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Effect of Nitrogen and Phosphorus Fertilizers on Growth, Yield and Yield Components of Black Cumin (*Nigella sativa* L.) at Konta District, South West Ethiopia

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ABSTRACT

Field experiment was conducted at Duka, Konta district to determine the effect of Nitrogen (N) and Phosphorous (P) fertilizers on growth, yield and yield components of black cumin. Five levels of N (0, 15, 30, 45 and 60 kg ha^{-1} in the form of urea) and three levels of P (0, 20, 40 kg ha^{-1} in the form of TSP), arranged in RCB design with three replications. Results indicated that interaction of N and P highly significantly (p<0.01) influenced the different growth and yield parameters except for 1000 seed weight. The highest seed yield (1336.7 kg ha^{-1} was obtained from 60/40 kg N P ha^{-1}. Highest number of pods per plant (45.9) was obtained from 60 kg N ha^{-1} and 40 kg P ha^{-1} interactions. The tallest plants (72.5 cm) were measured o plots fertilized at the rate of 60/40 kg N P ha^{-1}. The highest number of branches (46.1) was obtained from the interaction effect of 60/40 kg N P ha^{-1}. The highest numbers of seeds per pod (91.6) was achieved at treatment combination of 60/40 kg N P ha^{-1} followed by 88.4 seeds by the treatment combination of 60/20 kg N P ha^{-1}. The highest harvest index (20.8%) was obtained from the treatment that received 60/40 kg NP followed by 20.5%, which received 45/20 kg, N P ha^{-1} interactions and the lowest harvest index (15.1%) was recorded from the treatment that received 15 and 0 kg NP interaction. The longest days to 50% flowering (86.7 days) were observed for the treatment that received 60/40 kg N P ha^{-1}. However, the shortest flowering days (75.5) days were for the control treatment. Partial budget analysis has shown that two treatment combinations of (NP ha^{-1}) were found to be economically viable with marginal rate of revenue beyond the minimum acceptable level (150%). The highest MRR (%) was obtained with the interaction effect of 45/40 kg NP ha^{-1} with marginal rate of revenue (1272.2%) for net benefit 15254.1 birr, followed by the interaction effect of 15/20 kg NP ha^{-1} with marginal rate of revenue (485%) for net benefit 10325 birr over the control with a net benefit 8595.0 birr. Since the experiment was conducted at one place and only for one cropping season, it will not be appropriate to arrive at a strong recommendation. However, as a recommendation, growers can be advised to use a combination of 45/40 kg NP ha^{-1} followed by 15/20 Kg N P_2O_5 ha^{-1} for black cumin production in the area.

Key words: Black cumin, nitrogen, phosphorus, soil fertility

INTRODUCTION

Black cumin (*Nigella sativa* L.) belongs to the family Ranunculaceae. The crop is native to the Mediterranean region and it has been used for thousands of years by various cultures and civilizations. Naturally, it grows in Mediterranean region of Turkey and Cyprus (Davis, 1965). It is one of the most important medicinal plants, because it has multipurpose uses

(Leung and Foster, 1996; Badary, 1999). Black cumin is used as a whole or in crushed form for various pursues. Essential oils and oleoresins prepared by appropriate techniques to obtain value added products (Bruk and Berga, 1995).

Black cumin seed has been widely used in folk medicine for the treatment of a number of diseases, including diarrhea, jaundice, amenorrhea, helminthiasis, ophthalmic, paralysis and asthma. One of the most important plants containing volatile and fixed oil is black cumin family Ranunculaceae is an herbaceous indigenous plant in the Mediterranean region (Badary, 1999).

The World Health Organization (WHO) is providing emphasis on the exploration of medicinal plant species for the benefit of human care and systems. Emphasis have been given mainly on scientific information, on the safety, efficacy, quality control/quality assurance, dosage, toxicity description of the plant species, therapeutic uses, clinical trials, drug interactions amongst others. Effective utilization of *N. sativa* for therapeutic purposes as well as for trade will greatly depend upon yield (raw plant product-seeds; bioactive compounds- essential oil) and its quality.

More recently, great deal of attention has given to the seed and oils yields of black cumin. Due to this, their consumption has thus increased (Takrun and Dameh, 1998). In Ethiopia black cumin is the second cash crop exported next to ginger. Surprisingly, Ethiopia exported at a value of 1.18 USD kg^{-1} but imported 5.80 USD kg^{-1}. This shows that there is a wide room for black cumin production. This indicates that Ethiopia has about 12% share in the world market. However, 99% of the produce consumed locally.

Despite the country's favourable environmental condition for its production, black cumin cropping system, as a sole crop has not been practiced in the study area. In addition, recommended varieties were not identified and introduced to the farmers.

According to Konta agricultural office report, formerly black cumin production was not significant. However, owing to the introduction of settlements from other zones of the region (Hadeya and Wolayta), not only those farmers but also native farmers have adopted production of black cumin. Now black cumin is widely produced around the study area and the farmers are benefitting a lot from local market by selling seed yield (Melkie *et al*., 2008). However, the crop is produced on fragmented land and soils having long cereal cropping history where crop residues are removed for various purposes without any chemical fertilizer application. Additionally, information regarding its response to fertilizer is insufficient in the country. Even though, the production and land coverage of black cumin has been increasing, the productivity is still less than 300 kg ha^{-1}. Several problems including lack of improved seed, recommended fertilizer rate, lack of knowhow on postharvest handling; improved agriculture practices and extension system, marketing system, etc. are accountable for the continued low productivity and production of black cumin (Yosef, 2008).

Due to the increased demand of black cumin seed for local consumption and other importances, such as oil and oil rosin for medicinal purposes, its export market, its potentiality in crop diversification, income generation and its importance to reduce the risk of crop failure and others made black cumin as a best alternative crop under Ethiopian smaller land holdings. Despite its importance, little attention has been given to improve its production and productivity and hence, it remained an underutilized crop.

Moreover, today there is little available information pertaining to agronomic practices including optimum dose of nitrogen and phosphorous fertilizers. Therefore, this calls for initiative study to determine the optimum rate of N and P fertilizers to improve the existing problem of yield and quality of black cumin (*Nigella sativa* L.) under the agro-climatic conditions of Duka, Konta district, Southwest Ethiopia. In view of this fact, the present study was initiated with the following objective:

- To evaluate the effects of nitrogen and phosphorus fertilizers on growth, yield and yield components of black cumin along with its least cost fertilizer rate to obtain maximum possible benefit at Konta district, Southwest Ethiopia

MATERIALS AND METHODS

Description of the study site: The experimental site (Duka primary school) is geographically located 456 km from Addis Abeba and 110 km from Jimma at an altitude of 1960 m.a.s.l. The mean maximum and minimum temperatures are 26.8 and 11.4°C, respectively. The mean maximum and minimum relative humidity is 91.4 and 39.92%, respectively. The mean annual rainfall of the area is 1800 mm.

The experiment was conducted under field condition at Konta special woreda Duka primary school farmland in the year 20013/2014 under residual soil moisture from the main rain season (Meher) and some additional irrigation. Soil samples were collected from each plot at 0-20 cm soil depth and one composite sample was made for analysis. Soil characteristics of the experimental fields was silt loam; high in silt (53.8%), low in sand (22.92%) and a pH of (6-7), organic matter (6.97%) and total nitrogen (1.13%). Available phosphorus content of the soil was 2.92 ppm and while that of potassium was 2.54 ppm.

Experimental materials: Seeds of Black Cumin (variety Dershaye) were obtained from Kulumsa agricultural research center. This variety of black cumin was selected as it was widely produced in the country (MoARD., 2009).

Treatment and experimental design: The experiment consisted of three levels of Phosphorus (20 kg ha^{-1}, 40 kg ha^{-1} and control) and five levels of nitrogen (15, 30, 45 and 60 kg ha^{-1} and control). These fertilizer rates were chosen based on fertilizer recommendation given for teff; since most of the time farmers produce black cumin by intercropping with teff.

Triple Super Phosphate (TSP) fertilizer was used as phosphorus source, which was drilled in the row at the time of sowing, while Urea was used as source of nitrogen, which was applied in two splits, one half at first seedling stage and the rest as top dressing at flowering. Treatments were laid out in Randomized Complete Block Design (RCBD) with three replications.

Prior to sowing, the selected experimental land was brought to fine tilth by one deep plowing using oxen plowing. Seedbed harrowed and leveled three times by using different hand tools. Then the experimental site was partitioned into plots. The net size each plot was 9 m^2 squares (3×3 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 MoARD (2009), unpublished) and Ahmad *et al.* (2004). Accordingly, seven hundred and twenty plants were required, which is equivalent to 12 plants per row and 60 per each plot, respectively.

Seeds were socked for one overnight with cold water before sowing to enhance seed germination. Seeds were drilled in rows at 25 cm distance between rows and 10 cm between plants at depth of 3 cm. When seedlings reached 3-4 leaf stage, plants were thinned off to obtain the required densities.

All other cultural practices like, land preparation, additional irrigation (tap water), weeding, pest control measures, pre and post harvest handling etc. was kept uniform and normal for all the treatments as recommended for this crop. Weeds were controlled by hand weeding and application of 2-4-D before seed germination. No economically important pests and diseases were observed throughout the cropping period.

Harvesting was carried out by hand following at full 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 ten randomly selected and tagged plants for recording various observations on yield components of parameters. The harvested plants were dried in the open air for five days and weighted as biological yield data (Table 1). Threshing was done manually by beating the pods with wooden stick on a clean and dried floor. Then seeds were cleaned and further dried in well-ventilated shady room for three days. The mean weight of seeds from each treatment was recorded in kilograms for computation of yield data.

Data collected: Ten healthy plants were randomly selected in each plot as per treatment. Plastic coated labels were tagged for identification and recording of various observations. Data were recorded on some growth, yield and yield component parameters including plant height (cm), number of branches (branches/plant), number of pods (pods/plant), number of seeds in the pods (seed/pods), thousand-seed weight (g), seed yield (kg ha^{-1}), root length (cm) and flowering date were recorded on randomly selected ten plants and plot basis depending on the traits to be measured.

Table 1: Selected physical and chemical properties of the experimental soil

Parameter	Value	Methods
Particle size distribution (%)		Pipette method
Sand	22.92	
Silt	53.64	
Clay	23.44	
Textural class	Silt loam	
pH (H_2O)	6.1	Glass electrode pH meter
Organic carbon (%)	2.4	Walkley and Black method
Available phosphorus (ppm)	10.12	Bray method
Cation exchange capacity (mq/100 g)	32.44	Ammonium acetate method
Ca (cmolc kg^{-1})	6.21	”
Mg (cmolc kg^{-1})	3.62	”
K (cmolc kg^{-1})	2.54	”
Na (cmolc kg^{-1})	0.85	”

OM: Organic matter, TN: Total nitrogen, AP: Available phosphorus, CEC: Cation exchange capacity

Growth parameters

Days to 50% flowering: The number of days elapsed between date of sowing and date of 50% flowering was computed and expressed as average number of days to flowering.

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

Plant height (cm): Plant height was measured in centimeters at physiological maturity from the ground level to the tip of plant from ten randomly selected plants in each plot. The values are expressed as mean values.

Number of branches per plant: Number of primary and secondary branches per stem was randomly counted from selected ten middle row plants at final harvest.

Seed yield parameters

Number of pods per plant: On individual plant basis, number of pods in the tagged plants counted manually. The mean pods per plant taken for each treatment.

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

1000 seed weight (g): The seeds obtained from each of the ten-tagged plants were dried in the sun to around 8.0% moisture content, weighed and counted with a seed counter.

Their weight measured by an Analytical balance and the average weight was expressed in grams.

Seed yield per hectare (kg): Grain yield was determined by harvesting plants from the net middle plot area of 2.5×2.5 m^2 to avoid border effects. Seeds, which were obtained from the corresponding net plot were cleaned manually. After drying to around 8.0% moisture, weighed using sensitive balance and recorded as mean values of seed yield per hectare in kilograms.

Biological yield (kg): At maturity, the whole plant parts, including leaves, stems and seeds from the net plot area were harvested and dried for three days. Finally, weight of dried plants was recorded.

Harvest index (%): Harvest index was calculated by dividing seed yield by the total biological yield. Means expressed in percentage.

Data analysis: All the data were checked for normality and subjected to analysis of variance using statistical software package (SAS 9.1.3). The differences between treatment means were compared using Least Significance Difference (LSD) test at 5% level of significance. Simple Pearson's correlation was done to determine the relationship among response variables.

Profitability analysis: To determine the least cost and profitable treatments the partial budget technique was applied on the yield results. Economic analysis was done using the current market prices for inputs at planting and for outputs at the time the crop was harvested. All costs and benefits were calculated on hectare basis in Ethiopian Birr (ETB ha^{-1}). Potentially profitable treatments were selected from the range that was tested using dominance analysis procedure as described by CIMMYT (1988). Non-dominated treatments were ranked from the lowest (farmers' practice) to the highest cost treatment. For each pair of ranked treatments, 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.

RESULTS AND DISCUSSION

Growth, yield and yield components recorded during the study and the results discussed as follows. Overall statistical analyses showed that there were significant ($p<0.01$) interaction effects of nitrogen and phosphorous fertilizers. All the traits investigated in this study for; root length flowering date, plant height, the number of branch, the number of pods per plant, seed yield, biological yield and harvest index were positively affected by varying doses of NP interactions. However, 1000 seeds weight did not show significant differences ($p>0.05$) either the interaction or main effects of nitrogen and phosphorus fertilizers.

Root length: The interaction effects of nitrogen and phosphorus on root length were highly significant ($p<0.01$), (Table 2). Increased interaction of NP from zero to 60/40 kg ha^{-1} increased root length from 9.53-20.76 cm, respectively. This could be the positive effects of nitrogen and phosphorus interaction combined with physical and chemical properties of the soil condition enabling plants form deep tap root system. This result was closed with, the finding of Ozguven and Sekeroglu (2007). Root length had also demonstrated a positive and highly significantly correlation with most of growth and yield parameters.

Days to 50% flowering: The interaction effect of Nitrogen and Phosphorus on days to 50% flowering was highly significant ($p<0.01$) (Table 3). Increased interaction of NP from zero to 60/40 kg ha^{-1} prolonged the time required to attain 50% flowering from approximately 75.5-86.7 days. The minimum number of days to reach 50% flowering date observed from control of nitrogen and phosphorous (Table 3). This could be because of excessive nitrogen and phosphorous resulting in prolonged vegetative growth of the plant. This result is in close conformity Ozguven and Sekeroglu (2007). Moreover, there was highly significant and positive correlation with root length (0.99***), plant height (r = 0.89***), number

Table 2: Root length (cm) of *Nigella sativa* as affected by nitrogen and phosphorous application

	Phosphorus levels (kg ha^{-1})		
Nitrogen levels (kg ha^{-1})	0	20	40
0	9.53^{j}	10.23^{ij}	11.30^{h}
15	10.61^{ih}	12.83^{g}	13.96^{f}
30	14.34^{f}	14.73^{f}	15.84^{e}
45	16.83^{d}	17.56^{cd}	18.26^{cb}
60	18.88^{b}	19.87^{a}	20.76^{a}
$LSD_{(0.05)}$	0.99		
CV (%)	3.97		

Means followed by same letter(s) are not significantly different from each other at $p\leq 0.05$

Table 3: Days to 50% of flowering of *Nigella sativa* as affected by nitrogen and phosphorous application

	Phosphorus levels (kg ha^{-1})		
Nitrogen levels (kg ha^{-1})	0	20	40
0	75.50^{j}	76.20^{ij}	77.30^{h}
15	76.60^{ih}	78.80^{g}	79.90^{f}
30	80.30^{f}	80.70^{f}	81.80^{e}
45	82.80^{d}	83.50^{cd}	84.20^{cb}
60	84.80^{b}	85.80^{a}	86.70^{a}
$LSD_{(0.05)}$	1.00		
CV (%)	0.74		

Means followed by same letter(s) are not significantly different from each other at $p\leq 0.05$

of branches per plant (r = 0.91***), number of pods per plant (0.93***), number of seeds per pod (r = 0.95***), yield (r = 0.95***), biological yield (r = 0.95***) and harvest index (r = 0.86***).

Plant height: Plant height was significantly (p<0.01) affected by the interaction effect of nitrogen and phosphorus (Table 4). The tallest plant (72.533 cm) recorded at the interaction rate of 60/40 kg NP ha^{-1} while, the shortest plant height (45.567 cm) recorded from treatment that received no nitrogen and phosphorus (Table 4). This could be probably the two important plant nutrients had complementary metabolic and physiological functions, thereby, affecting the plant height. The increase in plant height could mainly be due to better availability of soil nutrients in the growing areas.

Nitrogen and Phosphorus, which 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 (Takrun and Dameh, 1998). This also confirms the finding of Gonzalez *et al.* (2001), 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. Plant height of black cumin in different studies varied in a wide range from 27.9-95.1 cm (Ceylan, 1995; Das *et al*., 1992; Geren *et al*., 1997; Ozguven and Sekeroglu, 2007). This is further strengthened by highly significant and positive correlation with days to 50% flowering (0.89***), number of branches per plant (r = 0.97***), number of pods per plant (0.94***), number of seeds per pod (r = 0.98***), seed yield (r = 0.94***), biological yield (r = 0.98***) and harvest index (r=0.76***).

Number of branches per plant: Number of branches per plant was highly significantly (p<0.01) affected by interaction effect of nitrogen and phosphorus (Table 5). During the study, the highest Number of branches per plant (46.1 cm) was recorded for the interaction effect of 60/40 kg NP ha^{-1} (Table 5). However, the minimum number of branches (20.5) obtained from control treatment.

Yield components: Mean number of pods per plant, number of seeds per pods, total biological yield, seed yield and harvest index were significantly (p<0.01) affected by NP interaction (Appendix Table 4). Their mean values showed an increasing trend with increased rate of applied NP interaction, whereas 1000 seed weight, was not statically significant (p>0.05) by main effects as well as their interaction.

Number of pods per plant: The interaction effect of nitrogen and phosphorus highly significantly (p<0.01) influenced pods/plant (Table 6). The highest number of pods per plant (45.9) was obtained from the combination of nitrogen 60/40 kg NP ha^{-1}) while the minimum numbers of pods/plant

Table 4: Mean separation of Plant height (cm) of *Nigella sativa* as affected by nitrogen and phosphorous application

	Phosphorus levels (kg ha^{-1})		
Nitrogen levels (kg ha^{-1})	0	20	40
0	45.5^{i}	48.7^{h}	51.9^{g}
15	53.5^{gf}	55.8^{def}	56.0^{edf}
30	54.1^{efg}	57.3^{d}	58.2^{d}
45	56.9^{de}	63.1^{c}	67.2^{b}
60	57.3^{d}	68.9^{b}	72.5^{a}
$LSD_{(0.05)}$	2.9		
CV (%)	3.03		

Means followed by same letter(s) are not significantly different from each other at $p \leq 0.05$

Table 5: Mean separation of root length (cm) *Nigella sativa* as affected by nitrogen and phosphorous application

	Phosphorus levels (kg ha^{-1})		
Nitrogen levels (kg ha^{-1})	0	20	40
0	9.53^{j}	10.23^{ij}	11.30^{h}
15	10.61^{ih}	12.83^{g}	13.96^{f}
30	14.34^{f}	14.73^{f}	15.84^{e}
45	16.83^{d}	17.56^{cd}	18.26^{cb}
60	18.88^{b}	19.87^{a}	20.76^{a}
$LSD_{(0.05)}$	0.99		
CV (%)	3.97		

Means followed by same letter(s) are not significantly different from each other at $p \leq 0.05$

(21.5) obtained from unfertilized treatment. This value is statistically similar with interaction of 60/20 kg NP ha^{-1}. On the other hand, interaction of 45/20 kg NP ha^{-1} statistically similar with interaction of 45/40 kg NP ha^{-1}.

In different studies, researchers found that the number of pods for black cumin were in the ranges of 5.7-6.0 (Ceylan, 1995; Geren *et al*., 1997). In addition, Datta (2004) 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 main factor for better plant height, for 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 pods formation. This assumption also agreed with Troug (1973). An adequate supply of nitrogen is associated with vigorous vegetative growth and more efficient use of other nutrients. Finally lead to higher productivity. This result also strength by positive and highly significant correlation on growth and yield parameters.

Thousand seeds weight: Main effects or interaction effects of N and P did not show statistically significant difference (p>0.05) (Table 7) on 1000 seed weight of black cumin, but numerically their mean differences range from 2.1-2.3 g for 0/0 N P kg ha^{-1} and 45/40 kg ha^{-1}, respectively (Table 7).

Table 6: Mean separation of number of pods per plant of *Nigella sativa* as affected by nitrogen and phosphorous application

	Phosphorus levels (kg ha^{-1})		
Nitrogen levels (kg ha^{-1})	0	20	40
0	21.5^{g}	23.4^{gf}	26.0^{ef}
15	25.2^{ef}	27.5^{ed}	29.6^{d}
30	26.3^{ef}	33.7^{c}	34.8^{c}
45	30.1^{d}	39.2^{b}	39.0^{b}
60	36.4^{cb}	43.2^{a}	45.9^{a}
$LSD_{(0.05)}$	3.2		
CV (%)	5.97		

Means followed by same letter(s) are not significantly different from each other at $p \leq 0.05$

Table 7: Mean separation of 1000 seed weight (g) of *Nigella sativa* as affected by nitrogen and phosphorous application

	Phosphorus levels (kg ha^{-1})		
Nitrogen levels (kg ha^{-1})	0	20	40
0	2.1^{ba}	2.2^{ba}	2.2^{ba}
15	2.2^{ba}	2.2^{ba}	2.3^{ba}
30	2.1^{ba}	2.3^{ba}	2.2^{ba}
45	2.3^{ba}	2.3^{ba}	2.3^{ba}
60	2.1^{ba}	2.2^{ba}	2.2^{ba}
$LSD_{(0.05)}$	2.9		
CV (%)	3.03		

Means followed by same letter(s) are not significantly different from each other at $p \leq 0.05$

Table 8: Mean separation of number of seeds per pods *of Nigella sativa* as affected by nitrogen and phosphorous application

	Phosphorus levels (kg ha^{-1})		
Nitrogen levels (kg ha^{-1})	0	20	40
0	55.1^{j}	59.0^{i}	63.3^{h}
15	64.1^{h}	68.7^{gf}	69.9^{gf}
30	68.4^{g}	72.1^{ef}	74.0^{ed}
45	73.8^{ed}	80.7^{c}	85.5^{b}
60	76.4^{d}	88.4^{ba}	91.6^{a}
$LSD_{(0.05)}$	3.5		
CV (%)	2.94		

Means followed by same letter(s) are not significantly different from each other at $p \leq 0.05$

Table 9: Mean separation of Biological yield (kg) of *Nigella sativa* L. as affected by nitrogen and phosphorous application

	Phosphorus levels (kg ha^{-1})		
Nitrogen levels (kg ha^{-1})	0	20	40
0	3854.7^{j}	4130.0^{i}	4428.7^{h}
15	4489.3^{h}	4809.0^{gf}	4897.7^{gf}
30	4790.3^{g}	5042.3^{ef}	5166.0^{ed}
45	5180.0^{ed}	5348.0^{d}	5651.3^{c}
60	5987.3^{b}	6192.7^{ba}	6416.7^{a}
$LSD_{(0.05)}$	250.0		
CV (%)	2.93		

Means followed by same letter(s) are not significantly different from each other at $p \leq 0.05$

Ozguven and Sekeroglu (2007) stated that there were no statistical differences among the different nitrogen doses in black cumin. In different studies, thousand seed weight of black cumin was reported as 3.50 g (Das *et al*., 1992), 2.15 g (Ceylan, 1995) and 2.15 g (Ozguven and Sekeroglu, 2007).

A wide range of factors, such as variety, growing conditions, climatic factors and soil properties affect thousand seed weight. This might be due to the over bearing of seeds in pods makes shrink seeds. The effect of NP interaction on 1000 seed weight also showed positive but non-significant correlation all growth and yield parameters.

Number of seeds per pods: The interaction effect of nitrogen and phosphorous fertilizer was highly significant on the number of seed per pods ($p<0.01$) (Table 8). The LSD test shows that the greatest number of seeds per pods (91.6) achieved by the treatment of 60/40 kg NP interaction followed by 88.4 seeds/pods from the treatment 60/20 kg NP interaction (Table 8). In fact, the number of seeds per pods is the reservoir capacity of the plant. Plants keep photosynthetic material and ultimately lead to increase in biomass. Plant height, Number of pods per plant and number of seeds per pods are good indicators of seed yield. The result is in line with Das *et al.* (1992). Number of seeds per capsules (65) found from 60/120 kg NP ha^{-1}. There was a positive correlation with root length (r = 0.95***), flowering date (r = 0.95***) Plant height (r = 0.95***), number of branches per plant (r = 0.98***), number of pods per plant (r = 0.97***), number of seeds per pod (r = 0.96***), yield (r = 0.96***), biological yield (r = 1.00***) and harvest index (r = 0.81***).

Total yield: The interaction effect of NP was highly significantly ($p<0.01$) influenced biological yield (Table 9). The maximum total yield 6416.7 kg ha^{-1}, obtained from the interaction effect of 60/40 kg NP ha^{-1}. Whereas the minimum value (3854.7 kg ha^{-1}) obtained from treatment that received zero NP (Table 9). Although the interaction effect of 30/40 kg NP and 45/0 kg NP ha^{-1} was statistically the same, numerically they are different. Total yield indicated an increasing tendency in response to all higher interaction effects. The increase in Biological yield of black cumin in response to the increased supply of combined NP could be due to more luxurious plant growth expressed a more leaf and higher rate of photosynthesis, which might have induced formation of many pods thereby resulting in higher yields. This result is agreement with Ozguven and Sekeroglu (1997) and Ashraf *et al.* (2005). Ozguven and Sekeroglu (1997) reported the highest biological yield (5758 kg ha^{-1}) obtained from application of 40 kg N ha^{-1}. Das *et al.* (1992) also found biological yield of 1967 kg ha^{-1} with the application of 60/120 kg NP ha^{-1}.

Average total yield was significantly and positively correlated with plant height (r = 0.98***), root length (r = 0.95***), flowering date (r = 0.95***), number of branches per plant (r = 0.97***), number of pods per plant (r = 0.96***), number of seeds per pod (r = 0.97***), Seed yield (r = 0.96***) and harvest index (r = 0.81***).

Seed yield: Interaction effect of nitrogen and phosphorus significantly ($p<0.01$) improved seed yields of black cumin (Table 10). Maximum seed yield (1336.7 kg ha^{-1}) recorded

Table 10: Mean separation of Seed yield (kg) of *Nigella sativa* as affected by nitrogen and phosphorous application

	Phosphorus levels (kg ha^{-1})		
Nitrogen levels (kg ha^{-1})	0	20	40
0	636.67^{i}	716.6^{hg}	756.6^{fg}
15	680.0^{hi}	810.0^{fe}	836.6^{e}
30	800.0^{fe}	920.00^{d}	1036.6^{c}
45	993.3^{c}	1013.3^{c}	1216.6^{b}
60	1060.0^{c}	1273.3^{ba}	1336.67^{a}
$LSD_{(0.05)}$	67.8		
CV (%)	4.3		

Means followed by same letter (s) are not significantly different from each other at $p \leq 0.05$

Table 11: Simple correlation (r) among growth, yield and yield components of *Nigella sativa* L. under N and P application

Variables	Flow	Root	PH	NoB	NoP	NoS	SeedW	TotalY	BioY	HarI
Flow	1.00									
Root	0.99***									
PH	0.89**	0.89**								
NoB	0.91***	0.90***	0.97***							
NoP	0.93***	0.93***	0.94***	0.93***						
NoS	0.95***	0.95***	0.98***	0.97***	0.96***					
SeedW	0.78**	0.57^{ns}	0.74**	0.74**	0.76**	0.75**				
Totally	0.95***	0.95***	0.93***	0.92***	0.95***	0.96***	0.75**			
BioY	0.95***	0.95***	0.98***	0.97***	0.96***	0.97***	0.78**	0.96***		
HarI	0.86***	0.78**	0.76**	0.77**	0.83**	0.81**	0.65**	0.92***	0.81 **	

p<0.05 0.632 p<0.01 0.765 at DF (n-2) from tabulated t- value, Where n = No of parameters to be measured, Flow: Days to 50% flowering = root length PH: Plant height, No B: No. of branches, No P: No. of pods, NoS: No. of seeds per pods, Seed W: 1000 seed weight, Total y: Seed yield per hectare, BioY: Biological yield, HarI: Harvest index *,** and *** significant difference at probability level of 5%, 1% respectively

Table 12: Interaction effect of harvest index (%) of *Nigella sativa* as affected by nitrogen and phosphorous

	Phosphorus levels (kg ha^{-1})		
Nitrogen levels (kg ha^{-1})	0	20	40
0	15.9^{g}	17.3^{ef}	17.0^{f}
15	15.1^{h}	16.8^{f}	17.0^{f}
30	16.6^{f}	18.2^{d}	20.0^{b}
45	19.2^{c}	17.9^{ed}	20.3^{ba}
60	19.8^{bc}	20.5^{ba}	20.8^{a}
$LSD_{(0.05)}$	0.8		
$CV_{(\%)}$	2.46		

Means followed by same letter (s) are not significantly different from each other at $p \leq 0.05$

due to combined effect of 60/40 kg NP ha^{-1} while the minimum yield (636.6 kg ha^{-1}) was recorded from the control of NP (Table 10). The result was linear increment with the increasing rate of Nitrogen and phosphorus through each levels of interaction. The present study was in contrast with Das *et al.* (1992) whose report 590 kg ha^{-1} found from application of 60/120 NP kg ha^{-1}. This could be; the type of cultivar, the cropping season difference or the type of soil and its constituents or else the type of managements that can increase or decrease the availability of fertilizer efficiency. The seed yield obtained from this research result is in line with the yields reported by Datta (2004) and Weiss (2002) who reported highest value 1200 and lowest value 1000 kg ha^{-1}. The result is in alignment with Squire (1990) who stated that associated improvement in straw yield response to fertilizer treatment with increased leaf area and root length, which resulted in interception of more solar energy and increased amount of water transpired during the growing season under availability of these nutrients in the soil. Similarly, the increment in seed yield under interaction of fertilizer might be associated with synthesis of more chlorophyll for photosynthesis resulting in promotion of plant development Ashraf *et al.* (2005). This result is supported by highly significantly and positively correlated with plant height (r = 0.93***), root length (r = 0.95***), number of branches per plant (r = 0.92***), number of pods per plant (r = 0.95***), number of seeds per pod (r = 0.97***), total yield (r = 0.96***) and harvest index (r = 0.92***) (Table 11).

Harvest index: Harvest index was found to be highly significantly (p<0.01) influenced by the interaction effect of nitrogen and phosphorus (Table 12). The highest harvest index (20.8%) obtained from treatment that received interaction of 60/40 kg NP ha^{-1}, followed by 20.5%, which received 45/20 kg NP ha^{-1} interaction (Table 12). It was statistically similar with interaction of 45/40 kg of NP. While the lowest value (15.1%), was recorded at 15/0 kg NP ha^{-1}. This result was consistent with the idea of Geren *et al*. (1997) who indicated that grain crops are strongly forced in favour of seed yield and their harvest index can increase. An adequate supply of Nitrogen might be associated with vigorous vegetative growth and efficient use of available nutrients, which finally

Table 13: Partial budget analysis for yield for all combinations of treatments of nitrogen and phosphorous fertilizer on *Nigella sativa* L.

N×P (kg ha^{-1})	Unadjusted yield (kg ha^{-1})	Adjusted yield (kg ha^{-1})	Benefit (Birr ha^{-1})	Total variable cost (Birr ha^{-1})	Net benefit (Birr ha^{-1})	Marginal rate of return (%)	Dominance
0/0	636.67	573.003	8595.045	-	595.045	-	-
0/20	716.6	644.94	9674.1	430	9244.1	150.943	Do
0/40	756.6	680.94	10214.1	730	9484.1	80.0	No Do
15/0	680	612	9180	310	8870	146.2143	No Do
15/20	810	729	10935	610	10325	485.0	Do
15/40	836.6	752.94	11294.1	910	10384.1	19.7	No Do
30/0	800	720	10800	490	10310	17.64286	No Do
30/20	920	828	12420	790	11630	440.0	No Do
30/40	1036.6	932.94	13994.1	1090	12904.1	424.7	No Do
45/0	993.3	893.97	13409.55	670	12739.55	39.17857	No Do
45/20	1013.3	911.97	13679.55	970	12709.55	-10.0	No Do
45/40	1216.6	1094.94	16424.1	1170	15254.1	1272.2	Do
60/0	1060	954	14310	850	13460	560.6563	No Do
60/20	1273.3	1145.97	17189.55	1150	16039.55	859.85	No Do
60/40	1336.67	1203.003	18045.05	1450	16595.05	185.1667	No Do

Table 14: Partial budget analysis for seed yield of *Nigella sativa* L. at economic viable points of nitrogen and phosphorous fertilizer application

N×P (kg ha^{-1})	Unadjusted yield (kg ha^{-1})	Adjusted yield (kg ha^{-1})	Benefit (Birr ha^{-1})	Total variable cost (Birr ha^{-1})	Net benefit (Birr ha^{-1})	Marginal rate of return (%)	Dominance
0/20	716.60	644.94	9674.10	430.00	9244.10	150.90	Do
15/20	810.00	729.00	10935.00	610.00	10325.00	485.00	Do
45/40	1216.60	1094.94	16424.10	1170.00	15254.10	1272.20	Do

might be leads to higher productivity (Das *et al*., 1992). Improved nutrient absorption increases the proportion of seed to dry mass by developing leaf area index and therefore, supplying more photosynthetic materials to seeds.

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 (15 birr per kg). The cost of fertilizers (Nitrogen 12 birr per Kg and for TSP depending on DAP cost 15 birr per Kg) was also taken from the study areas (Table 13 and 14).

Marginal rate of revenue (MRR%) analysis for seed yield indicated that the highest net benefit (15254.1 ETB ha^{-1}) was recorded from the combined application of 45/40 kg NP ha^{-1} over the control treatment which resulted in the net benefit of 8595.045 ETB ha^{-1}. Followed by 15/20 kg NP/ha with MRR (485%) and net benefit (10325 ETB ha^{-1}). Except the three treatments (interaction of 0/20 kg NP, 45/40 NP kg, 15/20 N P ha^{-1}), all other dominated treatments are removed from economic analysis. The highest marginal rate of revenue (1272.2%) obtained from interaction effect of 45/40 kg NP ha^{-1}. Followed by marginal rate of revenue (485%) obtained from 15/20 kg N P ha^{-1} over the control treatment (Table 13 and 14).

CONCLUSION

A field study was conducted at Konta district, southwest of Ethiopia with the objective of determining the effect of N and P on growth, yield and yield components of Black Cumin. Treatment combinations of 5 levels of N (0, 15, 30, 45 and 60 kg N ha^{-1}) and 3 levels of P (0, 20 and 40 kg P ha^{-1}) arranged in RCBD with three replications.

Results revealed that interaction of N and P significantly ($p<0.01$) influenced the different growth and yield parameters except for 1000 seed weight. The highest seed yield (1336.7 kg ha^{-1} was obtained from 60/40 kg N P ha^{-1}. Highest number of pods per plant (45.9) was registered from combined applications of 60kg N ha^{-1} and 40 kg P ha^{-1}. The highest numbers of seeds per pod (91.6) was achieved with the combined use of 60/40 kg NP. The highest harvest index (20.8%) was recorded from the treatment that received 60/40 kg NP followed by 20.5%, which received 45/20 kg, NP ha^{-1} while the lowest harvest index (15.1%) was recorded from the treatment that received 15 and 0kg NP in combination.

Out of the entire 15 NP interaction treatments, only two combinations are economically viable having marginal rate of revenue beyond the minimum acceptable level (150%). The highest MRR was obtained with the interaction of 45/40 Kg NP ha^{-1} with marginal rate of revenue (1272.2%) for net benefit 15254.1birr followed by the interaction effect of 15/20 Kg N P ha^{-1} with marginal rate of revenue (485%) for net benefit 10325 birr. In general, from the study result we can conclude that there is a tendency to increase yield and yield components, if both NP levels increased with some levels beyond 60/40 kg NP 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, until such time the following preliminary recommendation can be put forward.

Although the highest seed yield occurred due to the applications of 60/40 Kg N P_2O_5 ha^{-1}, the best economic advantage appeared at 45/40 kg NP/ha followed by

15/20 kg N P_2O_5 ha^{-1}. So in Konta special woreda; at higher agro ecological zone, using interaction of 45/40 kg NP/ha followed by 15/20 kg N P_2O_5 ha^{-1} for black cumin production are recommended.

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