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Essential Oil Yield and Yield Related of Basil (Ocimum basilicum L) as Affected by NPS and Nitrogen Fertilizer Rates at Wondo Genet, Southern Ethiopia

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ABSTRACT

The experiment was conducted on experimental field of Wondo Genet Agricultural Research Center (WGARC), southern Ethiopia under supplementary irrigation in 2017- 2018 cropping season, to assess the effects of NPS and N fertilizer rates on essential oil yield and yield related traits of basil. The experiment consisted of four rates of nitrogen (0, 23, 46, and 69 kg ha-1) and four rates of NPS fertilizer (0, 50,100 and 150 kg ha-1). The treatments were arranged in factorial combination using randomized complete block design (RCBD) with three replications. The analysis of variance revealed that the main effects of NPS and N fertilizer rates significantly affected plant height, number of leaves plant-1 and dry stem weight plant-1. The tallest plant height (32.87 cm) and highest dry stem weight (41.86 g plant-1) were recorded from 100 kg ha-1 NPS rate. Similarly, the tallest plant (31.90 cm) and highest dry stem weight (42.78 g plant-1) were recorded from the highest (69 kg N ha-1) rate. On other hand, the interaction effects of NPS and N fertilizer rates also significantly affected number of primary branches plant-1, fresh leaf weight plant-1, fresh stem weight plant-1, fresh inflorescence weight plant-1, aboveground dry biomass and essential oil yield of basil. Significantly, the highest fresh leaf weight (319.36 g plant-1) and fresh stem weight (176.30 g plant-1) were obtained from combined application of 150 kg ha-1 NPS + 69 kg ha-1 N rates. The highest number of primary branches plant-1(12.63), dry leaf weight (43.93 g plant-1) and aboveground dry biomass (4.64-ton ha-1) were obtained from combined application of 100 kg ha-1 NPS + 69 kg ha-1 N, whereas the highest essential oil yield (30.22 kg ha-1) was due to combination of 100 kg ha-1 NPS + 46 kg ha-1 N rate and it is statistically at par with 50 kg ha-1 NPS + 46 kg ha-1 N. Therefore, combined application of 50 kg ha-1 NPS + 46 kg ha-1 N would be suggested in case of basil used for extracting essential oil.

Key words: Essential oil, Interaction effect, Main effect

INTRODUCTION

Basil (Ocimum basilicum L) is an annual plant of the Lamiaceae family. The genus Ocimum (Lamiaceae) consists of about 50–150 species (Simon *et al.,* 1990). Among all Ocimum species, Ocimum basilicum L, is the most economic important, cultivated and utilized throughout the world (Marotti *et al.,* 1996). Basil is herbaceous species, native to warm regions of Asia, Africa and India, but it is grown commercially all over the Mediterranean region and in California (Heath, 1981).

Basil is important groups of aromatic and medicinal plants which yield many essential oils and aromatic chemicals and find diverse uses in perfumery and cosmetic industries as well as indigenous system of medicine. It is grown for its aromatic properties, while the green leaves are used fresh or dried used as an aromatic spice for flavouring of dishes, salads, stews, sausages and other food (Niederwireser 2001; Koba *et al*., 2009). The oil of basil also used for flavouring of food stuffs, confectionery, condiments, and in toiletry products. It is used in food industries and dental product (Prasad *et al*., 1986; Vieira and Simon 2000). Many medicinal and aromatic plants, including basil, are typically consumed without further processing after harvest (Banchio *et al.,* 2008).

Basil is grown in many countries of the world as spice, medicinal, and aromatic plant. The medicinal and aromatic properties of basil are associated with the presence of an essential oil that accumulates in large amount in its leaves and inflorescences. Its oil is mixture of numerous compounds and its composition is extremely rich and varied. The major essential oil components of basil are: methyl chavicol, linalool, 1, 8-cineole and methyl (Niederwireser 2001). In addition, several purple basil

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cultivars also contain anthocyanins which are powerful antioxidants, and the polyphenolic pigments responsible for the red and blue colors found in many plants (Nguyen and Niemeyer, 2008).

Traditionally, basil leaves are used in folk medicine as a remedy for a large number of diseases, including cancer, convulsion, diarrhea, epilepsy, gout, nausea, sore throat, toothaches, bronchitis coughs, constipation, warts, worms and kidney malfunction (Simon *et al.*, 1990; Simon *et al.*, 1999 and Duke, 2008). Hot tea of basil plant leaves is good for treating nausea, dysentery, and flatulence. Externally, basil formulations can be used for different skin infections such as treatment of acne, snake bites and insect stings (Khatri *et al.*, 1995). Basil also possesses various beneficial effects, e.g., antiseptic, carminative, antimicrobial and antioxidative properties (Baranauskiene *et al.,* 2003). The essential oil of basil is used as antifungal and insect-repelling Werner 1995). The curative properties of basil result from the presence of essential oils, phenolic compounds, flavonoids (Nurzyńska-Wierdak *et al*., 2012) and other substances revealing anti-bacterial (Nour *et al*., 2009), anti-mycotic and antioxidant activities (Sekar *et al*., 2009).

The growth and EO accumulation and composition of basil could be markedly affected by different factors such as environmental factors, physical and chemical properties of soil, seed source, plant age, parts of plant that which used for oil isolation, oil isolation method, genetic and agronomic practices (irrigation, fertilization, time of harvesting) etc. (Marotti *et al.*, 1996; Shahram, 2011). Growth and yield of basil, like other plants, depend upon the availability of all nutrients in the environment. The yield and quality is depends on macro- and micronutrient taken up (Zheljazkov *et al*., 2008). Nitrogen is required by plants in comparatively larger amounts than other elements. Nitrogen applied in the cultivation of herbal plants also stimulates the synthesis of other biologically active substances. Nitrogen contributes to the greatest extent to an increase in the biosynthesis of essential oil and its composition in numerous aromatic plant species (Renata, 2013). Essential oil yield and chemical composition of these plant species can be significantly depend on the rate of nitrogen. In addition to nitrogen essential oil yield is affected by phosphorous fertilizer. Despite the basil is economically important aromatic and medicinal crop, the fertilizer-based research in the country for this crop is limited. Therefore, the experiment was conducted to assess the effects of NPS and N fertilizer rates on essential oil yield and yield related traits of basil in Ethiopia.

MATERIALS AND METHODS

The study was conducted on experimental field of Wondo Genet Agricultural Research Center (WGARC), southern Ethiopia under supplementary irrigation in 2017/2018 cropping season. The geographical coordinate of the area is 7°19'N latitude and 38°38'E longitude with altitude of 1876 meters above sea level. The site receives mean annual rainfall of 1128 mm with minimum and maximum temperature of 11.5 and 26.2°C, respectively. The soil type of the experimental area is Nitosols. Its textural class is sandy clay loam with pH of 6.4 (Abayneh *et al.,* 2006). Wondo Genet has a bimodal rainfall distribution with two rainy seasons. Short rainy season from March to May and main rainy season occur from July to October. The dry season extends from November to February (Dawit and Bekele, 2008).

Basil (genotype B01), one of the promising genotypes collected from different parts of the country by Wondo Genet Agricultural Research Center. Urea as source of N and blended NPS as source of N, P2O5 and S was used.

The experiment consisted of four rates of nitrogen (0, 23, 46 and 69 kg ha-1) and four rates of NPS fertilizer (0, 50,100 and 150 kg ha-1). RCBD design with factorial arrangement was used. There were 16 treatment combinations. The experimental plot had an area of 7.2 m2 (2.4 m length x 3 m width). Spacing of 40 cm between plants and 60 cm spacing between rows were maintained. Three middle rows out of the five rows per plot were used as the sampling unit. Five randomly taken plants from net plot were used for sampling and data analysis. The pathways between blocks and plots were 1.5 m and 1 m, respectively. The gross plot was consisted of 5 rows of 2.4 m length. Thus, the size of gross plot was 5 x 0.60 x 2.4 = 7.2 m2. The net plot size was 1.6 x. 1.8 = 2.88 m2.

One composite soil sample per replication, each made from five sub samples, was collected from the depth of 0 to 30 cm using auger before planting. Physico-chemical parameters include organic carbon, total N, soil pH, available phosphorus (P), cation exchange capacity and soil texture were determined by using standard laboratory procedures at Hawassa University (Collage of Wondo Genet Forestry and Natural Resource). Analysis soil for available sulfur was done at laboratory of Debreziet Agricultural Research Center.

Data Collection and Measurement

Number of Primary Branches Per Plant

The total numbers of branches arising from the main stem of five randomly taken plants were counted manually and the mean value was determined when the plants reach maximum growth stage.

Fresh Leaf Weight Per Plant (g)

The harvested fresh leaf from five randomly taken plants was weighed by using sensitive analytical electronics balance and then the average fresh leaf weight per plant was determined.

Fresh Stem Weight Per Plant (g)

The harvested fresh stem from five randomly taken plants was weighed by using sensitive analytical electronics balance and then the average fresh stem weight per plant was determined.

Fresh Inflorescence Weight Per Plant (g)

It was determined by weighting the total fresh inflorescence produced by five randomly sampled plants at full blooming by using sensitive analytical electronics balance and mean was calculated to get leaf weight per plant.

Dry Leaf Weight Per Plant (g)

It was determined after leaves of randomly taken plants were dried using auto clave at 70 °C for 48 hrs as indicated in Gonzalez and Gonzalez-Vilar (2003).

Dry Stem Weight Per Plant (g)

It was determined after stems of randomly taken plants were dried using auto clave at 70 °C for 48 hrs as indicated in Gonzalez and Gonzalez-Vilar (2003).

Essential Oil Parameters

Essential Oil (EO) Content (%)

Was determined on dry weight (w/w) basis from 200 g of dry composite leaves and inflorescences harvested from the five randomly selected plants of a plot (Daniel *et al*., 2009). The laboratory analysis for basil essential oil content was extracted at WGARC. It was determined by hydro-distillation as illustrated by Guenther (1972).

Essential Oil Yield (kg ha-1)

Essential oil yield per hectare was determined by calculating essential oil content multiplying by dry herb yield (dry leaf yield + dry inflorescence yield) per hectare and dividing by 100.

$$\frac{\text{Essential oil (\%) x dry herb yield (kg/ha)}}{100}$$

Data Analysis

Statistical analysis of experimental data was performed by analysis of variance (ANOVA) using SAS PROC GLM (2002) at $P < 0.05$. Least significant difference (LSD) was conducted at a 5% level of probability, where significance was indicated by F - test (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Soil Physico- Chemical Analysis

The laboratory result of the selected physico-chemical properties of soil before planting is summarized in Table 1.

Growth, Yield and Yield Component Parameters

Number of Primary Branches Per Plant

Analysis of variance showed that NPS rate, N rate and their interaction had highly significant ($P< 0.01$) effect on number of primary branches per plant (Appendix Table 1).

The highest (12.63) and lowest (7.6) number of primary branches per plant were due to combined application of 100 kg NPS ha-1 with 69 kg N ha-1 and control rate of both NPS and N, respectively (Table 2). In general, the increasing number of primary branches per plant as the rate of NPS and N increased, indicating the positive effect of the two fertilizers and 100 kg NPS ha-1 with 69 kg N ha-1 was the best combination for this parameter (Table 2). This could be due the synergetic role of N, P and S nutrients on number of branches. The highest number of primary branches per plant at the highest rates of NPS and N could be due to the rapid conversion of synthesized carbohydrates into protein and consequently the increase in number and size of growing cells, ultimately resulting in increased number of branches. Nitrogen enhances vegetative growth since it plays role in photosynthesis process. On the other hand, phosphorous promotes early root development which helps to nutrient uptake (Uchida, 2000).

The finding agreed with Nurzyńska-Wierdak *et al*. (2012) who reported the highest number of branches at the medium and highest nitrogen rate. Hassan *et al*. (2015) and

Table 1: Physico-chemical properties of the soil of the experimental site before planting

Parameters	Result	Rating	References
Soil texture			
Clay (%)	36		
Sand (%)	40		
Silt (%)	24		
Textural class	Clay loam		
Total Nitrogen (%)	0.138	Medium	Tekalign (1991)
Organic carbon (%)	1.74	Medium	Tekalign (1991)
Soil pH (1: 2.5 H2O)	6.6	Slightly acid	Tekalign (1991)
Available Phosphorous (mg kg^{-1})	2.09	Very low	Cottenie (1980)
Available sulfur (mg kg^{-1})	7.23	Low	Ethiosis (2014)
CEC (34.72 cmol (+) kg^{-1} soil)	34.72	High	London (1991)

Table 2: Interaction effect of NPS and N fertilizers on number of primary branches per plant of basil

Number of primary branches per plant				
NPS rates (kg ha^{-1})		N rates (kg ha^{-1})		
0	23	46	69	
0	7.6^{f}	8.2^{e}	8.93^{d}	9.67^{c}
50	8.53^{ed}	8.87^{d}	9.67^{c}	10.2^{bc}
100	8.87^{d}	8.86^{d}	10.4^{b}	12.63^{a}
150	9.07^{d}	9.8^{c}	10.07^{bc}	12.47^{a}
LSD (0.05)		0.57		
CV (%)		3.54		

Means with the same letter in the column are not significantly different at 5% level of significance; CV (%) =Coefficient of variation, LSD = Least Significant Difference at 5% level.

Kandil *et al*. (2009) reported that the highest number of basil branches due to highest NPK fertilizer rate. Patel and Kushwaha (2003) also reported similar trend in basil. The result of this study also in agreement with Rashid *et al*. (2013) who reported the increasing of number of branches as N rate increased and highest number of branches obtained at 60 kg N ha-1 for stevia crop. According to these authors the lowest number of primary branches per plant was recorded from control/untreated. Yeboah *et al*. (2012) also conducted experiment on artemisia crop and reported that the highest number of branches was obtained due to highest (90 kg N ha-1) whereas the lowest recorded from unfertilized treatment.

Fresh Leaf Weight Per Plant

The analysis of variance revealed that fresh leaf weight per plant was highly significantly ($P< 0.01$) affected by NPS rate, N rates and the interaction of two factors (Appendix Table 1).

The highest (319.36 g plant-1) and lowest (201.79 g plant-1) fresh leaf weight were obtained from the highest rate of the two fertilizers (150 kg NPS ha-1 and 69 kg N ha-1) and the control (0 rate of the NPS and N), respectively (Table 3). The highest weight per plant due to highest combination rate of the two fertilizers was statistically at par with combined application of 100 kg NPS ha-1 and 69 kg N ha-1. Generally, the highest combined application of NPS and N fertilizer rate gave the highest fresh leaf weight and the lowest was due to control/unfertilized. This higher leaf weight under highest NPS and N rate might be due to increased plant height, more leaves per plant and number of leaves per plant. This could be due to the synergetic effects of N, P and S in plant growth. N is a constituent of amino acids, which are required to synthesize proteins and other related compounds;

Table 3: Interaction effect of NPS and N fertilizer rates on fresh leaf weight per plant of basil

	Fresh leaf weight (g plant^{-1})			
NPS rates (kg ha^{-1})	N rates (kg ha^{-1})			
0	23	46	69	
0	201.79^{ef}	245.68^{ef}	264.78^{cd}	270.81^{c}
50	240.35^{f}	264.57^{cde}	269.79^{c}	272.23^{c}
100	245.5f	265.20^{cd}	2792.54^{b}	308.58^{ab}
150	250.37^{def}	243.46^{f}	257.22^{cdef}	319.36^{a}
LSD (0.05)		18.93		
CV (%)		4.31		

Means with the same letter in the column are not significantly different at 5% level of significance; CV (%) =Coefficient of variation, LSD = Least Significant Difference at 5% level.

Table 4: Interaction effects of NPS and N rates on fresh stem weight per plants of basil

	Fresh stem weight (g plant^{-1})			
NPS rates (kg ha^{-1})	N rates (kg ha^{-1})			
	0	23	46	69
0	140.56^{h}	153.88^{g}	167.96^{g}	157.68^{defg}
50	154.92^{fg}	162.18^{cdefg}	174.46^{ab}	166.43^{abcde}
100	155.06^{fg}	165.22^{bcdef}	172.42^{abc}	169.33^{abc}
150	169.11^{abc}	156.64^{efg}	169.41^{abc}	176.30^{a}
LSD (0.05)		10.97		
CV (%)		4.03		

Means with the same letter in the column are not significantly different at 5% level of significance; CV (%) = Coefficient of variation, LSD = Least Significant Difference at 5% level

Table 5: Interaction effects of NPS and N rates on fresh inflorescence weigh per plants of basil

	Fresh inflorescence weight (g plant^{-1})			
NPS rates (kg ha^{-1})		N rates (kg ha^{-1})		
	0	23	46	69
0	80.02^{hg}	85.10^{g}	115.10^{bcd}	86.22^{g}
50	88.16^{g}	101.60^{f}	122.67^{b}	75.83^{h}
100	$107.0d^{ef}$	119.39^{bc}	141.29^{a}	140.03^{a}
150	105.31^{ef}	110.06^{def}	111.61^{cde}	114.44^{bcd}
LSD (0.05)		8.78		
CV (%)		4.94		

Means with the same letter in the column are not significantly different at 5% level of significance; CV (%) = Coefficient of variation, LSD = Least Significant Difference at 5% level.

it plays a role in almost all plant metabolic processes, which enhances vegetative growth (Tucker, 1999). The result was in conformity with Golcz *et al*. (2006) and Kandil *et al*. (2009) who reported increase of leaf weight of basil under increased nitrogen and NPK fertilizer rate.

Fresh Stem Weight Per Plant

Analysis of variance showed that fresh stem weight was highly significantly (P< 0.01) affected by main effects of NPS and N fertilizer rates. It was significantly (P< 0.05) affected by interaction of the two factors (Appendix Table 1).

Fresh stem weight per plant was increased as NPS and N fertilizer rate increased and reach maximum at highest combination of two fertilizer rates. The highest (176.3 g plant-1) and significantly lowest (140.56 g plant-1) fresh stem weight were due to highest combination of 150 kg NPS ha-1 + 69 kg N ha-1 rate and control (0 rate of NPS and N), respectively (Table 4). The fresh stem weights at each combination rates were statistically higher than control/untreated. The highest fresh stem weight per plant at highest combination of NPS and N rate indicated that, fertilizers enhance vegetative growth of basil. This could be due to positive effects of three nutrients on plant growth. Nitrogen and sulfur play vital role in the structure of chlorophyll, the primary light harvesting compound of photosynthesis, which contributes in plant growth and development (Boroomand and Grouh 2012). Phosphorus is an essential nutrient both as a part of several key plant structure compounds and as a catalysis in the conversion of numerous key biochemical reactions in plants (Griffith, 2010). The finding was in agreement with study of Kandil *et al*. (2009) who reported that the increasing trend of basil fresh stem weight as NPK fertilizer rate increased. Farrokh *et al*. (2012b) reported that fresh stem weight was increased as N rate increased and the highest weight produced at 65 kg ha-1 N application in tobacco.

Fresh Inflorescence Weight Per Plant

Analysis of variance revealed that NPS rate, N rate and the interaction effects of two factors had highly significant (P< 0.01) effect on fresh inflorescence weight (Appendix Table 1).

The combined application of 100 kg NPS ha-1 with 46 kg N ha-1 and 50 kg NPS ha-1 with 69 kg N ha-1 gave the highest (141.29 g plant-1) and lowest (75.83 g plant-1) fresh inflorescence weight, respectively (Table 5). The highest fresh inflorescence weight produced by combination of 100 kg NPS ha-1 and 46 kg N ha-1 could be due to the positive effects of three nutrients in inflorescence growth. This might be due to nitrogen role in create amino acids, which are used in forming protoplasm, the site for cell division and thus for plant growth and development. On other hand, phosphorous promotes early root development which helps to nutrient uptake and play role in flower initiation (Uchida, 2000). Kandil *et al*. (2009) reported that basil fresh inflorescence weight was increased with increasing of NPK fertilizer rates.

Dry Leaf Weight Per Plant

Dry leaf weight per plant was highly significantly (P< 0.01) affected by main effects of NPS and N fertilizer rates. On other hand, the interaction of two factors had significant (P< 0.05) effect on dry leaf weight (Appendix Table 2).

The combined application of 100 kg NPS ha-1 + 69 kg N ha-1 produced the highest dry leaf weight (43.93 g plant-1) and it was statistically at par with the highest rate of 150 kg NPS ha-1 + 69 kg N ha-1 combination rate.

However, the lowest (26.31 g plant-1) dry leaf weight was recorded at control/unfertilized (Table 6). The highest dry leaf weight at combined application of 100 kg NPS ha-1 + 69 kg N ha-1 fertilizer rates might be due to synergetic effects of three nutrients in leaf growth and development. This could be due to the role of nitrogen in the structure of chlorophyll, the primary light harvesting compound of photosynthesis, which contributes in plant growth and development (Boroomand and Grouh 2012). Phosphorous enhance early root growth which allow absorbing nutrients for normal plant growth. Sulfur and N play roles in chlorophyll formation and increase photosynthesis rate. The result was in agreement with Farrokh *et al.* (2012a) who reported that dry leaf weight of tobacco was consistently increased with N fertilizer rate and the highest dry leaf weight was obtained at 65 kg N ha-1 rate. The authors also reported that the lowest dry leaf weight was due to control treatment.

Table 6: Interaction effects of NPS and N rates on dry leaf weight per plant of basil.

	Dry leaf weight (g plant^{-1})			
NPS rates	N rates (kg ha^{-1})			
(kg ha^{-1})	0	23	46	69
0	26.31^{g}	32.37^{f}	38.83^{abcde}	38.12^{abcdef}
50	33.84^{ef}	40.84^{abcd}	37.59^{bcde}	38.86^{abcde}
100	35.22def	38.33^{abcde}	41.62^{abc}	43.93^{a}
150	36.08^{cdef}	33.47^{ef}	34.47^{ef}	43.23^{ab}
LSD (0.05)	5.93			
CV (%)	9.59			

Means with the same letter in the column are not significantly different at 5% level of significance; CV (%) = Coefficient of variation, LSD = Least Significant Difference at 5% level.

Table 7: Main effects of NPS and N rates on dry stem weight per plant and dry stem yield per hectare

Treatments	Dry stem weight (g plant^{-1})
NPS rates (kg/ha)	
0	35.96^{b}
50	39.34^{ab}
100	41.86^{a}
150	39.12^{ab}
LSD (0.05)	4.05
N rates (kg/ha)	
0	34.90^{b}
23	38.79^{ab}
46	39.80^{a}
69	42.78^{a}
LSD (0.05)	4.05
NPS*N	NS
CV (%)	12.43

Means with the same letter in the column are not significantly different at 5% level of significance; CV (%) = Coefficient of variation, LSD = Least Significant Difference at 5% level; NS= non-significant

Table 8: Interaction effects of NPS and N rates on essential oil yield of basil

	Essential oil yield (kg ha^{-1})			
NPS rates	N rates (kg ha^{-1})			
(kg ha^{-1})	0	23	46	69
0	15.30^{i}	20.12^{gh}	24.43^{cdefg}	25.37^{bcdef}
50	21.21^{fgh}	25.04^{bcdef}	27.59^{abcd}	23.08^{efgh}
100	19.68^{hi}	26.92^{abcde}	30.22^{a}	29.30^{ab}
150	24.19^{cdefg}	25.08^{bcdef}	23.31^{defgh}	28.23^{abc}
LSD (0.05)	4.44			
CV (%)	10.94			

Means with the same letter in the column are not significantly different at 5% level of significance; CV (%) =Coefficient of variation, LSD = Least Significant Difference at 5% level.

Dry Stem Weight Per Plant

Analysis of variance showed that dry stem weight per plant was significantly (P< 0.05) and highly significantly (P< 0.01) affected by NPS and N rates, respectively. However, it was not significantly affected by interaction effects of the two factors (Appendix Table 2).

The highest (41.86 g plant-1) and lowest (35.96 g plant-1) dry stem weight per plants were obtained at 100 kg NPS ha-1 rate and control/untreated, respectively (Table 7). The highest dry stem weight per plant due to 100 kg NPS ha-1 was significantly higher than control. However, it was at par with 50, and 150 kg NPS ha-1.

The lowest (35.96 g plant-1) dry stem weight per plants due to control was statistically equal with all NPS and N rates except 100 kg ha-1. The highest dry stem weight at 100 kg NPS ha-1 rate could be due to fertilizers role in increasing plant height, number of branches per plant, internodes length and stem thickness. Nitrogen can strengthen and support plant roots, enabling plants to take in more water and nutrients; and allows a plant to grow more rapidly (Eckert, 2010). Similarly, P stimulated root development, increased stem strength and enhance vegetative growth (Uchida, 2000).

Dry stem weight per plant was consistently increased with increasing N fertilizer rate and reach highest (42.78 g plant-1) at 69 kg ha-1 N rate. However, the lowest (34.90 g plant-1) was obtained due to control/unfertilized. The lowest dry stem weight recorded from control might be due to the soil of experimental site was deficient in P and S as listed in Table 2. Dry stem weight was increased by 22.58% as N rate increased from 0 to 69 kg ha-1. The increased dry stem weight per plant with increasing of N fertilizer rate might be due to the fact nitrogen is an integral part of chlorophyll manufacture through photosynthesis enhance rapid vegetative growth (Tucker, 1999). The result was in agreement with Farrokh *et al*. (2012a) who reported the highest dry stem weight of tobacco was due to N application as compared to control/unfertilized.

Essential Oil Content

Analysis of variance revealed that NPS, N rates and their interaction did not significantly affect essential oil content (Appendix Table 2). Similar result was supported by Verma *et al*. (2017) reported on mint, Kandil *et al*. (2009) on Ocimum basilicum L..

Essential Oil Yield

Analysis of variance showed that the main effects of NPS and N rate highly significantly (P< 0.01) and interaction of two the factors significantly (P< 0.05) affected essential oil yield (Appendix Table 2).

The result indicated that essential oil yield increased with increasing fertilizer rates and the highest essential oil yield (30.22 kg ha-1) was obtained at combined application of 100 kg ha-1 NPS + 46 kg ha-1 N followed by 100 kg NPS ha-1 + 69 kg N ha-1 (29.30 kg ha-1), while the lowest (15.3 kg ha-1) was recorded at control/untreated (Table 8). Even though the highest essential oil yield was recorded at combined application of 100 kg NPS ha-1 with 46 kg N ha-1 N rates, statistically it was at par with 50 kg NPS ha-1 + 46 kg N ha-1 N. Thus, combined application of 50 kg NPS ha-1 with 46 kg N ha-1 N rates is optimum for enhancing essential oil yield. The production of highest essential oil yield at combination of 100 kg NPS ha-1 + 46 kg N ha-1 N rates could be due to positive effects of N, P and S on leaf and inflorescence growth and development which contribute for essential oil yield. Moreover, N application increased essential oil yield by enhancing the amount of leaf and inflorescence produced per unit land area through increasing leaf area development, photosynthesis rate and vegetative growth (Tucker, 1999).

The result was in agreement with Verma *et al*. (2017) who found that the significantly increasing of essential oil yield of mint as N and P2O5 increased. The authors also reported that the lowest essential oil yield obtained at control/untreated. The result of present study also in conformity with Alsafar and Al-Hassan (2009) who reported that highest essential oil yield was recorded due to

N and P2O5 fertilizer application as compared to unfertilized treatment.

Moghadam and Gurbuz (2013) also stated that essential oil yield of basil increased as N fertilizer increased and the highest yield was obtained at 100 kg N ha-1 fertilizer rate. Similar result was reported by Singh and Ramesh (2002) on Ocimum basilicum L.

Summary and Conclusion

Basil production in Ethiopia is limited due to lack of different technologies, such as; plant spacing and population density, harvesting stage, post-harvest drying and storage and lack of site-specific fertilizer recommendation. Even though basil is the most economic important crop, the study on the fertilizer aspect of this plant in Ethiopia in general and in Sidama zone in particular is limited. Therefore, this experiment was conducted on experimental field of Wondo Genet Agricultural Research Center (WGARC), southern Ethiopia under supplementary irrigation in 2017/2018 cropping season, to assess the effects of NPS and N fertilizer rates on yield and yield related traits of basil and evaluate the economic feasibility of fertilizer rates for basil crop.

Data was collected on: number of primary branches per plant, fresh leaf weight per plant, fresh stem weight per plant, fresh inflorescence weight per plant, dry leaf weight per plant, dry stem weight per plant, essential oil content and essential oil yield. The analysis of variance revealed that the main effects of NPS and N fertilizer rates significantly affected dry stem weight per plant of basil. The highest dry stem weight (41.86 g plant-1) was obtained from 100 kg NPS ha-1 rate. On other hand, the highest dry stem weight (42.78 g plant-1) was recorded due to highest N fertilizer rate (69 kg N ha-1). However, the lowest value of dry stem weight per plant was recorded at control (0 kg ha-1 NPS and N rate).

The interaction effects of NPS and N fertilizer rates significantly affected number of primary branches per plant, fresh leaf weight per plant, fresh stem weight per plant, fresh inflorescence weight per plant and essential oil yield of basil crop. The combined fertilizer application of highest (150 kg NPS ha-1 and 69 kg N ha-1) rates resulted in highest fresh leaf weight (319.36 g plant-1) and fresh stem weight (176.3 g plant-1). However, the lowest fresh leaf weight (201.79 g plant-1), fresh stem weight (140.56 g plant-1) were recorded from control/unfertilized.

Likewise, the highest number of primary branches per plant (12.63) and dry leaf weight (43.93 g plant-1) were obtained from combined application of 100 kg ha-1 NPS + 69 kg ha-1 N rates. However, the lowest number of primary branches per plant (7.6) and dry leaf weight (26.31 g plant-1) were obtained from control treatment. On other hand, highest fresh inflorescence weight (141.29 g plant-1) and essential oil yield (30.22 kg ha-1) were obtained due to combined application of 100 kg ha-1 NPS with 46 kg ha-1 N rate, whereas the lowest fresh inflorescence weight (75.83 g plant-1) was recorded from combined fertilizer application of 50 kg NPS ha-1 with 69 kg N ha-1 rate. The highest essential oil yield (30.22 kg ha-1) produced by combined application of 100 kg NPS ha-1 + 46 kg N ha-1 was statistically at par with 50 kg NPS ha-1 + 46 kg N ha-1 (27.59 kg ha-1). The lowest essential oil yield was recorded due to control/unfertilized treatment. In general, for almost all parameters the lowest value was recorded from control/unfertilized treatment as compared to application of NPS and N fertilizer rates. Thus, combined application of 50 kg NPS ha-1 + 46 kg N ha-1 would be suggested in case of basil used for extracting essential oil. However, since the present study was conducted at one location for one season, further study at different location for minimum of three seasons at different agro ecologies is needed to come up with dependable recommendation for basil production.

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APPENDICES

Appendix Table 1: Mean squares of ANOVA for growth, yield and yield related traits of basil as affected by NPS and N rates

Source of Variation	DF	NPBPP	FLWPP	FSWPP	FIWPP
Rep	2	0.50	281.03	136.22	45.98
NPS rates	3	7.79**	2172.97**	382.66**	2972.64**
N rates	3	17.36**	7319.99**	649.28**	1612.53**
NPS X N	9	0.93**	758.16**	102.81*	409.11**
Error	30	0.11	128.88	43.24	27.71
CV (%)		3.54	4.31	4.03	4.94

ns; not significant at P< 0.05, * significant at P< 0.05; ** significant at P<0.01 probability level; DF=Degree of freedom; Rep=Replication, NPBPP=Number of primary branches per plant, FLWPP=Fresh leaf weight per plant, FSWPP=Fresh stem weight per plant and FIWPP=Fresh inflorescence weight per plant.

Appendix Table 2: Mean squares of ANOVA for yield and yield related traits of basil as affected by NPS and N rates

Source of Variation	DF	DLWPP	DSWPP	EOC	EOY
Rep	2	22.03	5.24	0.0032	6.08
NPS rates	3	71.56**	70.20*	0.0088ns	59.02**
N rates	3	140.89**	127.17**	0.0375ns	107.38**
NPS X N	9	29.76*	122.16ns	0.0144ns	20.27*
Error	30	12.64	23.86	0.0135	7.08
CV (%)		9.59	12.43	11.11	10.94

ns; not significant at P<0.05, * significant at P<0.05; ** significant at P<0.01 probability level; DF=Degree of freedom; Rep=Replication, DLWPP=Dry leaf weight per plant, DSWPP= Dry stem weight per, EOC= Essential oil content, EOY= Essential oil yield.