifelew *et al.* (2017) reported that the national average productivity of black cumin varieties "Dershaye" and "Eden" produced 0.9 to 1.6 t seed yield per hectare. This means the potential seed yield of the crop is higher than the actual yield obtained by farmers in the country. Hence, there is a large yield gap between the actual and potential yield of black cumin in the country, for example, the yield produced in research fields is almost double that produced in farmers' fields. Therefore, this research hypothesized that the integrated application of NP and blended NPSB mineral fertilizers increases the seed yield and yield components of black cumin. The specific objective of this research was to evaluate the effect of NP and NPSB mineral fertilizer on yield and yield components of black cumin in the central highlands of Ethiopia.

Materials and Methods

Description of the study area

The field experiment was conducted in the Dandi and Ambo districts in the West Shewa zone of the Oromiya National Regional State, central highlands of Ethiopia. Dandi district is situated 80 km west of the capital Addis Ababa. The geographical coordinate of the study area is 09^{0}02'N latitude and 38^0 12' E longitudes and the altitude of the experimental site is 2230 m above sea level. The soil type is characterized as Pellic Vertisols with weathered basalt parent materials (Morton, 1977). The pH of the experimental site soil is 5.78, which is moderately acidic according to the rating (Murphy, 1968). Adunga *et al*. (2021) reported that the soil of the Dandi area has a medium organic carbon content of (1.9 %), low available phosphorus (4.1%), and medium total nitrogen of 0.15% according to a rating made by (Takalign *et al*., 1991)

The average long-term annual precipitation of the district is 1095 mm and the average monthly maximum and minimum temperature ranged from 8.4^{0}C to 24.6^{0}C respectively (Dandi district Agriculture and Rural Development Office report, 2014 unpublished).

Ambo district is geographically situated at a coordinate of 8^0 57' N and 38^0 07' E and the altitude of the experimental site is 2175 m above sea level (Ambo District Agriculture and Rural Development Office Report, 2014 unpublished). The soil type of the area is Pellic Vertisols with Colluvium parent materials (Morton, 1977) having medium OM and phosphorus with slightly acidic soil with pH (5.62). Samuel *et al*. 2021 characterized the soil of the Ambo area as low organic carbon (1.4 %) and medium available P (16.2 mg kg^{-1}) according to the rating of (Tekalign *et al*., 1991). The district has a uni-model rainfall pattern with an average total annual rainfall of 1020 mm. The mean minimum and maximum temperature ranges from 10 to 27^{0}C (Ambo District Agriculture and Rural Development Office Report, 2014 unpublished).

Description of experimental materials

Planting materials: Black cumin seed Variety (Dershaye) which has a growth habit of erected and condensed branched and leafy at the head with leaves 2.5 to 3.0 cm long and yielded 0.9-1.9 on research field station and flourishes well on 1850 to 2800 meter above sea level with an annual rainfall of 400–500 mm and optimum temperature of 12 to14^{0}C. This variety of black cumin was selected because it is widely produced in the country (MoARD, 2009).

Fertilizer: The fertilizers used for the experiment were tri-super phosphate (TPS) as a source of phosphorus, UREA fertilizer as a source of N fertilizer, and blended NPSB. TPS contains 46% phosphate (P_2O_5), Urea [CO $(NH_2)_2$] contains 46% nitrogen (N), and blended NPSB is blended in a proportion of (18.9 N: 37.7 P_2O_5: 6.95 Sulfur (S): 0.1 Boron (B).

Soil sampling and analysis

The soil sample was taken by auger randomly from the top 30 cm before planting. For soil physical and chemical analysis a composite of one sample was made. The sub-sample of the composite was labeled, foreign materials were removed, air dried, ground using mortar and pestle, and sieved through a 2 mm sieve and 0.2 mm sieve to determine the physicochemical and organic matter, respectively. Soil pH was determined from the filtered suspension of a 1:10 soil-to-water ratio using a glass electrode attached to a digital pH meter. Soil texture was determined by the Bouyoucos Hydrometer method. The method determines the ratio of each particle depending on the particle size (Day, 1965).

The soil organic carbon content was determined by the Walkley-Black method (Bartlett *et al.,* 1994). The percentage of organic matter (OM) was calculated by multiplying the percent of organic carbon by a factor of 1.724. Total nitrogen was determined by the Kjeldhal method (Navas *et al*., 2013). Available phosphorus was determined by the Olsen method of extraction with the help of 0.5 M NaHCO3 for 30 minutes (Olsen *et al.,* 1954). The value of exchangeable basic cations (Ca, Mg, K, and Na) was determined by saturating the soil samples with a 1M NH_4OAC (ammonium acetate) solution at pH 7.0 (Thomas, 1983). Then the amount of exchangeable Ca and Mg were determined by using atomic absorption spectrophotometry (AAS), while exchangeable K and Na were measured by a flame photometer from the same extract. Soil CEC (Cation Exchangeable Capacity) was determined by the ammonium acetate method (Hazelton & Murphy, 2016).

Treatments and experimental design

The treatments consisting of three rates of combined NP fertilizer (20/15, 40/30, and 60/45 kg N/P_2O_5 ha^{-1} in the form of urea and TSP) and four levels of blended NPSB mineral fertilizer i.e. 0, 50,100, and 150 kg ha^{-1} of NPSB. The experiment was laid out as a randomized complete block design (RCBD) in a factorial arrangement and replicated three times per treatment. The treatments were assigned to each plot randomly.

Experimental procedure and crop management

A plot size of 2.4 m x 1.2 m, area of (2.88 m2) was used for this experiment. A free spacing of 0.5 and 1.0 m was maintained between each plot and block, respectively. The plots were leveled manually before sowing the seed. After the seedbed was leveled, rows of 20 cm were manually made and the seed of the improved black cumin variety named Dershaye was drilled on the rows manually. In this experiment, the seed rate of 12 kg ha^{-1} was used. Planting was undertaken on 17 and 18 August 2017 at the Dendi site and Ambo site, respectively. During seed sowing, the whole amount of phosphorus (TSP 46% P_2O_5 and blended NPSB) and half the nitrogen (UREA 46% N) were applied in rows and the remaining UREA was top-dressed during the flower initiation stage as per the treatments. All the other agronomic (crop management) practices were followed uniformly as per the recommendation. One outermost row on both sides of a plot and 10 cm on each end of the rows were considered as the border. The produce from the net plot was harvested by observing the color of the capsule when the crop capsule color changed to pale/yellow. The total harvested crop was packed in sacks and the above biomass weight was measured; after drying in the sun for about two weeks, threshing and winnowing were done manually, and seed weight was measured by adjusting the seed moisture to 10% after measuring the moisture of the seed-by-seed moisture tester.

Data collection and measurements

Number of branches: The branch number was recorded by counting the number of branches of ten randomly selected plants from the central rows of each plot and the average value was taken as the number of branches per plant for each plot.

Plant height (cm): It was recorded by measuring the length of ten randomly selected plants from the ground level to the tip of the main stem after capsule formation when plants attain their maximum height and the average value was taken as plant height per plot

Number of capsules: It was recorded by counting the number of capsules of ten randomly selected plants from each plot and the average value was taken as the number of capsules per plant for each plot.

Number of seeds per capsule: The number of seeds per capsule was counted from ten randomly selected plants and capsules, then the average value was taken as the number of seeds per capsule for each plot.

Aboveground biomass yield: The above-ground biomass was taken from the weight of harvested produce from the net plot area during crop harvesting. The measurement was taken as soon as all above-ground biomass was harvested and packed into sacks.

Seed yield: The seed yield was taken from the yield obtained from the net plot after the crop was threshed winnowed, adjusted at 10% seed moisture content, and changed weight per ha.

Harvest index (%): The harvest index was calculated by dividing the seed yield per plot by the total above-ground biomass yield per plot and multiplying by 100.

$$\text{Harvest Index (\%)} = \frac{\text{Seed yield per plot*100}}{\text{Above-ground biomass per plot}}$$

Statistical analysis

In all cases, the variations in the two locations of the study were not significantly different and the error variances were homogeneous using the F-test as illustrated by Gomez and Gomez (1984). As the procedure illustrates (the ratio of larger MSE to smaller MSE of two locations was less than the tabulated F value at a given degree of freedom of error for both locations). Thus, combined analysis of variance (ANOVA) for the two-location data was performed using SAS 9.2 (SAS, 2004). Tukey's test at a 95% confidence level was employed to test the significant difference between means of treatment.

Partial Budget Analysis

The pooled experimental data were compared and analyzed for yield, input, and output costs. Partial budget analysis was done using the existing market prices for inputs (NP and NPSB fertilizers) at planting time and for the output (seed yield) at the time the crop was harvested. All costs and benefits were calculated on a hectare basis in Ethiopia currency (ETB ha^{-1}), where, 24.16 ETB was the average equivalent to 1US$ during the cropping season.

The components of partial budget analysis used for this research were:

i. Mean cumin seed yields (kg ha^{-1}).

ii. Adjusted yield (kgha^{-1}), in which the yield of all treatments was adjusted downward by 10% to minimize plot management effect by the research or to reflect the actual farm level performance.

iii. Gross field benefit (GFB) which is the product of field price and the adjusted seed yield for each treatment

$$GFB = Pf \times Yadj. \qquad (1),$$

where, Pf= field price and Yadj= adjusted yield.

iv. Total variable costs (TVC) (ETB ha^{-1}) are the sum cost of fertilizer purchase, fertilizer transportation and fertilizer applications.

v. Net benefits (NB) (ETB ha^{-1}) which is calculated as the difference between the GFB and TVC for each treatment:

$$NB = GFB - TVC \qquad (2)$$

vi. The dominance analysis procedure, which was used to select potentially profitable treatments, comprised a ranking of treatments in ascending order of total variable cost from the lowest to the highest cost to eliminate treatments costing more but producing a lower or equal net benefit than the next lowest costing treatment was undertaken (CIMMYT, 1988).

vii. Marginal rate of return (%): -The MRR% between any pair of undominated ranked treatments denotes the return per unit of investment in rates of NP and NPSB mineral fertilizer application expressed as a percentage (%) (CIMMYT, 1988).

$$MRR= \frac{\triangle NB}{\triangle TVC} x100 \quad (3)$$

Results and Discussion

Physical and chemical properties of the experimental soil

The soil physical and chemical property laboratory analysis was done before planting the crop from soil samples taken from the top 30 cm and the result is shown in (Table 1). The result of soil texture analysis showed that the soil texture of both experimental areas was clay. Clay soil is the most suitable soil for the successful growth and production of black cumin due to its good water-holding capacity, root penetration, moisture retention during the late growth stage, and good plant nutrient retention capacity (Orgut, 2007). According to Murphy, (1968) the soil of both experimental sites (Dandi and Ambo) was found in the range of moderately acidic pH. The optimum pH for black cumin production ranges from 6.5 to 7.5 (Orgut, 2007; Läuchli and Grattan, 2012). Kebede *et al*. (2009) reported that pH values of 10 and more, as well as 4 and less, would result in very poor yields of crop production. According to Barrow *et al.* (2020), the availability of phosphate increases when soil pH is between the range of 6.0 and 7.0. Therefore, depending on the result of the analysis there is a slight limitation on the in-soil pH of the study area to grow black cumin as a result of which some amendment may be required to increase the viability of phosphorus.

Table 1. Selected physical and chemical properties of the experimental sites at Ambo and Dendi Districts in Central Ethiopia during the main cropping season of 2017/18

	Ambo		Dendi		Reference
Property	**Value**	**Rating**	**Value**	**Rating**	
pH (1:2.5 soil-water ratio)	5.62	Moderately acidic	5.78	Moderately acidic	(Murphy, 1968)
Organic carbon (%)	1.92	Medium	1.67	Medium	(Berhanu , 1980;
Total N (%)	0.168	High	0.162	High	(Berhanu, 1980;
Available P (mg kg soil^{-1})	10.12	Medium	10.17	Medium	(Cottenie, 1980)
CEC (cmol$_{(+)}$ kg soil^{-1})	42.44	Very high	45.07	Very high	(Landon, 1991)
Na^{+1} (cmol$_{(+)}$ kg soil^{-1})	0.45	Non-saline	0.49	Non-saline	(Richards, 1954)
K^{+1} (cmol$_{(+)}$ kg soil^{-1})	0.82	High	0.84	High	(FAO, 2006)
Ca^{+2} (cmol$_{(+)}$ kg soil^{-1})	3	Low	3.3	Low	(FAO, 2006)
Mg^{+2}(cmol$_{(+)}$ kg soil^{-1})	1.4	Medium	1.5	Medium	(FAO, 2006)
Bulk density	1.42	Medium	1.46	Medium	
Particle density	2.61	Medium	2.57	Medium	
Porosity (%)	45.59	Medium	46	Medium	
Sand (%)	17.8		10		
Silt (%)	32.7		23.7		
Clay (%)	49.4		66.3		
Texture	Clay		Clay		

The cations exchange capacity (CEC) of soils of both districts was found to be in the range of very high according to the rating of Landon (1991). This shows that the soils of both sites have no limitation in terms of the exchange of cations for producing black cumin. The organic carbon content of the soil at the Dendi experimental site was found to be medium, according to the rating of (Berhanu, 1980), as cited by (Tekalign *et al.,* 1991). However, the organic carbon of the Ambo experimental site was found to be high, according to the rating of the same authors. The total nitrogen content of both experimental sites is also medium according to the rating by (Tekalign *et al.,* 1991). The site in the Ambo district has a good amount of soil organic carbon content. These results also show that the soils of both experimental sites have considerable total nitrogen content, which could release enough nitrate or ammonium for uptake by the plant during the growing season upon mineralization. However, the results showed that there are limitations in organic carbon content, especially at the site in the Dendi district. Therefore, application of organic matter is required for the successful growth of the crop. The available phosphorus content was found to be in the medium range according to the rating (Cottenie, 1980, Landon, 2014). Furthermore, there may be slight limitations in phosphorus availability due to soil acidity. Therefore, the soils of both sites would require the application of phosphorus from external sources.

The soil of both experimental sites has low contents of calcium, high contents of potassium, medium contents of magnesium, and very high cation exchange capacity according to the rating of (FAO, 2006). The result of the analysis showed that the soil has no limitation in potassium content and cation exchange capacity. However, the exchangeable calcium of the soil is low indicating the relative deficiency in exchangeable calcium and possible predisposal of the soil-to-soil acidity. There also appears to be a limitation in the availability of exchangeable magnesium in the soils of both sites which may lead to exposure of soil acidity problems.

Effect of NP and NPSB on growth parameters, yield and yield components

Number of branches per plant

The number of branches per plant of black cumin was significantly ($P \leq 0.01$) influenced by the main effects of the combined NP fertilizer and the blended NPSB mineral fertilizer. The interaction of NP and blended NPSB mineral fertilizer also significantly ($P \leq 0.05$) affected this variable (Table 2).

Table 2: Mean squares of ANOVA for yield and yield components of black cumin as affected by application of NP and NPSB fertilizer in central highlands of Ethiopia during the 2017/18 main cropping season

Source	**Mean squares**							
	DF	**NBP**	**PHt**	**NCPP**	**NSPC**	**BMY**	**SY**	**HI**
BLk	2	0.665 ns	33.185ns	5.823ns	5.478ns	0.012ns	0.003ns	0.924ns
NP	2	38.916**	308.196**	122.828**	222.529**	7.841**	0.430**	5.935**
NPSB	3	26.417**	222.010**	168.296**	333.393**	2.610**	0.515**	29.405**
NP*NPSB	6	3.905**	81.292*	14.394*	26.818*	0.242*	0.031**	3.920**
Error	22	0.951	28.817	4.825	7.162	0.076	0.003	0.456
CV%		11.684	8.954	9.690	2.812	3.734	3.411	3.341

The number of branches per plant significantly increased in response to increasing the combined application of NP mineral fertilizer across the increasing rates of the blended fertilizer. Thus, the application of 40/30 kg N/P_2O_5 and 150 kg blended NPSB ha^{-1} resulted in the highest number of branches per plant. However, the number of branches per plant decreased significantly by about 90% when the rate of the blended NPSB fertilizer was reduced to nil kg ha^{-1}. Moreover, the number of branches per plant increased significantly again with the increasing the rate of combined NP to 60/45 across 50 and 100 kg ha^{-1} NPSB fertilizer but remained in statistical parity with the number of branches produced at the aforementioned medium rates of combined NP fertilizers and highest rate of NPSB fertilizers, where the optimum number of branches per plant was already obtained. However, the smallest number of branches per plant was recorded in response to the application of minimum combined NP (20/15 kg N/P_2O_5) and 0 kg blended NPSB ha^{-1} (Table 3). Thus, the number of branches per plant produced in response to the application of 40/30 kg N/P_2O_5 and 150 kg blended NPSB ha^{-1} exceeded the number of branches per plant produced in response to applying 20/15 kg N/P_2O_5 and 0 kg blended NPSB ha^{-1} by about 100% (table 3).

Table 1. Mean branch number per plant, Plant height, capsule number per plant, seed number per capsule, above-ground biomass, seed yield, and harvest index of black as affected by interaction effect of NP and blended NPSB mineral fertilizer

N/P_2O_5 kg ha^{-1}	NPSB kg ha^{-1}	NBP	PHt (cm) (cm)	NCPP	NSPC	BMY(t)on	SY (t)	HI (%)
20/15	0	5.77^{c}	52.27^{b}	15.03^{d}	83.87^{e}	6.02^{g}	1.11^{e}	18.59^{de}
	50	6.07^{c}	53.05^{b}	16.33^{d}	88.67^{de}	6.40^{fg}	1.25^{de}	19.49^{de}
	100	6.78^{c}	54.72^{ab}	18.82^{cd}	92.60^{bcd}	6.59^{efg}	1.35^{cd}	20.57^{a-d}
	150	7.33^{bc}	60.27^{ab}	26.12^{ab}	99.17^{ab}	7.24^{cde}	1.420^{c}	19.60^{cde}
40/30	0	6.10^{c}	58.53^{ab}	16.15^{d}	89.92^{cde}	6.52^{efg}	1.17^{e}	18.02^{ef}
	50	7.65^{bc}	56.38^{ab}	23.48^{abc}	90.92^{cde}	6.92^{def}	1.49^{c}	21.64^{abc}
	100	8.43^{bc}	53.57^{b}	27.38^{a}	97.57^{abc}	7.83^{abc}	1.69^{b}	21.67^{abc}
	150	11.72^{a}	69.90^{a}	27.87^{a}	100.43^{a}	8.21^{ab}	1.85^{a}	22.49^{a}
60/45	0	6.90^{c}	53.32^{b}	20.48^{bcd}	88.05^{de}	7.59^{bcd}	1.22^{de}	16.17^{f}
	50	9.88^{ab}	67.62^{ab}	24.82^{abc}	102.03^{a}	8.30^{ab}	1.66^{b}	20.06^{b-e}
	100	11.70^{a}	69.95^{a}	27.63^{a}	103.87^{a}	8.38^{a}	1.85^{a}	22.08^{ab}
	150	11.85^{a}	69.88^{a}	27.90^{a}	104.67^{a}	8.44^{a}	1.86^{a}	22.08^{ab}
CV		11.68	8.95	9.69	2.81	3.73	3.41	3.44

Where NBP = number branch per plant; PH t= Plant height; NCPP = capsule number per plant; NSPC = number of seed per capsule; BMY= above ground biomass yield; SY = seed yield and HI = harvest index

The increased number of branches recorded in response to increasing the combined application of NP and blended fertilizers could be ascribed to the complementary effect of nitrogen and phosphorus on metabolic and physiological functions as nitrogen is a component of chlorophyll and phosphorus as a source of energy storage and transfer (ATP and ADP) that promotes plant cell division, elongation, and increased lateral growth and capsule formation (Hammo & Al-Atrakchii, 2006, Fageria, 2016).

In line with the present study result, Tuncturk *et al*. (2012) reported the highest number of branches per plant of black cumin on plots that received the highest rates of NP ha^{-1}. Rana *et al.* (2012) also reported that the highest number of branches (17.3) of black cumin in response to application of (60/120 kg NP ha^{-1}) mineral fertilizer in Mandsaur, India. In other study results, Moradzadeh *et al.* (2021) also reported that the application of biological NPK increased the efficiency of mineral urea to maximize the branch number of black cumin and the highest number of auxiliary branches of black cumin was reported in plots that received a combination of optimum biological NPK and a moderate amount of UREA.

*Significantly affected at ($P \leq 0.05$); ** highly significantly affected at ($P \leq 0.01$); DF = Degrees of freedom; NBP = number of branch per plant; PHt = Plant height; NCPP = number of capsules $plant^{-1}$; NSPC = number of seed $capsule^{-1}$; BMY = above ground biomass; SY = Seed yield; HI = harvest index

Plant height

The main effects of the combined NP fertilizer and blended NPSB mineral fertilizer significantly ($P \leq 0.01$) influenced plant height. Moreover, the interaction of NP and blended NPSB mineral fertilizer significantly ($P \leq 0.05$) affected this variable (Table 2).

Increasing application rates of combined NP fertilizer across increasing rates of blended NPSB increased plant height. The application of a minimum rate of combined nitrogen and phosphorus (20/15 kg N/P_2O_5) and the highest rate of blended NPSB fertilizer (100 kg blended NPSB ha^{-1}) resulted in the tallest black cumin plants. In this study increasing the rates of combined nitrogen and phosphorus fertilizers to the highest levels (40/30 and 60/45 kg N/P_2O_5 ha^{-1}) across the highest rate of the blended NPSB fertilizer (150 kg blended NPSB ha^{-1}) did not further significantly increase plant height. Thus, the optimum plant height of black cumin attained in response to the application of 20/15 kg N/P_2O_5 and 100 kg blended NPSB ha^{-1} exceeded the shortest black cumin plant height attained in response to the application of 20/15 kg N/P_2O_5 and nil or 0 kg blended NPSB ha^{-1} by about 5% (table 3). This could probably be due to N and P, important plant nutrients, having complementary metabolic and physiological functions, thereby affecting cell division and elongation. It may be also due to the impact of the positive interaction of nitrogen with sulfur and boron in the blended fertilizer, which is according to the finding of Fageria *et al*. (2002) who reported positive relations between N with S and B fertilizers for improving crop growth and flowering.

In line with the results of the present study, Ebrie *et al*. (2015) reported that the tallest plants of black cumin were observed in plots that received 60/40 kg of N/P ha^{-1}. Rana *et al.* (2012) also reported that the tallest plants of black cumin were observed in response to the application of 60/120 kg of NP ha^{-1}. Ozguven & Sekeroglu (2007), Yosef (2008); Tuncturk *et al*. (2012) also reported that the plant height of black cumin increased with increasing doses of NP fertilizer.

Number of capsules per plant

The result of the analysis of variance (ANOVA) showed that the main effects of the combined NP fertilizer and the blended NPSB mineral fertilizer significantly ($P \leq 0.01$) influenced the number of capsules per plant. The interaction of combined NP and blended NPSB mineral fertilizer also significantly ($P \leq 0.05$) affected the number of capsules per plant (Table 2).

The number of capsules per plant increased significantly in response to increasing rates of the combined NP mineral fertilizer across increasing rates of blended NPSB mineral fertilizer application. The application of 20/15 kg N/P_2O_5 and 150 kg ha^{-1} blended

NPSB produced the highest number of capsules per plant. However, the number of capsules produced per plant decreased significantly by about 74% when the rate of the blended NPSB fertilizer hit the nail rate. But, increasing the rates of combined NP mineral fertilizer from 20/15 to 60/45 slightly increased the number of capsules per plant but remained in statistical parity with the number of capsules per plant produced at the aforementioned minimum rates of NP fertilizers and highest rate of NPSB fertilizers. The application of 20/15 kg N/P_2O_5 along with 0, 50, and 100 kg of blended NPSB ha^{-1}, 40/30 kg N/P_2O_5 along with nil blended NPSB ha^{-1}, and 60/45 kg N/P_2O_5 along with nil blended NPSB ha^{-1} resulted in the lowest number of capsules per plant. The optimum number of capsules per plant produced in response to the application of 20/15 kg N/P_2O_5 and 150 kg blended NPSB ha^{-1} exceeded the smallest number of capsules per plant produced in response to the application of 20/15 kg N/P_2O_5 and 0 kg blended NPSB ha^{-1} by about 74% (table 3).

It was observed that minimum doses of combined NP and higher doses of blended NPSB mineral fertilizer resulted in the optimum number of capsules per plant. This implies that NPSB mineral fertilizer, especially sulfur in the blended fertilizer is the most influential mineral in the formation of capsules due to the essential role of S in the process of DNA formation and nuclear division, which led to higher capsule formation. This assumption is supported by the findings of Khurana and Chetterjee (2002) which state sulfur has an essential role in the processes of DNA formation and nuclear division as well as in the process of cellular division, which led to a high number of branches and capsule formation. The significant increase in the number of capsules per plant obtained in response to increasing the combined NP and blended fertilizers could be attributed to the roles the two nutrients (nitrogen and phosphorus) play in plant metabolism and physiological function in cytokinin synthesis, which promotes cell division, expansion, and increased capsule formation during the mid-growth stage (Rahayu *et al*., 2005).

In line with the results of the present study, Ali *et al.* (2015) reported the highest number of capsules per plant of black cumin with the application of 120–40–60 kg N–P–K mineral fertilizers. Samuel *et al.* (2021) also reported the highest (25.0) capsule number per plant in response to the application of 100 kg NPSB ha^{-1} and 7.5 ha^{-1} of cattle manure at Guder, Ethiopia. Similarly, Hammo & Al-Atrakchii (2006), Rana *et al*. (2012), Tuncturk *et al.* (2012) also reported an increased capsule number per plant of black cumin with an increased NP fertilizer level.

Number of seed per capsule

The main effects of the combined NP fertilizer and the blended NPSB mineral fertilizer significantly ($P \leq 0.01$) influenced the number of seeds per capsule. This variable was also significantly ($P \leq 0.05$) influenced by the interaction of combined NP and blended NPSB mineral fertilizer (Table 2).

The number of seeds per capsule increased significantly in response to the application of increasing rates of combined NP mineral fertilizer across the increasing levels of the blended NPSB mineral fertilizers. The highest number of seeds per capsule was produced in response to the application of minimum NP (20/15 kg N/P_2O_5 and 150 kg blended NPSB ha^{-1}). But, increasing the rates of combined NP mineral fertilizer from 20/15 to 60/45 slightly increased the number of seeds per capsule but remained in statistical parity with the number of seeds per capsule produced at the aforementioned minimum rates of combined NP fertilizers and highest rate of NPSB fertilizers. However, the number of seeds per capsule decreased significantly by about 18% when the rate of the blended NPSB fertilizer decreased to the nail rate. The lowest number of seeds per capsule produced at the application of minimum NP (20/15 kg N/P_2O_5 along with 0 kg blended NPSB ha^{-1}). Thus, the optimum number of seeds per capsule produced in response to the application of 20/15 kg N/P_2O_5 and 150 kg blended NPSB ha^{-1} exceeded the number of seed per capsule produced in response to the application of 20/15 kg N/P_2O_5 and 0 kg blended NPSB ha^{-1} by about 18% (table 3).

In the current finding, increasing application of combined NP mineral fertilizer from minimum to maximum rates of NP slightly increased number of seed per capsule but the figures remain statistically similar. The highest number of seed per capsule produced in response to minimum application rates combined NP mineral fertilizer along the highest rates of blended NPSB mineral fertilizers. This implies that blended NPSB mineral fertilizer is the most influential in the formation of seed number per capsule due to the influence of boron in flower formation and seed formation in the capsule. The increased number of seeds per capsule due to interaction of NP and blended NPSB mineral fertilizer could be probably due to important plant nutrients N and P having complementary metabolic and physiological functions, thereby affecting cell division and elongation. Nitrogen and phosphorus also have an enhancing effect on cytokinin synthesis, which promotes nuclear cell division and seed formation in pods. According to Hammo & Al-Atrakchii (2006), Fageria (2016), increased application of NP in plants improves physiological function such as nuclear cell division and elongation, resulting in an increase in seed formation.

The current study result is in line with the findings of Toncer & Kizil (2004), who reported that the number of seeds per capsule produced by black cumin plants increased as the rate of NP fertilizer increased. Ali et al. (2015) also reported that the highest number of seed per capsule of black cumin achieved by the application of 120–40–60 kg N–P–K mineral fertilizer, respectively. Ebrie et al. (2015) also reported the highest number of seed per capsule of black cumin achieved by the application of 40/60 NP mineral fertilizer. The same author states that the number of seeds per capsule is the eternal capacity of the crop yield. The author concluded the number of capsules per plant and the numbers of seeds per capsule is good indicators of seed yield which significantly influenced by NP fertilizer

Above ground biomass yield

The above ground biomass yield was significantly ($P \leq 0.01$) influenced by the main effects of the combined NP fertilizer and the blended NPSB mineral fertilizer. This parameter was also significantly ($P \leq 0.05$) affected by the interaction of NP and blended NPSB mineral fertilizer (table 2).

Increasing the rates of the combined NP mineral fertilizer along increasing the blended fertilizer increased the above ground biomass yield of the crop. Thus, the highest biomass yields were obtained in response to the application of 40/30 kg N/P_2O_5 along with100 and 150 kg blended NPSB ha^{-1}, and the application of 60/45 kg N/P_2O_5 along with 50, 100, and 150 kg blended NPSB ha^{-1}. Thus, the optimum biomass yield of the crop was obtained already in response to the application of the moderate rate of the combined NP fertilizer (40/30 kg N/P_2O_5 ha^{-1}) and the moderate rate of the blended fertilizer (100 kg NPSB ha^{-1}) (table 3). On the other hand, the lowest biomass yield of the crop was obtained in response to the application of 20/15 kg N/P_2O_5 along with 0 kg blended NPSB ha^{-1}. Thus, the biomass yield obtained in response to the application of 40/30 kg N/P_2O_5 and 100 kg blended NPSB ha^{-1} exceeded the biomass yield obtained in response to the application of 20/15 kg N/P_2O_5 and 0 kg rate of the blended NPSB ha^{-1} by about 30% (table 3).

The significantly maximized above-ground biomass yield of black cumin in response to combined application of nitrogen and phosphorus mineral fertilizer may be due to increased rates of nitrogen fertilizer and high doses of phosphorus mineral fertilizer which led to luxurious vegetative growth expressed a more leaf and higher rate of photosynthesis, which might have induced formation of many branches and capsules thereby resulting in higher above ground biomass yields (Ashraf et al., 2005).This also confirms the finding of Gonzales et al. (2001), who reported that organic fertilizers and inorganic fertilizers supplied most of the essential nutrients at a growth stage, resulting in an increase in growth parameters.

The present study result is in agreement with Ashraf *et al.* (2005); Ozguven & Sekeroglu (2007) reported the highest biomass yield of black cumin obtained from application of 40 kg N ha^{-1}. Das et al. (1992) also reported highest biomass yield of black cumin with the application of 60/120 kg N/P_2O_5 ha^{-1}. Samuel et al. (2021) also reported the highest biomass yield of black cumin in response to application of 150 kg NPSB ha^{-1} combined with 7.5 t cattle manure ha^{-1}. Tuncturk et al. (2012), Ebrie et al. (2015) also reported significant influence of nitrogen and phosphorus levels on the above ground biomass yield in black cumin.

Seed yield

The seed yield of the crop was significantly ($P \leq 0.01$) influenced by the main effects of the combined NP fertilizer and blended NPSB mineral fertilizer. The interaction of NP and blended NPSB mineral fertilizer also significantly ($P \leq 0.01$) influenced this variable (table 2).

Increasing the rates of the combined NP mineral fertilizer along increasing the blended NPBS mineral fertilizer increased the seed yield of the crop. The crop attained its highest seed yields at the application rates of 40/30 kg N/P_2O_5 and 150 kg blended NPSB ha^{-1}, and 60/45 kg N/P_2O_5 along with 150 kg NPSB ha^{-1}. Thus, the highest optimum seed yield of the crop was obtained already at the application rates of 40/30 kg N/P_2O_5 ha^{-1} and 150 kg NPSB ha^{-1}) (table 3). However, the lowest seed yield of the crop was obtained in response to the application of minimum NP (20/15 kg N/P_2O_5) along with 0 kg blended NPSB ha^{-1}. This result was statistically similar with the seed yield obtained at application of 20/15 N/P_2O_5 and 50 kg blended NPSB ha^{-1}. The result of current study also showed that increasing combined NP from 20/15 to 40/30 kg N/P_2O_5 mineral fertilizer combined with nil rates of NPSB also statistically similar results with application of 20/15 kg N/P2O5 and 0 kg NPSB mineral fertilizer.

This implies that blended NPSB mineral fertilizer is the most important in determining seed yield of black cumin. The optimum seed yield (1.85 t ha^{-1}) obtained in response to the application of 40/30 kg N/P_2O_5 and 150 kg blended NPSB ha^{-1} exceeded the minimum seed yield obtained in response to the application of 20/15 kg N/P_2O_5 and nil rate of the blended NPSB ha^{-1} by about 67% (table 3).This seed yield is also twice as much as the national average seed yield of 0.89 t ha–1 (MoARD, 2019) obtained from farmers' fields in the country.

The result revealed that, the seed yield of black cumin highly responded to the moderate rate of NP combined with highest rates of blended NPSB. The interaction of combined NP and blended NPSB mineral fertilizer significantly increased the number of seeds per capsule of black cumin. 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. The availability of boron in blended NPSB mineral fertilizer may have also promoted vegetative growth and seed formation through increased branching and flower differentiation in plants that led to higher seed yields. This hypothesis is consistent with that of Soetan et al. (2010), Brown et al, (2002), which state that boron plays an important role in the formation of cell walls, pollen germination, cell division, flowering, and flowering processes that leads to high yields of fruits and seeds of crop plants.

In line with the results of this study, Yemisrach et al. (2008) reported highest seed yield of black cumin in response to combined application of 45 kg nitrogen ha^{-1} and 30 kg P_2O_5 ha^{-1}. Ali et al. (2005) also reported a maximum seed yield (2.3 t ha^{-1}) of black cumin and higher dry matter in plots that received 120–40–60 kg ha–1 of N–P–K mineral fertilizer, respectively. Ebrie et al. (2015) reported the highest seed yields (1.34 t ha^{-1}) of black cumin under the application of 60/40 kg ha^{-1} of NP fertilizer. Yosef (2008), Tuncturk et al. (2012) and Ali et al. (2015) also reported that increasing nitrogen and phosphorus doses positively influenced seed yield in black cumin.

Harvest index

The harvest index was calculated as the ratio of seed yield to above ground biomass yield of black cumin and multiplied by 100. The result of the study revealed that harvest index was significantly ($P \leq 0.01$) influenced by the main effects of combined NP fertilizer and blended NPSB mineral fertilizer. The interaction of

NP and blended NPSB mineral fertilizer had also significantly ($P \leq 0.01$) affected harvest index (table 2).

Increasing combined NP fertilizer from 20/15 kg to 60/45 kg N/P_2O_5 ha^{-1} along with increasing blended NPSB mineral fertilizer from 0 kg to 150 kg ha^{-1} increased harvest index. The highest harvest index was obtained in response to application of 20/15 kg N/P_2O_5 and 100 kg ha^{-1} blended NPSB mineral fertilizer. This result was statistically similar with harvest index produced in response to application of 40/30 kg N/P_2O_5 along with 50, 100 and 150 kg ha^{-1} blended NPSB mineral fertilizers, and 60/45 kg N/P_2O_5 along with 100, and 150 kg ha^{-1} blended NPSB mineral fertilizer. The minimum harvest index was also recorded in response to application of 40/30 N/P_2O_5 ha^{-1} along with nil blended NPSB mineral fertilizer which is statistically parity with application of 60/45 N/P_2O_5 along with nil NPSB mineral fertilizer (table 3). This implies that application of highest rates of NP along with nil blended NPSB mineral fertilizer highly decreased the harvest index. This may be due to the influence of increased nitrogen in combined NP fertilizer that highly facilitates the vegetative growth and resulted in greater rates of biomass yield accumulation than the rate of seed yield. In line with the current study result Hepperly et al. (2009) reported that in grain crops agronomic practices that strongly encourage in favor of seed yield and can increase their harvest index and that promotes vegetative growth resulted in low harvest index. In line with the current finding Ali et al. (2015), Ebrie et al. (2015), Tuncturk et al. (2005) reported highest value of harvest index at moderate application of nitrogen fertilizer.

Partial Budget Analysis

The partial budget analysis of this study revealed that the highest net benefit (78,137ETB ha^{-1}) was obtained at the treatment that received 40/30 kg N/P_2O_5 and 150 kg ha^{-1} blended mineral fertilizer.

Table 4. Partial budget and dominance analysis of NP, and NPSB fertilizer on black cumin (two site data pooled)

N/P_2O_5kg ha^{-1}	NPSB kg ha^{-1}	Average yield ($t\ ha^{-1}$)	Y_{adj}($t\ ha^{-1}$)	TVC (ETB ha^{-1})	GFB (ETB ha^{-1})	NB (ETB ha^{-1})	B:C ratio	Dominance test
20/15	0	1.11	0.999	1296	49950	48654	37.54	UD
20/15	50	1.25	1.125	2176	56250	54074	24.85	UD
40/30	0	1.17	1.053	2473	52650	50177	20.29	D
20/15	100	1.35	1.215	3056	60750	57694	18.88	UD
40/30	50	1.49	1.341	3353	67050	63697	19.00	UD
20/15	150	1.42	1.278	3763	63900	51137	13.59	D
60/45	0	1.22	1.098	3936	54900	59964	15.23	D
40/30	100	1.69	1.521	4233	76050	71817	16.97	UD
60/45	50	1.66	1.494	4643	74700	70057	15.09	D
40/30	150	1.85	1.665	5113	83250	78137	15.28	UD
60/45	100	1.85	1.665	5523	83250	77727	14.07	D
60/45	150	1.86	1.674	6403	83700	77297	12.07	D

TVC = Total variable cost; SYadj = Adjusted seed yield; GB = Gross field benefit; NB = Net benefit; D = dominated; UD =Undominated while the lowest net benefit (48,654ETB ha^{-1}) was recorded at 20/15 kg N/P_2O_5 ha^{-1} and nil NPSB mineral fertilizer as shown in (table 5).

Table5. Marginal rate of return analysis of NP, and NPSB fertilizer application for black cumin production (two site pooled data)

N/P_2O_5kg ha^{-1}	NPSB kg ha^{-1}	SY (t ha^{-1})	SY_{adj} (t ha^{-1})	TVC (ETB ha^{-1})	GFB (ETB ha^{-1})	NB (ETB ha^{-1})	MRR (%)
20/15	0	1.11	0.999	1296	49950	48654	-
20/15	50	1.25	1.125	2176	56250	54074	615.9091
20/15	100	1.35	1.215	3056	60750	57694	411.3636
40/30	50	1.49	1.341	3353	67050	63697	2021.212
40/30	100	1.69	1.521	4233	76050	71817	922.7273
40/30	150	1.85	1.665	5113	83250	78137	718.1818

TVC= Total variable cost; SYadj = Adjusted seed yield; GB = Gross field benefit; NB = Net benefit, MRR= Marginal rate of return

This might be due to the fact that integrated application of NP and NPSB fertilizers improved yields and yield components of black cumin which improved the economic advantage of the farmers cultivating black cumin.

Marginal rate of return analyzed for treatments indicated that the highest marginal rate of return was observed at treatment application of 40/30 kg N/P_2O_5 and 50 kg NPSB ha^{-1} mineral fertilizer followed by 40/30 kg N/P_2O_5 and 100 kg ha^{-1} blended NPSB mineral with MRR of 2021% and 922%, respectively. In this study result treatment with moderate NP and NPSB more profitable than other treatments and NP alone was not earned better profit. The current result an application of minimum NP and nil NPSB mineral fertilizer, and application of maximum NP and NPSB fertilizer may result lower marginal rate of return.

In this comparison by MRR of return all the undominated treatments are economically feasible for farmers producing black cumin (CIMMYT, 1988). The treatment with 40/30 kg N/P_2O_5 and 150 kg NPSB ha^{-1} mineral fertilizer had the highest net benefit (78,137 ETB ha^{-1}). Therefore, treatment with 40/30 kg N/P_2O_5 and 150 kg ha^{-1} blended NPSB mineral fertilizer can be taken as the best combination for optimum black cumin yield offering package and higher marginal rate of return above the proposed minimum acceptable rate of return of 100% and highest net benefit from black cumin production (CIMMYT, 1988).

Conclusion

The results of this study have demonstrated that an optimum black cumin seed yield of 1.85 t ha^{-1} was obtained in response to the interaction effect of applying 40/30 N/P_2O_5 ha^{-1} and 150 kg blended NPSB fertilizer ha^{-1}. This yield exceeded the national average yield of the country by about 108% (more than two fold). However, the amounts of black cumin seed yield and the net benefit obtained in this study have not varied significantly from the amounts obtained in the earlier experiment at the rates of 69 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1}. Thus, farmers in the study are can use 40/30 N/P_2O_5 ha^{-1} and 150 kg blended NPSB fertilizer ha^{-1}as an alternative depending on accessibility and economics. Although chemical fertilizers are important inputs for increasing crop productivity, over-reliance on chemical fertilizers alone, combined with a decline in some soil chemical properties due to prolonged use of chemical fertilizer may inhibit the intensive exploiting the yield potential of black cumin. Therefore, further research needs to be done in the future to investigate the effect of mineral NP and/or blended NPSB as well as organic fertilizers to realize any remaining yield potential of the crop in response to integrated application of more nutrients and soil organic carbon.

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تأثير السماد المعدني (NP) وخليط النيتروجين والفسفور والكبريت والبورون (NPSP)على انتاجية الكمون الاسود في المرتفعات الوسطى في اثيوبيا

Eticha Shiberu , Nigussie Dachassa , Temesgen Desalegn and Tesfaye Balami

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ملخص

الكمون الأسود (حبة البركة L) هو نبات من التوابل والطبية الهامة المزروعة في إثيوبيا. ومع ذلك، فإن إنتاجية بذور المحصول منخفضة بسبب انخفاض خصوبة التربة وسوء إدارة خصوبة التربة. أجريت تجربة حقلية لتحديد تأثير سماد النتروجين والفوسفور (NP) والمخلوط من النيتروجين والفوسفور والكبريت والبورون (NPSB) على إنتاجية البذور ومكونات إنتاجية الكمون الأسود. تتكون التجربة من ثلاثة مستويات من N/P2O5 (15/20، 30/40، 45/60 كجم N/P2O5 هكتار-1 على شكل يوريا وثلاثي سوبر فوسفات)؛ وأربعة مستويات من NPSB الممزوج (0 و 50 و 100 و 150 كجم هكتار -1) موضوعة في تصميم RCBD مرتبة في مضروب ومتكرر ثلاث مرات. تم إجراء البحث خلال الموسم الرئيسي 18/2017 في المرتفعات الوسطى في إثيوبيا. أثر تفاعل NP و NPSB المخلوط بشكل ملحوظ (P ≥0.01) على مكونات المحصول. أدى تطبيق 30/40 كجم N/P2O5 و150 كجم ممزوج NPSB هكتار-1 إلى أعلى إنتاجية للبذور (1.85 طن هكتار-1) وأعلى فائدة صافية قدرها (ETB 78,137 هكتار-1). ولذلك، فإن تطبيق 30/40 كجم N/P 2O5 و150 كجم NPSB ha-1 ادى الى اكثر من ضعف متوسط الإنتاج الوطني الحالي ويفيد المزارعين المنتجين للكمون الأسود في المرتفعات الوسطى في إثيوبيا.

الكلمات الدالة: إنتاج الكتلة الحيوية، الأسمدة غير العضوية، معاملات النمو، المغذيات النباتية، الخواص الفيزيائية للتربة، الخواص الكيميائية للتربة

* الباحث المعتمد للمراسلة: eticha23@gmail.com