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Effect of NPS Fertilizer Rates on Yield Components, Yields and Quality of Coriander (*Coriandrum sativum* L.)

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Abstract: *Coriander is an important aromatic annual condiment and spice crop grown for both green leaves and dried seeds. The field experiment was conducted at three locations of Adami Tulu, Dugda and Lume for two successive years to identify economically feasible rates of NPS fertilizer. The six level of fertilizers rates (0, 30, 60, 90, 120 and 150 kg NPS ha^{-1}) were laid out in randomized complete block design with three replications. Statistical analysis of the data revealed that highly significant differences in days to 50% flowering (DTF), days to maturity (DTM), plant height (PH), number of seeds per umbel (SPU) in 2019/20 and Number of umbels per plant (UPP) in 2020/21 across three locations were observed. While number of primary branch (NPB), number of umbelets per umbel (UPU), seed yield (SY), and essential oil content (EC) showed highly significant variation in both years with high concentrations on NPS fertilizer rates. The minimum (DTF) 65 from 120 kg NPS ha^{-1}, early maturing (DTM) 116 from 90 kg NPS ha^{-1}, the highest (PH) 131.67cm from 90 kg NPS ha^{-1}, (SPU) 855.5 from 90 NPS kg ha^{-1}, (UPP) 44.47 from 150 kg NPS ha^{-1}, (NPB) 7.47 from 90 kg NPS ha^{-1}, (UPU) 8.93 from 120 kg NPS ha^{-1}, the highest (SY) 18.33q from 90 kg NPS ha^{-1}and (EC) 0.79 from 90 kg NPS ha^{-1} were recorded. The results indicated that the overall performance of the seed yield and essential oil content of the crop was the best in both years with respect to NPS fertilizers rates. In general, the economic feasibility of the fertilizer indicated that application of (90, 120 and 120 kg NPS ha^{-1}) with marginal rate of return (1861, 3242 and 658 %) at Adami Tulu, Dugda and Lume in 2019/20 and application of (90, 120 and 150 kg NPS ha^{-1}) with marginal rate of return (3910, 1574, 1586 %) was obtained at Adami Tulu, Dugda and Lume in 2020/21 respectively. However, as compared to overall two years treatments the highest net benefits increments for (90, 120 and 120 kg NPS ha^{-1}) fertilizer rates were economically feasible. Therefore, the soil nourished with (90, 120 and 120 kg NPS ha^{-1}) at Adami Tulu, Dugda and Lume respectively was suggested to the coriander growers.*

Keywords: *coriander, economic analysis, essential oil content, NPS, yield*

1. INTRODUCTION

Coriander (*Coriandrum sativum*, L.) is an important aromatic annual condiment and spice crop belongs to family *Umbelliferae* (*Apiaceae*) (Hassan *et al*., 2012). It is an annual herb and grown for both green leaves and dried seeds. Coriander is used in many industries, including the manufacture of pharmaceuticals, food and cosmetics. The plant material used for processing by the herbal industry is the fruit (*Fructus Coriandri*) and essential oil (*Oleum Coriandri*) extracted from coriander fruit (Bourdock and Carabin, 2009). The green leaves are used in chutneys, sauce, curry and other preparation because of its pleasant aroma along with flavoring of dishes and seasoning the curry and soups. Coriander seed rich in volatile oil is used as a spice and folk remedy, and essential oil derived from seeds is also used in perfumery, food, tobacco, soft and alcoholic beverage, and pharmaceutical industries and this could be answer why coriander seeds are an important ingredient of curry powder widely used in world cuisines (Moniruzzaman *et al*., 2014; Yousuf *et al*., 2014). Coriander oil also possesses medicinal properties, such as: antibacterial, anti-fungal or anti-oxidant properties (Singh *et al*., 2006, Matasyoh *et al*., 2009,

Asgarpanah and Kazemivash, 2012). Studies indicated that one hectare of coriander allows honeybees to collect about 500 kg of honey (Diederichesen, 1996). The residues left after extraction of the essential oils are used as best ruminant feed since they still contain as nearly the same digestible fat and protein content as the whole fruits (Diederichesen, 1996).

The yield and essential oil content of coriander is influenced by weather conditions, agronomic and genetic factors. The productivity of coriander is influenced by several factors such as soil, varieties, fertilizer management and various agro techniques used for growing crop. Among the production techniques the basic agronomic management practices like time of sowing, planting geometry, seed rate and nutrient management practices plays an important role in enhancing the productivity of the coriander (Kurubetta *et al*., 2008). Nutrients play a vital role in functioning of normal physiological processes during the period of growth and development of the plants.

Fertilizations are the major factors affecting the growth, yield and volatile oil content of coriander (Hassan *et al*., 2012). Appropriate use of fertilizers rates are the supreme importance for new released variety. The released variety has its own requirement of fertilizer rates for growth and maturity. Fertilizers applications for crop plays major role in crop yield improvement with better plant health. For sustainability in crop production and improvement in soil health, balanced fertilization is very important (Sharif *et al*., 2004).

Considering the importance of the coriander crop and its nutritional requirements, to have consistently higher yield of quality produce for the recently released coriander varieties, standardization of fertilizer requirement is very important.

Therefore, this study was undertaken with the following objectives**:**

- to determine the effect of NPS fertilizer rates on yield components, yield and seed quality of coriander; and
- to identify economically feasible rates of NPS fertilizer in the study area

2. MATERIALS AND METHODS

2.1. Description of the Study Area

The field experiment was conducted at Adami Tulu, Dugda and Lume site from July to November for two consecutive years of 2019/20 and 2020/21 under rain fed conditions at each location.

2.2. Experimental Materials

2.2.1. Plant Material

The recently released coriander variety of '*Batu'* was used as test crop. This varieties where released from Adami Tulu agricultural research centers, which have a good adaptation and better performance in the area.

2.2.2. Fertilizer Materials

The NPS fertilizers (19% N, 38% P2O5 and 7% S) were used as the sources of fertilizers.

2.3. Soil Sampling and Analysis

One representative soil sample was taken at a depth of 0-30 cm from five randomly selected spots diagonally across the experimental field using auger before planting. The sample was air dried under shade. The sample was analyzed for selected physico-chemical properties, namely organic carbon, texture, soil pH, cation exchange capacity (CEC), total N, available P and S.

2.4. Treatments and Experimental Design

The treatments were consisted of coriander seeding rates (12 kg ha^{-1}) and six levels of NPS fertilizer rates (0, 30, 60, 90, 120 and 150) where arranged in a randomized complete block design (RCBD) with three replications. The gross plot size was 8 rows of three meter length (3 m×2.4 = 7.2 m^2) with net harvestable rows of 6 with 2.5 m length (2.5 m×2.0 m = 5 m^2) were considered as net plot. The spacing between rows, plots and blocks were 0.30, 0.5 and 1 m, respectively.

2.5. Experimental Procedures and Field Management

The experimental field was ploughed with oxen to a fine tilth three times and the plots were leveled manually. According to the design, a field layout was made and each treatment was assigned randomly to the experimental units within a block. Coriander seeds were sown in rows of 30 cm spacing manually by drilling. The whole amount of NPS fertilizer rates were applied at the time of sowing for each treatment. Weeding was done as needed; and harvesting and threshing was done manually.

2.6. Crop Data to be Collected

Growth parameters

Days to 50 per cent flowering

The number of days was counted from the date of sowing till 50 per cent of the flowering and recorded as days taken for 50 per cent flowering.

Days to maturity (crop duration)

The number days taken to attain maturity was counted from sowing to harvest. The harvesting was done when 90 percent of umbels turned dark green to light brown color the duration in each plot is expressed in number days.

Plant height (cm)

The height of the plant was measured in centimeter from the ground level to the top most nodes in the main stem at 90 DAS and expressed in centimeters.

Number of branches per plant

The number of primary branches per plant were counted and recorded at 90 DAS. Secondary branches were recorded at 90 DAS stage and expressed as total number branches per plant.

Yield and yield parameters

Number of umbels per plant

The numbers of umbels in each of ten plants were counted at 90 days after sowing and the average value was expressed as number of umbels per plant.

Number of umbellets per umbel

Umbellets were counted in ten umbels per plant and average value was per umbel express of number of umbellets per umbel.

Number of seeds per umbel

From each selected plant, ten umbels were selected randomly and seeds were counted. Average was recorded as mean seed count per umbel.

Seed yield per hectare (q)

The yield per hectare was calculated based on the yield obtained per plot, and expressed in quintals per hectare.

Quality parameters (seed)

Essential oil content (%)

Essential oil content was done at Wendo Genet Spice crop laboratory by hydro-distillation of 250 g of coriander at seed powder of each plot was measured and expressed as dry based volume by weight.

2.7. Data Analysis

All data collected was subjected to analysis of variance (ANOVA) procedure using GenStat (17^{th} edition) software (GenStat, 2014). The comparisons among treatments means with significant difference for measured characters will be done by LSD test at 5% level of significance.

2.8. Economic Analysis

The economic analysis was carried out by using the methodology described in CIMMYT (1988) in which prevailing market prices for inputs at planting and for outputs at harvesting were used. All costs and benefits were calculated on hectare basis in Birr. The concepts used in the partial budget analysis were the mean of seed yield of each treatment, the gross benefit (GB) ha^{-1} (the mean yield for each treatment) and the field price of fertilizers (the costs of NPS). Marginal rate of return, which refers to net income obtained by incurring a unit cost of fertilizer application, was calculated by dividing the

net increase in yield of Coriander due to the application of each fertilizers rate. The net benefit (NB) was calculated as the difference between the gross field benefit and the total variable (TVC) using the formula.

NB= GFB -TVC

Where GFB = Gross Field Benefit, TVC = Total Variable Cost

Actual yield was adjusted downward by 10% to reflect the difference between the experimental yield and the yield of farmers could expect from the same size field.

The dominance analysis procedure as described in CIMMYT (1988) was used to select potentially profitable treatments from the range that was tested. Any treatment that has higher TVC but net benefits that are less than or equal to the preceding treatment (with lower TVC but higher net benefits) is **dominated treatment** (marked as "**D**"). The dominance analysis illustrates that to improve farmers' income, it is important to pay attention to net benefits rather than yields, because higher yields do not necessarily mean high net benefits. The discarded and selected treatments using this technique were referred to as dominated and undominated treatments. For each pair of ranked treatments, % marginal rate of return (MRR) was calculated using the formula:-

$$\text{MRR (\%)} = \frac{\text{Change in NB (NBb}-\text{NBa)}}{\text{Change in TCV (TVCb}-\text{TVCa)}} \times 100$$

Where NB_a = NB with the immediate lower TCV, NB_b = NB with the next higher TCV, TVC_a = the immediate lower TVC and TVC_b = the next highest TCV.

The % MRR between any pair of undominated treatments was the return per unit of investment in fertilizer. To obtain an estimate of these returns, the % MRR was calculated as changes in NB (raised benefit) divided by changes in cost (raised cost). Thus, a MRR of 100% implied a return of one birr on every birr spent on the given variable input. The fertilizer cost was calculated for the cost of each fertilizer of NPS (Birr 14.96 kg $^{-1}$) during sowing time. The average open price of Coriander at Ziway, Maki and Koka market was Birr 60 and 70 kg $^{-1}$ in December 2019/20 and 2020/21 respectively during harvesting time.

3. Results and Discussion

3.1. Soil Physico-chemical Properties of the Experimental Site

According to the laboratory analysis, the soil texture of the experimental area is sandy loam, loam and clay loam in 20219/20 and loam, clay loam and clay loam in 2020/21 at Adami Tulu, dugda and Lume area respectively. The soil texture influences water contents, water intake rates, aeration, root penetration, and soil fertility. The pH of the soil was 7.53, 7.11 and 6.67 in 20219/20 and 7.79, 6.90 and 8.08 in 2020/21 for AdamiTulu, Dugda and Lume respectively. FAO (2000) reported that the preferable pH ranges for most crops and productive soils are 4 to 8. Thus, the pH of the experimental soil was within the range for productive soils except for Lume in 2020/21. Sahlamedihin (1999) reported the pH of the soil between (5.00 -7.55) was found within the suitable range for crop production.

The Netherlands commission of the ministry of agriculture and fisheries (1985) classified soils having total organic C % greater than 3.50, 2.51-3.5, 1.26-2.5, 0.60-1.25 and less than 0.6 is categorized as very high ,high, medium, low, and very low respectively. According to the Ethiosis (2014) reference soil organic carbon content in both years of the experimental site was low. The result of soil analysis has poor total nitrogen in both years according to the rating of Tekalign *et al*, (1991). Soil analysis also indicated that very high available phosphorus content in both years according to the rating of Olsen *et al*. (1954).

The analysis for available sulfur indicated that optimum for three sites in 2019/20 and Very high, Very high and high results was recorded in 2020/21 at Adami Tulu, Dugda and Lume respectively according to Ethiosis (2014). The CEC value of the soil sample is high in both years except for Lume in 2020/21which recorded very high according to the rating of Landon (1991) which indicates the soil has high capacity to hold exchangeable cations. Cation Exchange Capacity (CEC) is an important parameter of soil, because it give an indication of the type of clay minerals present in the soil, soil texture, organic matter content of the soil and its capacity to retain nutrients against leaching (Sahlamedihin, 1999).

Table2. *Selected physico-chemical properties of the soil of the experimental site before sowing*

No	Soil characters	Values of soil samples for two year						References and rating
		Adami Tulu		Dugda		Lume		
1.	Soil texture	**2019/20**	**2020/21**	**2019/20**	**2020/21**	**2019/20**	**2020/21**	
	Sand (%)	53.91	48.00	40.58	30.50	36.00	32.87	
	Clay (%)	12.57	19.76	21.22	34.75	29.87	32.51	
	Silt (%)	33.52	32.24	38.20	34.75	34.14	34.61	
	Texture Class	Sandy loam	Loam	Loam	Clay loam	Clay Loam	Clay loam	
2.	pH-H_2O(1:1.25) in 2019/20 pH-H_2O(1:2.5) in 2020/21	7.53	7.79	7.11	6.90	6.67	8.08	Ethiosis (2014), <5.5 Strongly 5.6-6.5 Moderately acidic 6.6-7.3 Neutral 7.3-8.4 Moderately alkaline >8.4 Strongly alkaline
3.	Organic Carbon (OC) (%)	1.05	0.583	1.01	0.74	0.45	0.43	Ethiosis (2014), <0.2 Very low 2.0–3.0 Low 3.0–7.0 Optimum 7.0–8.0 High > 8.0 Very high
4.	CEC (meq/100 gm of soil)	38.18	31.60	32.64	32.43	38.34	46.33	Landon (1991), >40 cmol (+) / kg very high 25-40 cmol (+) / kg high 15-25 medium 5-15 low < 5 cmol (+) / kg very low
5.	Total Nitrogen (%)	0.15	0.07	0.13	0.10	0.06	0.06	Tekalign *et al*. (1991), < 0.05% very low 0.05-0.12% poor 0.12-0.25% moderate > 0.25 % high
6.	Available P (mg P_2O_5/kg soil)	50.74	44.83	20.91	87.16	22.65	38.35	Olsen *et al*.(1954), 3ppm very low 4-7ppm low 8-11ppm medium 12-20ppm high >20ppm very high
7.	Available S (mg/kg soil)	62.12	117.76	29.92	160.23	22.54	95.82	Ethiosis (2014), 20-80 Optimum 80-100 High > 100 Very high
8.	EC (mS/cm) (1:1.25) and (1:2.5) in 2020/21	0.51	0.25	0.20	0.33	0.14	0.18	Ethiosis (2014), < 2 Salt free 2-4 Very slightly 4-8 salines 8-16 slightly saline >16 moderately saline

Days to 50 Per cent Flowering

The analysis of variance revealed that NPS fertilizer rates highly significant difference ($P < 0.01$) at three locations in 2019/20 and the non significant data was recorded at Adami Tulu and Dugda except for Lume highly significant difference ($P \leq 0.01$) observed in 2020/21 (Table 2). The highest prolonged duration to reach days to flowering was observed in both years in response to zero rates of the fertilizers application. However, the minimum duration of days to flowering (65.67, 65.67 and 65.00) was observed at Adami Tulu, Lume and Dugda respectively with NPS fertilizer rate of 120 kg ha^{-1} in 2019/20, whereas (66.33) with 120 kg ha^{-1} of NPS fertilizer rate at Lume in 2020/21 (Table 2). The performance of coriander from vegetative to reproductive phase might be differed due to production of flowers. Application of fertilizer has been documented to enhance plant growth and development. This might be due to the NPS fertilizer enable plants to more active shoot growth and to synthesize hormones for more flower initiations. The result is similar with Suman *et al*. (2018) reported that bio fertilizer treated plants became physiologically more active and enable to synthesize required amounts of hormones and also reported 50 per cent flowering (47.30 days).

Days to Maturity

The main effect of NPS fertilizer rates was highly significantly ($P < 0.01$) on days to maturity of coriander at three locations in 2019/20 years, while highly significantly ($P \leq 0.01$) at Adami Tulu, the non significant was obtained at Dugda and significant difference ($P \leq 0.05$) at Lume was recorded in 2020/21. The early maturing (116.00 days) was obtained from 90 kg NPS ha^{-1} at Lume in 2019/20 whereas the early maturing (103.33 and 106.33 days) was obtained from 150 kg NPS ha^{-1} at Adami Tulu and Lume in 2020/21 respectively. While the longest days to maturity (112.67, 117.00, 124.00 days) and 111.00, 114.3, 112.67 days) was recorded in 2019/20 and 2020/21 at Adami Tulu, Dugda, Lume respectively from both years with zero fertilizer rates (Table 2). This type of variation to attain maturity might be the availability of P element as an energy source in the form of ATP. Hence, P element deficiency has the ability to affect the growth and development as well as the maturity of plant. On the other hand, limitation of P supply has been shown to decrease the production of floral structures (Ma *et al*., 2001). Similarly, Nitrogen deficiency in soil also leads to retarded growth and loss of weight of plant aerial organs as well as premature ripeness of plants (Oliveira *et al*. 2003).

Table2. *Main effects of NPS fertilizer rates on days to heading (DH) and days to maturity (DM) of coriander*

Year	In 2019/20						In 2020/21					
Treatments	DTF			DTM			DTF			DTM		
	Location			Location			Location			Location		
NPS rates (kg ha^{-1})	Atarc	Dugda	Lume	Atarc	Dugda	Lume	Atarc	Dugda	Lume	Atarc	Dugda	Lume
0	69.67 b	69.67 c	72.33 c	112.67 b	117.00 c	124.00 b	67.33	69.33	71.33 b	111.00 b	114.33	112.67 b
30	69.33 b	69.00 bc	70.33 c	112.33 b	115.00 b	121.33 b	66.33	69.00	71.33 b	110.33 b	114.00	110.00 ab
60	68.67 b	67.67 ab	67.33 b	106.33 a	112.67 a	117.33 a	65.33	66.00	66.67 a	104.67 a	109.67	106.67 a
90	66.00 a	66.00 a	66.67 ab	106.33 a	111.67 a	116.00 a	65.67	68.33	66.67 a	105.33 a	112.67	107.67 a
120	65.67 a	65.67 a	65.00 a	106.67 a	111.33 a	117.33 a	63.33	66.67	66.33 a	105.33 a	111.00	107.33 a
150	66.00 a	67.00 a	66.00 ab	107.00 a	112.00 a	117.00 a	64.67	67.33	67.00 a	103.33 a	111.00	106.33 a
LSD(0.05)	1.62 ***	1.88 ***	2.14 ***	2.93 ***	1.62 ***	2.92 ***	NS	NS	3.04 ***	2.44 ***	NS	3.63 **
CV (%)	1.3	1.5	1.7	1.5	0.8	1.3	2.1	2.2	2.4	1.3	1.8	1.8

Plant Height (cm)

The main effect of NPS fertilizer rates significantly ($P < 0.01$) influenced plant height of coriander. The main effect of NPS fertilizer rates was highly significant ($P < 0.01$) on Plant height of coriander

at three locations in 2019/20 years, while highly significant ($P < 0.01$) and ($P \leq 0.01$) was recorded at Adami Tulu and Lume respectively and the non significant difference at Dugda was obtained in 2020/21. The tallest plant height of (131.67, 121.2 and 127.5 cm) was recorded at Adami Tulu, Dugda and Lume with fertilizer rate of 90, 90 and 120 kg ha^{-1} respectively in 2019/20 and the highest plant height (106.73, 118.1 and 115.07 cm) was recorded at Adami Tulu, Dugda and Lume with fertilizer rate of 120, 150 and 150 kg ha^{-1} in 2020/21 respectively, while the shortest plant height was obtained at zero fertilizer rates in both year. This might be due to the adequate supply of balanced fertilizer increased cell elongation and rapid cell division in the growing portion leading to increased length of internodes. These results were in conformity with Singh (2015) increased plant height may be due to increased uptake of nitrogen, which being the constituent of protein and protoplasm, vigorously induce the vegetative development of the plant.

Number of Primary Branch (NPB)

The analysis of variance indicated that Number of primary branch was highly significant ($P \leq 0.01$) affected by the main effects of NPS fertilizer rates at both years (Table 3). The maximum number of primary branch (7.47, 6.63 and 5.97) was produced at Adami Tulu, Dugda and Lume under application of the NPS fertilizer rates of (90, 90 and 150 kg ha^{-1}) in 2019/20 respectively and (4.80, 4.00 and 4.27) was produced at Adami Tulu, Dugda and Lume under application of the NPS fertilizer rates of (60, 150 and 60 kg ha^{-1}) in 2020/21 respectively. Whereas, the minimum number of primary branches (4.93, 5.23, and 4.80) and (3.47, 3.07, 3.07) were recorded in 2019/20 and 2020/21 from Adami Tulu, Dugda and Lume with zero fertilizer rate respectively. This might be due to balanced NPS nutrient enhances maximum growth of crop and encourages vegetative growth of the crop and also increases the main stem diameter, the biggest and most strongly number of lateral branches, longest internodes length. In line with this result, application of nitrogen encourages vegetative growth, which results in the increased yield of leaves and seeds of coriander (Datta *et al*., 2008). Deficiency of nitrogen induces several morphological and physiological hazards like growth retardation, decreased leaf and branch number (Nasim *et al.*, 2012).

Table3. *Main effects of NPS fertilizer rates on Plant heights (PH) and number of primary branch (NPB) of coriander*

Year	In 2019/20						In 2020/21					
Treatments	PH			NPB			PH			NPB		
	Location			Location			Location			Location		
NPS rates (kg ha^{-1})	Atarc	Dugda	Lume	Atarc	Dugda	Lume	Atarc	Dugda	Lume	Atarc	Dugda	Lume
0	103.00 a	98.0 a	97.8 a	4.93 a	5.23 a	4.80 a	93.73 a	101.9	93.33 a	3.47 a	3.07 a	3.07 a
30	103.33 a	102.7 ab	108.0 a	6.07 b	5.53 a	5.00 ab	94.47 a	103.9	98.07 ab	3.80 ab	3.12 a	3.33 ab
60	124.00 b	111.1 bc	120.1 b	7.33 c	6.17 b	5.40 abc	99.80 b	116.9	110.53 c	4.80 c	3.87 b	4.27 c
90	131.67 c	121.2 d	124.3 b	7.47 c	6.63 b	5.53 bc	104.53 cd	115.7	107.07 bc	4.47 bc	3.83 b	4.13 c
120	126.67 bc	119.8 cd	127.5 b	7.40 c	6.43 b	5.53 bc	106.73 d	117.6	109.30 c	4.53 bc	3.30 a	3.67 abc
150	128.67 bc	120.1 cd	126.8 b	7.20 c	6.43 b	5.97 c	102.13 bc	118.1	115.07 c	4.57 bc	4.00 b	3.93 bc
LSD(0.05)	6.67 ***	9.22 ***	10.58 ***	1.10 ***	0.59 ***	0.60 ***	4.09 ***	NS	9.61 ***	0.74 ***	0.51 ***	0.61 ***
CV (%)	3.1	4.5	5.0	9.0	5.4	6.1	2.2	6.9	5.0	9.5	7.9	8.9

Number of Secondary Branch (NSB)

The analysis of variance indicated that number of secondary branch was highly significantly ($P \leq 0.01$) affected by the main effect of NPS fertilizer rates at Lume and significantly ($P \leq 0.05$) affected at Adami Tulu as well as the non significant data was recorded from dugda in 2019/20. Whereas the number of secondary branch was significant ($P \leq 0.05$) at Dugda and Lume except non significant

data obtained at Adami Tulu in 2020/21 (Table 4). The maximum number of secondary branch (8.73 and 7.83) was recorded at Adami Tulu and Lume from the application of the highest rates of (120 and 150 kg NPS ha^{-1}) in 2019/20 respectively, as well as (8.87 and 9.67) was recorded at Dugda and Lume from the application of (150 and 90 kg NPS ha^{-1}) in 2020/21 respectively. Whereas, the minimum number of secondary branches (5.67 and 5.70) and (5.27 and 5.00) were recorded in 2019/20 from Adami Tulu and Lume and in 2020/21 from Dugda and Lume with zero fertilizer rate respectively. The increase in number of primary and secondary branches could be due to application of nitrogen as NPS made exuberant growth of the basal buds there by leads to increased branching. This might be due to adequate supply of balanced NPS nutrients associated with high the biomass production leading to vigorous vegetative growth. The application of NPS fertilizer nutrient allows the high number of branch set and provides better canopy structure. Wenting *et al*. (2016) reported that nitrogen deficiency can reduce canopy growth and cause premature senescence, and thereby reduce yields.

Number of Umbels per Plant (UPP)

The analysis of variance showed that the main effects of NPS fertilizer rates was highly significant ($P \leq 0.01$) and ($P < 0.01$) at Dugda and Lume in 2019/20 and in 2020/21 respectively, on the number of umbels per plant. The highest number of umbels per plant (43.60 and 30.43) was counted at Dugda and Lume in 2019/20 with NPS fertilizer level of 120 kg ha^{-1} respectively. Whereas the maximum number of umbels per plant (44.47, 31.93 and 25.87) was recorded at Adami Tulu, Dugda and Lume in 2020/21 with highest NPS fertilizer level of (150, 150 and 90 kg ha^{-1}) while lowest number of umbels per plant (32.73 and 21.40) and (30.73, 18.40 and 15.80) from Dugda and Lume in 2019/20 and Adami Tulu, Dugda and Lume in 2020/21 respectively at zero level of NPS fertilizer (Table 4). The result showed that giving NPS fertilizer in soil with high P status (87.16 mg/kg P_2O_5) could still increase number of umbels per plant and the number of umbels per plant with highest NPS fertilizer level of (150 kg ha^{-1}) was 44.47. More number of umbels per plant and umbelets per umbel might be attributed to the abundant supply of available phosphorus nutrients from soil convey more translocation from source to arial parts for synthesis proteins and other compounds which probably have led to an improvement in yield and yield related attributes. It is widely found that increasing P as a fertilizer promote reproductive yields and inflorescence production (Egle *et al*., 1999), particularly when P is limiting in natural systems (Feller, 1995). The maximum number of umbels per plant (31.70) was reported by Anilkumar *et al*., (2018). Nahed and Darwesh (2015) reported that nitrogen fertilization 60 kg nitrogen feed as urea produced the maximum values of number of umbels per plant and the highest plant height for both seasons.

Table4. *Main effects of NPS fertilizer rates on number of secondary branch (NSB) and number of umbels per plant (UPP) of coriander*

Year	In 2019/20						In 2020/21					
Treatments	NSB			UPP			NSB			UPP		
	Location			Location			Location			Location		
NPS rates (kg ha^{-1})	Atarc	Dugda	Lume	Atarc	Dugda	Lume	Atarc	Dugda	Lume	Atarc	Dugda	Lume
0	5.67 a	5.93	5.70	48.3	32.73 a	21.40 a	8.60	5.27 a	5.00 a	30.73 a	18.40 a	15.80 a
30	6.67 ab	6.23	6.03	49.1	34.07 ab	22.57 a	9.53	5.73 ab	5.93 ab	32.80 a	20.67 ab	18.67 ab
60	7.07 abc	6.57	7.10	53.2	40.17 c	26.47 b	11.67	8.27 c	8.67 c	41.47 ab	28.27 bc	21.60 bc
90	8.07 bc	7.43	7.17	55.9	39.63 c	26.6 b3	10.33	7.93 bc	9.67 c	39.83 ab	32.93 c	25.87 c
120	8.73 c	7.03	7.53	57.3	43.60 c	30.43 b	10.23	7.40 abc	7.87 bc	44.13 b	24.80 abc	25.20 c
150	7.73 bc	6.70	7.83	54.6	39.70 bc	26.83 b	10.60	8.87 c	8.13 bc	44.47 b	31.93 c	23.40 bc
LSD(0.05)	1.71 **	NS	0.88 ***	NS	5.50 ***	2.50 ***	NS	2.31 **	2.52 **	10.35 *	8.79 **	5.21 ***
CV (%)	12.8	9.5	7.0	8.6	7.9	5.3	13.9	17.5	18.4	14.6	18.5	13.2

Number of Umbelets per Umbel (UPU)

Analysis of variance revealed that main effects of NPS fertilizer rate were highly significant ($P \leq 0.01$) in 2019/20 on number of umbelets per umbel and significant of ($P < 0.05$) as well as ($P < 0.01$) data was recorded at Adami Tulu as well as Dugda and Lume respectively in 2020/21 (Table 5). The highest number of umbelets per umbel (7.73, 8.93 and 7.13) was counted at Adami Tulu, Dugda and Lume in 2019/20 with NPS fertilizer level of (120 kg ha^{-1}) respectively. Whereas the maximum number of umbelets per umbel (7.40, 7.06 and 6.89) was recorded at Adami Tulu, Dugda and Lume in 2020/21 with NPS fertilizer level of (150, 90 and 60 kg ha^{-1}) respectively, while the lowest number of umbelets per umbel (6.03, 7.75 and 5.81) and (5.63,5.39 and 5.18) from Adami Tulu, Dugda and Lume in 2019/20 and Adami Tulu, Dugda and Lume in 2020/21 respectively at zero level of NPS fertilizer except in 2020/21with 30 kg ha^{-1} from Lume (Table 5). This might be due to the optimum application of NPS results higher number of umbelets per umbel. Izgi (2020) reported that, applications over 60 kg of nitrogen per hectare resulted in a decrease in the number of umbels in the plant.

Number of Seeds per Umbel (SPU)

The analysis of variance showed that the main effect of NPS fertilizer rates had highly significant ($P < 0.01$) at Lume as well as significant ($P < 0.05$) difference at Adami Tulu and Dugda in 2019/20 on number of seeds per umbel of coriander. Whereas, significant ($P < 0.05$) effect of NPS fertilizer rates were recorded at Dugda and Lume in 2020/21 (Table 5). The highest number of seeds per umbel (855.5, 541.0 and 499.7) was recorded from Adami Tulu, Dugda and Lume with fertilizer rates of (90, 120 and 120 NPS kg ha^{-1}) in 2019/20 as well as (422.93 and 451.81) was recorded from Dugda and Lume with fertilizer rates of (60 and 150 NPS kg ha^{-1}) in 2020/21 respectively. Where, the lowest number of seeds per umbel of (316.14) was recorded from zero NPS fertilizer rates at Dugda in 2020/21 (Table 5). Phosphorus feed as NPS is required in large quantities in young cells, such as shoots and for rapid cell division states more number of flowers and more number of seed set per umbels. The result is in agreement with Yousuf *et al*. (2014) reported that increase in number of capsules per plant is due to production of more number of flowers per umbel, higher percentage of capsule set and reduced shedding of flowers and capsule and resulted in increased yield.

Table5. *Main effects of NPS fertilizer rates on number of umbelets per umbel (UPU) and Number of seeds per umbel (SPU) of coriander*

Year	In 2019/20						In 2020/21					
Treatments	UPU			SPU			UPU			SPU		
	Location			Location			Location			Location		
NPS rates (kg ha^{-1})	Atarc	Dugda	Lume	Atarc	Dugda	Lume	Atarc	Dugda	Lume	Atarc	Dugda	Lume
0	6.03 a	7.75 a	5.81 a	716.8 a	485.4 a	413.9 a	5.63 a	5.39 a	5.23 a	374.83	316.14	339.60
30	6.18 a	7.86 a	6.01 a	721.1 a	492.4 a	427.2 a	6.07 ab	6.12 b	5.18 a	403.79	339.44	346.77
60	7.32 b	8.63 b	7.09 b	783.2 ab	530.1 b	494.8 b	7.13 bc	6.70 c	6.89 b	481.90	422.93	423.83
90	7.59 b	8.88 b	7.07 b	855.5 b	531.2 b	492.0 b	7.00 bc	7.06 c	6.44 b	438.44	401.44	431.65
120	7.73 b	8.93 b	7.13 b	769.5 ab	541.0 b	499.7 b	7.37 c	6.72 c	6.79 b	466.53	403.71	418.01
150	7.46 b	8.52 b	6.80 b	758.9 a	535.8 b	476.1 b	7.40 c	6.96 c	6.46 b	430.68	416.31	451.81
LSD(0.05)	0.81 ***	0.52 ***	0.73 ***	88.8 *	33.70 **	40.79 ***	1.05 **	0.54 ***	0.48 ***	NS	64.44 **	74.47 **
CV (%)	6.3	3.4	6.0	6.4	3.6	4.8	8.5	4.6	4.3	10.7	9.2	10.2

Seed Yield per Hectare (SYh) (q)

The analysis of variance showed that the main effect of NPS fertilizer rates had highly significant ($P \leq 0.01$) in both years on seed yield of coriander (Table 6). The highest seed yield of coriander (16.27,

16.81 and 14.18 q ha^{-1}) was obtained from Adami Tulu, Dugda and Lume in 2019/20 at NPS fertilizer rates of (90, 120 and 120 kg NPS ha^{-1}) respectively as well as (18.33, 14.23 and 11.44 q ha^{-1}) was recorded from Adami Tulu, Dugda and Lume in 2020/21 with NPS fertilizer rates of (90, 120 and 150 kg ha^{-1}) respectively. While the lowest seed yields were recorded from zero fertilizer applications in both years from all the lowest (6.54 q ha^{-1}) was obtained from Lume in 2020/21 (Table 6). The NPS fertilizer rates at highest rates up to 90 kg ha^{-1} for Adami Tulu and 120 kg ha^{-1} for Dugda caused a significant increase of coriander (*Coriandrum sativum* L.) seed yield in both years. NPS is an essential nutrient in creating the plant growth and development, as well as have many energy-rich compounds that regulate photosynthesis and plant production. This might be the main component N feed as NPS is used for plant amino acids and chlorophyll formation as usually acquired by plants in greater quantity from the soil than any other element. The result is in agreement with, Karoline *et al*., (2016) and Carrubba (2009) Coriander has variable response to N application and its use efficiency depends on the general conditions of soil fertility and such dependence is probably the reason why the adequate supply of N, increases the probability of maximizing production. On the other hand, with higher rates of NPS fertilizer application increase seed yields may be due to Phosphorus feed as NPS have the role of structural, energy transfer and improvement of root growth. The result showed that giving NPS fertilizer in soil with high P status (87.16 mg/kg P_2O_5) could still increase seed yield and the highest seed yield with (90 kg ha^{-1}) NPS fertilizer was 18.33 q ha^{-1}. These results may prove that Coriander crop needs a high demand for phosphorus fertilizer. In line with this results, in as much as P application has been found to increase yields in coriander (Moslemi *et al*., 2012). The increase in the yield might be due to the adequate supply of NPS fertilizer upshots the production of maximum number of umbels and umblets per plant this contributed seed set and increase in yield components. It might also due to; Phosphorus has the role of structural, energy transfer and improvement of root growth and also adjusts the effect of extra nitrogen in maturity delay (Mostafa *et al*., 2012). Wladysław and Justyna (2015) achieved the highest coriander in fruit yield up to 1.84 t ha^{-1} in soil nourished with just 20 kg N ha^{-1}.

Essential Oil Content (EC) (%)

Essential oil content of coriander was highly significantly ($P \leq 0.01$) affected by main effect of NPS fertilizer rates in 2019/20 and high significant effect of ($P < 0.01$) NPS fertilizer rates in 2020/21 (Table 6). The highest EC of (0.69, 0.66 and 0.66 %) where obtained from main effect of (150, 120 and 60 kg ha^{-1} NPS) in 2019/20 at Adami Tulu, Dugda and Lume respectively (Table 6) and the lowest (0.44, 0.41 and 0.36 %) where obtained from zero kg ha^{-1} NPS in 2019/20 at Adami Tulu, Dugda and Lume respectively. Whereas the highest EC (0.79, 0.77 and 0.60 %) was obtained from the NPS fertilizer rate of (90, 60 and 90 kg ha^{-1}) in 2020/21 at Adami Tulu, Dugda and Lume respectively, while the lowest EC (0.53, 0.42 and 0.32) was obtained at Adami Tulu, Dugda and Lume respectively with 0 kg ha^{-1} NPS fertilizer rates. NPS fertilization caused a significant increase in the essential oil content of coriander, with its highest 0.79 % concentrations determined in seed from plants fertilized with 90 kg NPS ha^{-1}.

This might be attributed to the Nitrogen feed as NPS increased photosynthetic CO_2 fixation which provides more carbohydrates and proteins for metabolism and leads to accumulation of metabolites like oil. Similarly, the uptake of NPS showed positive effect on essential oil content than over the control. Phosphorus aids in root development, flower initiation, seed and fruit development and P has been shown to reduce disease incidence in some plants and has been found to improve the quality of certain crops (Silva and Uchida, 2000). Similarly, P as fertilizer decomposes carbohydrate in photosynthesis, as well as required in many other metabolic processes for normal growth and fatty acid production. Application of phosphorus fertilizer had a positive effect on essential oil content and yield of cumin plant (Tuncturk and Tuncturk, 2006). Sulphur, an essential secondary plant nutrient, plays a vital role in biosynthesis of primary metabolities for improving yield and quality of oil seed crops and for accruing better yield under balanced fertilization (Anwar *et al.*, 2002). Oil concentration in seed increased with S fertilization (Malhi *et al*., 2007).

Table6. *Main effects of NPS fertilizer rates on Seed yield per hectare (SYh) (q) and Essential oil content (EC) (%) of coriander*

Year	In 2019/20						In 2020/21					
Treatments	SY			EC			SY			EC		
	Location			Location			Location			Location		
NPS rates (kg ha$^{-1)}$	Atarc	Dugda	Lume	Atarc	Dugda	Lume	Atarc	Dugda	Lume	Atarc	Dugda	Lume
0	9.60 a	10.49 a	8.86 a	0.44 a	0.41 a	0.36 a	10.11 a	8.60 a	6.54 a	0.53 a	0.42 a	0.32 a
30	10.88 a	11.52 ab	10.24 ab	0.49 a	0.46 a	0.42 a	11.00 a	9.83 a	7.74 a	0.62 ab	0.55 ab	0.34 a
60	14.64 b	13.32 bc	12.55 bc	0.63 b	0.60 b	0.66 b	15.00 bc	12.46 b	9.87 b	0.70 bc	0.77 c	0.54 b
90	16.27 c	14.31 c	13.55 c	0.66 b	0.61 b	0.59 b	18.33 c	12.84 bc	9.74 b	0.79 c	0.70 bc	0.60 b
120	15.07 bc	16.81 d	14.18 c	0.65 b	0.66 b	0.63 b	15.96 bc	14.23 c	10.04 b	0.75 c	0.77 c	0.51 b
150	15.07 bc	15.13 cd	13.45 bc	0.69 b	0.60 b	0.58 b	12.73 ab	13.31 bc	11.44 c	0.78 c	0.71 bc	0.51 b
LSD(0.05)	1.41***	2.36***	3.07***	0.10***	0.12***	0.12***	3.45***	1.46***	1.32***	0.09***	0.19***	0.15***
CV (%)	5.7	9.5	13.9	9.5	11.4	12.5	13.7	6.8	7.9	7.4	15.8	17.9

Partial Budget Analysis

Partial budget analysis is important to identify experimental treatments with an optimum return to the farmer's investment and to develop recommendation for the agronomic data. Experimental yields are often higher than the yields that farmers could expect using the same treatments; hence in economic calculations, yields of farmers are adjusted by 10% less than that of the research results (CIMMYT, 1988). As indicated in Table 7, the partial budget analysis showed that the highest net benefit of (86511.6, 99064.8 and 74776.8) Birr ha^{-1} with marginal rate of return (1861, 3242 and 658 %) was obtained for coriander that received (90,120 and 120 kg NPS ha^{-1}) at Adami Tulu, Dugda and Lume in 2019/20 respectively. However, the lowest net benefits of (51840, 56646 and 47844) Birr ha^{-1} were obtained from the unfertilized treatment at Adami Tulu, Dugda and Lume in 2019/20 respectively. In case of second table 8, the highest net benefit of (113909.4, 87556.2 and 69456) Birr ha^{-1} with marginal rate of return (3910, 1574, 1586 %) was obtained for coriander that received (90, 120 and 150 kg NPS ha^{-1}) at Adami Tulu, Dugda and Lume in 2020/21 respectively. While, the lowest net benefits of (63693, 54180 and 41202) Birr ha^{-1} were obtained from the unfertilized treatment at Adami Tulu, Dugda and Lume in 2020/21 respectively.

The results of this study indicate that, the higher economic yield with balanced supply of fertilizer rates obtained at application of (90, 120, 120 kg NPS ha^{-1}) in 2019/20 and (90, 120, 150 kg NPS ha^{-1}) in 2020/21fertilizer rates at Adami Tulu, Dugda and Lume respectively. Therefore, as compared to overall two years treatments of highest net benefits (90, 120 and 120 kg NPS ha^{-1}) fertilizer rates were economically feasible and recommended for production of coriander crop at Adami Tulu, Dugda and Lume respectively and other areas with similar agro ecological condition.

Table7. *Summary of economic analysis of the effects of NPS fertilizer rates on coriander at three locations in 2019/20 cropping season*

Treatments	AGY (kg ha^{-1})			Income (ETB ha^{-1})			GFB (ETB ha^{-1})			TVC (ETB ha^{-1})	NB (ETB ha^{-1})			MRR (%)		
				Seed grain												
Ferti	AT	DG	LU	AT	DG	LU	AT	DG	LU		AT	DG	LU	AT	DG	LU
0	864	944.1	797.4	51840	56646	47844	51840	56646	47844	0	51840	56646	47844			

30	979.2	1152	921.6	58752	69120	55296	58752	69120	55296	448.8	58303.2	68671.2	54847.2	1440	2679	1560
60	1317.6	1332	1129.5	79056	79920	67770	79056	79920	67770	897.6	78158.4	79022.4	66872.4	4424	2306	2679
90	1464.3	1431	1219.5	87858	85860	73170	87858	85860	73170	1346.4	86511.6	84513.6	71823.6	1861	1224	1103
120	1356.3	1681	1276.2	81378	100860	76572	81378	100860	76572	1795.2	79582.8	99064.8	74776.8	D	3242	658
150	1356.3	1513	1210.5	81378	90780	72630	81378	90780	72630	2244	79134	88536	70386	D	D	D

Where, AGY = adjusted seed yield; GFB = gross field benefit; TVC = total variable costs; NB = net benefit, MRR = marginal rate of return; ETB ha^{-1} = Ethiopian Birr per hectare; D = dominated treatments. Market price of coriander = 60.00 ETB kg^{-1}; Cost of NPS= 14.96 kg^{-1}

Table8. *Summary of economic analysis of the effects of NPS fertilizer rates on coriander at three locations in 2020/21 cropping season*

Treats	AGY (kg ha^{-1})			Income (ETB ha^{-1}) Seed grain			GFB (ETB ha^{-1})			TVC (ETB ha^{-1})	NB (ETB ha^{-1})			MRR (%)		
Ferti	AT	DG	LU	AT	DG	LU	AT	DG	LU		AT	DG	LU	AT	DG	LU
0	909.9	774	588.6	63693	54180	41202	63693	54180	41202	0	63693	54180	41202			
30	990	884.7	696.6	69300	61929	48762	69300	61929	48762	523.2	68776.8	61405.8	48238.8	972	1381	1345
60	1350	1121.4	888.3	94500	78498	62181	94500	78498	62181	1046.4	93453.6	77451.6	61134.6	4717	3067	2465
90	1649.7	1155.6	876.6	115479	80892	61362	115479	80892	61362	1569.6	113909.4	79322.4	59792.4	3910	358	D
120	1436.4	1280.7	903.6	100548	89649	63252	100548	89649	63252	2092.8	98455.2	87556.2	61159.2	D	1574	261
150	1145.7	1197.9	1029.6	80199	83853	72072	80199	83853	72072	2616	77583	81237	69456	D	D	1586

Where, AGY = adjusted seed yield; GFB = gross field benefit; TVC = total variable costs; NB = net benefit, MRR = marginal rate of return; ETB ha^{-1} = Ethiopian Birr per hectare; D = dominated treatments. Market price of coriander = 70.00 ETB kg^{-1}; Cost of NPS= 17.44 kg^{-1}

4. Conclusions and Recommendation

As conclusions, the results indicated that the overall performance of the seed yield and essential oil content of the crop was the best in both years with respect to NPS fertilizers rates. The parameters such as number of primary branch, number of umbelets per umbel, seed yield, and essential oil content showed highly significant variation in both years with high concentrations on NPS fertilizer rates. In general, the higher economic yield and feasible NPS fertilizer rates was the soil nourished with (90, 120 and 120 kg NPS ha^{-1}) at Adami Tulu, Dugda and Lume respectively was suggested to the coriander growers.

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