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Research article

Effects of Nitrogen and Phosphorous on Yield and Yield Component of Sage (*Saliva officinal's* L.) at Wondo Genet and Koka, Ethiopia

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Field experiment was conducted at Wondo Genet Agricultural Research Center and Koka substation in 2017/2018 and 2018/2019 cropping season in order to identify economically optimum nitrogen and phosphorus rates for some selected agronomic characteristics, essential oil yield and oil content of sage. Four nitrogen levels (0, 46, 92 and 138 kg N ha^{-1}) and four phosphorus levels (0, 30, 60 and 90 kg P ha^{-1}) would be laid out in factorial RCBD with three replications. At both testing sites, results revealed that plant height, leaf and stem fresh and dry weight, above ground fresh biomass, essential oil yield were significantly affected by separate effect of nitrogen and phosphorus rates. At koka, essential oil content, on the other hand, was significantly affected by nitrogen and phosphorus while didn't show any significant variation at Wondo Genet. At both testing sites, the interaction effect didn't show any significant effect in all collected parameters. At Wondo Genet, application of 46 kg N ha^{-1} and 30 kg P ha^{-1} gave the highest plant height, leaf and stem fresh and dry weight, above ground fresh biomass and essential oil yield of sage. Similarly, at koka, the highest plant height, leaf and stem dry weight were obtained at 138 kg N and 30 kg P ha^{-1}; leaf fresh weight at 46 kg N ha^{-1} and 30kg P ha^{-1}; above ground fresh biomass at 138 kg N and 60kg P ha^{-1}; EOY at 46kg N and 60 kg P ha^{-1}and EOC at 0 kg N and 30kg P ha^{-1}. Thus, at Wondo Genet N and p at the rate of 46 kg N ha^{-1} and 30 kg P ha^{-1}could be recommended for maximum economic yield of sage. While at Koka and other similar soil type and agro ecologies, application of N and P at the rate of 46 and 30 kg for leaf fresh weight;138 kg N and 30 kg P ha^{-1}for leaf dry weight and 46 and 60 for essential oil yield is recommended.

Key words: Sage, Nitrogen and Phosphorus, oil content and oil yield

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INTRODUCTION

During the recent past, there has been a resurgence of interest in study and use of medicinal plants. Now the medicinal plants as a whole occupy a stable position in modern medicine, since the pharmaceutical industry is showing special interest in using or synthesizing natural substance extracted from the plant. Further, there has been an ever increasing demand especially from developed countries for more and more drugs from plants sources. The increasing reliance on the use of medicinal plants in the industrialized societies has been traced to the extraction and development of several drugs and chemotherapeutics from these plants as well as from traditionally used rural herbal remedies (UNESCO 1998). According to a World Bank study, the world market is controlled to grow to US$ 5 trillion by 2050. Herbal medicinal plants contain phytochemical compounds which have demonstrated bioactive properties. A plant product may be standardized based on the level of a particular bioactive phytochemical. The increasing global interest and expanding market of herbal drugs have led to their introduction into cultivation to meet the demand at reasonable economic price. Cultivation of medicinal and aromatic plants can also facilitate in maintaining standards in quality, potency and chemical composition of the products. However, the economic values of medicinal and aromatic plants in Ethiopia are recently known. Due to this, there is no research conducted on most agronomic management to increase crop productivity and quality of the end products. Among the different agronomic management practices, determination of fertilizer rate for the specific crop is one of the most essential for maximum yield of the crop.

Fertilizer application generally causes an increase in herbage yield, bioactive and volatile oil yield of medicinal and aromatic plants. Different scholars elsewhere in the world reported that certain definite level of fertilizer rate is important for maximum economic and agronomic yield of medicinal and aromatic plants. N fertilization has been reported to reduce essential oil content in creeping juniper (Juniperus horizontalis) (Robert, 1986), although it has been reported to increase total essential oil yield in thyme (Thymus vulgaris L.) (Baranauskienne *et al.*, 2003). Baranauskienn et al., (2003) found that N fertilizer increased herb yield, but essential oil content was not remarkable of thyme (Thymus vulgaris). Ashraf *et al.*, (2006) showed that N fertilization had a significant increase in the oil content but did not affect on the nutrient content of black cumin (Nigella sativa L.). Marigold plant height, number of flowers per plant, number of branch per plant and flower yield per hectare was recorded significantly highest with application of 60kg P_2O_5 (Jadhav *et al.*, 2014). Manojkumar (2012) reported the highest N and P level (100 kg ha^{-1}) produced significantly higher yield of marigold flower over the lower N and P. However, medicinal and aromatic plant in Ethiopia being new crops, little is known about their fertilizer requirement especially nitrogen & phosphorous. Among the different aromatic and medicinal plants, sage is one of the most essential and most adopted plant in Ethiopia, where their optimum nitrogen and phosphorus rate is not yet determined. Therefore, there is a need to study on responses of sage plant to nitrogen and phosphorous fertilizer rates to come up with optimum N and P rats for use by small scale growers and investors.

Specific objective

- To determine agronomic optimum rates of Nitrogen and Phosphorous for improved yield and yield components of sage

MATERIAL AND METHODS

The experiment was conducted under irrigated condition in the research field of Wondo Genet and Koka during two successive season of 2017/18 and 2018/19 cropping seasons.Wondo Genet experimental site was geographically located at 07° 19.1' North latitude, 38° 30' East longitude and an altitude of 1780 m.a.s.l. It was received mean annual rain fall of 1128 mm with minimum and maximum temperature of 11 and 26°c, respectively.The texture of the top soil (0-20cm) was clay with slightly acidic (pH 6.28, 1:2.5 soil water suspensions). Koka was geographically located at 08°26.1' North latitude, 39° 01' East longitude with an altitude of 1617m.a.s.l. The texture of the top soil (0-20cm) was loam with moderately alkaline (pH 7.75).

Composite soil sample was taken at random from different spots to make a composite sample per test field at depths of 0-20 cm before fertilizer application through the help of Auger. A sizeable quantity of composite soil samples was air-dried and sieved through a 2 mm mesh and subjected to physical and chemical analysis. The soil was analyzed for pH and available phosphorus following standard laboratory procedures (Sahlemedhin Sersu and Taye Bekele, 2000). Seedlings of sage were raised in the nursery for three months and transplanted to well-prepared actual field for planting. Factorial combination of four level of Nitrogen (0, 46, 92 & 138 kg ha^{-1}) and phosphorous (0, 30, 60 & 90 $kgha^{-1}$) with total of sixteen treatment combinations were laid out in Randomized Complete block Design (RCBD) with three replications.Urea and TSP were used as source of nitrogen and phosphorous fertilizer, respectively. Full dose of phosphorous was applied as basal dressing during planting. Nitrogen containing urea fertilizer was applied in split form (1/3 during planting and remaining 2/3 two month after transplanting). Plot size for each treatment was 3.60m width x 3m length to which sage was planted with intra and inter row spacing of 60 and 60 cm apart respectively. All agronomic practices including weeding and harvesting was done as per the recommendation for the crop.Over all, there was five rows per plot and 6 (six) plants per row that accommodate total of 30 plants per plot.

Five plants were selected randomly from each plot by excluding borders to collect yield and yield contributing characters such as plant height(cm), above ground fresh biomass(g), Leaf fresh weight(g), stem fresh weight(g), leaf dry weight(g), essential oil yield(g), and essential oil content (w/w, wet based, %) of the plant. Essential oil yield analysis was done using gas chromatography-mass spectrophotometer apparatus. Depending on the climatic condition and the crop need, supplementary irrigation was used. The collected data were statistically analyzed using SAS computer soft ware version 9.0 English (SAS, 2000). For those parameters in which their ANOVA results found to be significant, further means separations were done using least significant difference (LSD) at 5% probability level.

RESULT AND DISCUSSION

Soil Physic-chemical Properties of the experimental soil before planting

Selected physico-chemical properties of the composite surface soil (0-20 cm) collected before planting showed that the textural class of the soil was clay with slightly acidic (pH 6.28) at Wondo Genet and loam with moderately alkaline (pH 7.75) at Koka based on soil textural classification triangle (Table 1) indicating that these properties are favorable for sage production.

Available P of the two experimental sites were 7.81 and 9.58 mg kg^{-1} (Table 1) could be considered as medium accordance with Landon (1991), who classified available P of the soil <5, 5-15 and > 15 as low, medium and high respectively. This indicated that P is probably a limiting nutrient for optimum crop growth and yield in the experimental sites.

Table 1. Selected soil physical and chemical properties of the experimental site before planting at Wondo Genet and koka in 2017/18 and 2018/19 cropping seasons

Wondo Genet											**Koka**		
Physical property				**Chemical properties**			**Physical property**				**Chemical properties**		
Particle size distribution			Textural class	pH (H_2O)	Total N (%)	Available P(mg kg^{-1})	Particle size distribution			Textural class	pH (H_2O)	Total N (%)	Available P(mg kg^{-1})
clay	silt	Sand	Clay	6.28	ND	7.81	clay	Silt	sand	loam	7.75	ND	9.58
50	40	10					26	32	42				

Plant Height

At Wondo Genet, the analysis of variance in both consecutive cropping seasons and pooled mean revealed that plant height was significantly affected by nitrogen (Table 2). The tallest plant height (71.40 cm) in 2017/18 cropping season, (48.05cm) in 2018/19 cropping season and (59.73cm) in the pooled mean was found from application of 138 kg N ha^{-1} though statistically similar with 46 and 92 kg N ha^{-1} (Table 2).The significant variation was observed compared with the control treatments.The combined analysis of two years data showed that application of nitrogen at the rate of 46, 92 and 138 kg ha^{-1} gave about 8, 7 and 11% height increment compared with the control treatments (without nitrogen).The significant difference in different rates of nitrogen in both consecutive cropping seasons and pooled mean might be because of the lower total nitrogen in the soil and application of nitrogen solved its deficiency which agrees with the findings of other studies (Jayalakshmi*et al.*, 2013; Amira, 1998). Besides, plant height increment due to successive increase of nitrogen from zero to higher dose could be due to large cells development at increasing N levels (Black, 1967) with higher meristematic activities, which consequently benefited the growth. Similarly, except 2018/19 cropping season, application of phosphorus had significant effect on plant height of sage (Table 2). Similar to nitrogen, the significant variation was observed compared with the control treatments. The tallest sage (70.83cm) in 2017/18 cropping season and (59.05cm) in the pooled mean was found with the application of 60 kg P ha^{-1} even though there was no statistical significant variation compared with 30 and 90 kg P ha^{-1}. Observing the pooled mean, about 2, 6 and 3% height increment respectively was found compared with unfertilized plots. The order of superiority with regard to highest dose of phosphorus might be due to medium level of phosphorus in the soil which could probably be a limiting nutrient for plant height of sage. When the Phosphorus level is too low to sustain plant growth, the plants become shorter and the total biomass is lower compared with the plants with sufficient phosphorus (Marschner, 1995; Dordas, 2009). In addition, Hull and Liu, 2005 and Bauer *et al.,* 2012 explained that nitrogen and phosphorous were responsible for transfer or storage of energy, producing protein, improving the various growth characters and development of plants.

Similarly, at Koka testing site, except the first cropping season, application of nitrogen gave significant variation on plant height of sage (Table 3). Nitrogen at the rate of 138 kg N ha^{-1}gave the tallest plant height (74.14cm) in 2018/19 cropping season and (65.64cm) in the pooled mean (Table 3). Compared with control (unfertilized) plots, application of nitrogen at the rate of 138 kg N ha^{-1} gave about 22 and 15% height increment in 2018/19 and pooled mean respectively. The non significant variation in the first year might be due to other environmental factors and growing condition of the plant. In the same way, the analysis of variance in both consecutive cropping seasons and pooled mean indicated that plant height was significantly affected by phosphorus though the variation was compared with the control treatments (Table 3). In 2017/18 cropping season, the tallest plant height (57.03cm) was found at the rate of 30 kg P ha^{-1} while in 2018/19 cropping season and the pooled mean 90 kg P ha $^{-1}$ gave the tallest plant height (71.26cm) and (63.64cm) respectively though statistically similar with 30 kg P ha^{-1}. Mengel and Kirkby, (1980), in support of this result, explained that favorable effect of phosphorus fertilizer on plant growth could be due to its importance in the overall metabolism of plant. Similarly, Belstie *et al.* (2017) reported that the tallest mean plant height of Artemisia (133.97cm) was found at 30kg P ha^{-1}. Sharma and Kumar (2012) also reported that N fertilizer encouraged growth parameters of Clary sage (Salvia sclarea Linn.) compared with the control.

Table 2: Mean yield of Sage (*Saliva officinal's* L.) as affected by nitrogen and phosphorus rates at Wondo Genet in 2017/18, 2018/19 cropping seasons and pooled mean

Treatment	2017/18				2018/19				Over years			
	PH (cm)	LFW (ton/ha)	SFW (ton/ha)	AGFB (ton/ha)	PH (cm)	LFW (ton/ha)	SFW (ton/ha)	AGFB (ton/ha)	PH (cm)	LFW (ton/ha)	SFW (ton/ha)	AGFB (ton/ha)
Nitrogen												
0	63.35^{b}	9.54^{c}	4.80^{c}	14.34^{b}	43.60^{b}	8.86^{c}	2.18^{b}	11.04^{c}	53.48^{b}	9.20^{b}	3.49^{b}	12.69^{b}
46	70.57^{a}	11.84^{ab}	6.64^{a}	18.49^{a}	46.17^{a}	9.89^{ab}	2.76^{a}	12.65^{ab}	58.37^{a}	10.86^{a}	4.70^{a}	15.57^{a}
92	67.68^{a}	11.20^{b}	5.99^{ab}	17.19^{a}	47.43^{a}	10.45^{a}	2.95^{a}	13.40^{a}	57.56^{a}	10.82^{a}	4.47^{a}	15.29^{a}
138	71.40^{a}	12.80^{a}	5.79^{b}	18.59^{a}	48.05^{a}	9.03^{bc}	2.73^{a}	11.76^{bc}	59.73^{a}	10.92^{a}	4.26^{a}	15.17^{a}
LSD (0.05)	4.21	1.21	0.85	1.65	2.37	0.98	0.36	1.18	2.83	0.75	0.50	1.05
Significant level	**	***	***	***	**	**	***	**	***	***	***	***
Phosphorus												
0	63.82^{b}	9.72^{b}	5.07^{b}	14.78^{b}	47.49	9.47	2.97	12.43	55.65^{b}	9.59^{b}	4.02	13.61^{b}
30	68.37^{a}	12.23^{a}	6.24^{a}	18.47^{a}	45.45	9.93	2.50	12.44	56.91^{ab}	11.08^{a}	4.37	15.45^{a}
60	70.83^{a}	11.49^{a}	5.93^{a}	17.42^{a}	47.27	9.79	2.66	12.45	59.05^{a}	10.64^{a}	4.29	14.93^{a}
90	69.98^{a}	11.97^{a}	5.98^{a}	17.94^{a}	45.04	9.04	2.50	11.54	57.51^{ab}	10.50^{a}	4.24	14.74^{a}
LSD (0.05)	4.21	1.21	0.85	1.65	ns	ns	ns	ns	2.83	0.75	ns	1.05
Significant	**	***	*	***	ns	ns	ns	ns	*	**	ns	**
N*P	ns	ns	ns	ns	ns	ns	ns	ns	Ns	ns	ns	Ns
CV (%)	7.40	12.75	17.63	11.55	6.12	12.28	16.27	11.63	5.93	8.63	14.20	8.59

*,**,***Significant at p≤0.05, p≤0.01 and p≤0.001, respectively; ns= not significant. Means with the same letter in column are not significantly different at p<0.05; LSD: Least Significant Difference; PH: Plant height; LFW: Leaf fresh weight; SFW: Stem Fresh weight, AGFB: Above ground fresh biomass

Table 3: Mean yield of Sage (*Saliva officinal's* L.) as affected by nitrogen and phosphorus rates at koka in 2017/18, 2018/19 cropping seasons and pooled mean

Treatment	2017/18				2018/19				Over years			
	PH (cm)	LFW (ton/ha)	SFW (ton/ha)	AGFB (ton/ha)	PH (cm)	LFW (ton/ha)	SFW (ton/ha)	AGFB (ton/ha)	PH (cm)	LFW (ton/ha)	SFW (ton/ha)	AGFB (ton/ha)
Nitrogen												
0	53.57	13.79^{d}	5.28^{b}	19.07^{b}	57.50^{d}	15.95^{d}	6.73^{c}	22.36^{c}	55.53^{c}	14.87^{c}	6.01^{c}	20.71^{d}
46	54.80	**16.68^{a}**	5.50^{b}	22.18a	69.66^{b}	19.81^{b}	8.10^{b}	27.91^{b}	62.23^{b}	18.24^{a}	6.80^{bc}	25.04^{b}
92	54.87	15.47^{b}	5.66^{b}	21.13^{a}	65.77^{c}	17.67^{c}	8.47^{ab}	26.14^{b}	60.32^{b}	16.57^{b}	7.07^{b}	23.63^{c}
138	57.13	14.68^{c}	**6.98^{a}**	21.65^{a}	74.14^{a}	21.47^{a}	9.56^{a}	31.03^{a}	65.64^{a}	18.07^{a}	8.27^{a}	26.34^{a}
LSD (0.05)	ns	0.70	0.87	1.15	3.50	1.28	1.16	1.96	3.22	0.81	0.82	1.27
Significant level	ns	***	**	***	***	***	***	***	***	***	***	***
Phosphorus												
0	52.23^{b}	14.22^{c}	4.72^{b}	18.93^{b}	61.40^{c}	18.00^{b}	7.43^{b}	25.43^{b}	56.82^{b}	16.74	6.50^{b}	23.24^{c}
30	57.03^{a}	14.75^{bc}	6.48^{a}	21.23^{a}	68.43^{ab}	19.27^{ab}	8.28	27.55	62.73^{a}	16.38	6.95	23.33^{bc}
60	55.08^{ab}	15.40^{b}	6.13^{a}	21.53^{a}	65.96^{b}	19.56^{a}	8.31	27.53	60.53^{a}	17.48	7.22	24.53^{ab}
90	56.02^{ab}	16.24^{a}	6.10^{a}	22.34^{a}	71.26^{a}	18.07^{b}	8.85	26.92	63.64^{a}	17.16	7.48	24.63^{a}
LSD (0.05)	4.30	0.70	0.87	1.15	3.50	1.28	ns	ns	3.22	ns	ns	1.27
Significant level	*	***	**	***	***	*	ns	ns	***	ns	ns	*
N*P	Ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	Ns
CV (%)	9.36	5.54	17.9	6.55	6.28	8.19	16.87	8.73	6.33	5.72	13.84	6.36

*,**,*** Significant at p≤0.05, p≤0.01 and p≤0.001, respectively; ns= not significant. Means with the same letter in column are not significantly different at p<0.05; LSD: Least Significant Difference; PH: Plant height; LFW: Leaf fresh weight; SFW: Stem Fresh weigt, AGFB: Above ground fresh biomass

Leaf, stem and above ground fresh biomass (ton ha^{-1})

At Wondo Genet, in both consecutive cropping seasons and pooled mean, leaf fresh weight, stem fresh weight and above ground fresh biomass were significantly(p≤0.01) influenced by nitrogen fertilizer (Table 2). In both cropping seasons and pooled mean, significant highest leaf, stem and above ground fresh biomass were found in treatments which receive nitrogen in different rates while the lowest was recorded in the control treatment. Accordingly, maximum leaf fresh weight (12.80ton ha^{-1}) in the first cropping season, (10.45ton ha^{-1}) in the second cropping season and (10.92ton ha^{-1}) in the pooled mean were found at 138, 92 and 138 kg N ha^{-1} respectively though statistically similar with the lowest rate of nitrogen (46 kg N ha^{-1}) in the two consecutive cropping seasons and 92 and 46 kg N ha^{-1} in the pooled mean (Table 2). Similarly, the highest stem fresh weight (6.64 ton ha^{-1}) in 2017/18, (2.95 ton ha^{-1}) in 2018/19 and (4.70 ton ha^{-1}) in the pooled mean was obtained at 46, 92 and 46 kg N ha^{-1} respectively. However, stem fresh weight obtained at 92 kg N ha^{-1} in the second year was statistically at par with 46 kg N ha^{-1}. In the same way, the highest above ground fresh biomass (18.59 ton ha^{-1}) in 2017/18, (13.40 ton ha^{-1}) in 2018/19 and (15.57 ton ha^{-1}) in the pooled mean was found at 138, 92 and 46 kg N ha^{-1} respectively. The highest above ground fresh biomass obtained at 138 and 92 kg N ha^{-1} in the first and second cropping season was statistically similar with 46 kg N ha^{-1}. Observing the combined analysis of two years data, above ground fresh biomass was increased by 18, 17 and 16% at 46,92 and 138kg N ha^{-1} respectively compared with control (unfertilized) plots.

Similarly, application of phosphorus in 2017/18 cropping season had significant effect on leaf fresh weight (p≤0.001), stem fresh weight (p≤0.05) and above ground fresh biomass (p≤0.001) (Table 2). The highest leaf fresh weight (12.23 ton ha^{-1}), stem fresh weight (6.24 ton ha^{-1}) and above ground fresh biomass (18.47 ton ha^{-1}) in 2017/18 cropping season were found at 30 kg P ha^{-1} though statistically at par with the highest two rates of phosphorus (60 and 90 kg P ha^{-1}). However, in 2018/19 cropping season, phosphorus didn't show significant (p>0.05) effect on leaf, stem and above ground fresh biomass (Table 2). The pooled mean revealed that different phosphorus rates showed significant effect on leaf fresh weight (p≤0.01) and above ground fresh biomass (p≤0.01) but not on stem fresh weight (Table 2). Maximum leaf fresh weight (11.08 ton ha^{-1}) and above ground fresh biomass (15.45 ton ha^{-1}) were found at 30 kg P ha^{-1} even though statistically similar with 60 and 90 kg P ha^{-1}. Application of 30 kg P ha^{-1} showed about 13% leaf fresh weight and 12% above ground fresh biomass increment compared with the control plots. This evidenced that the right rate of nitrogen and phosphorus enhanced sage efficiency in utilization of resources by reducing inter and intra specific competition. Besides, due to the synergistic effect of N and P fertilizer, application N might have stimulated effect on the uptake of P and vice versa (Sharma and Tandon, 1992). In line with this study, Ram *et al. (*1999) reported that increase in level of nitrogen with combination of phosphorous were significant yield response on herbage of lemongrass. Similarly, it was found that high P concentrations produced significantly more leaf biomass of *Calendula officinalis* L. (Stewart and Lovett-Doust, 2003).

At koka, in both consecutive cropping seasons and pooled mean, application of nitrogen gave significant (p≤0.001) effect on leaf, stem and above ground fresh biomass (Table 3). The highest leaf fresh weight (16.68ton ha^{-1}) in 2017/18, (21.47ton ha^{-1}) in 2018/19 and (18.24ton ha^{-1}) in the pooled mean was found at 46, 138 and 46kg N ha^{-1} respectively. Similarly, maximum stem fresh weight (6.98, 9.56 and 8.27 ton ha^{-1}) and above ground fresh biomass (21.65, 31.03 and 26.34 ton ha^{-1}) in the first, second cropping season and the pooled mean respectively were found at 138 kg N ha^{-1}. The pooled mean analysis showed that application of nitrogen at the rate of 46, 138 and 138 kg N ha^{-1} gave 18%, 27% and 21% increment of leaf, stem fresh weight and above ground fresh biomass respectively compared with the control. On the same way, application of phosphorus had significant effect on leaf fresh weight (p≤0.001), stem fresh weight (p≤0.01) and above ground fresh biomass (p≤0.001) in the first year; leaf fresh weight (p≤0.05) in the second year and above ground fresh biomass (p≤0.05) in the pooled mean (Table 3). However, it didn't show any significant (p>0.05) effect on stem and above ground fresh biomass in 2018/19 cropping season and leaf and stem fresh weight in the pooled mean (Table 3). The highest leaf fresh weight (16.24ton ha^{-1}), stem fresh weight (6.48ton ha^{-1}) and above ground fresh biomass (22.34ton ha^{-1}) in 2017/18 cropping season was found at the rate of 90, 30, 90 kg P ha^{-1} respectively (Table 3). However, the highest above ground fresh biomass found at 90 kg P ha^{-1} was statistically similar with 30 and 60 kg P ha^{-1}. Similarly, maximum leaf fresh weight (19.56 ton ha^{-1}) in 2018/19 and above ground fresh biomass (24.63 ton ha^{-1}) in the pooled mean were found at 60 and 90 kg P ha^{-1} respectively though it was statistically at par with 30 and 60 kg P ha^{-1} for leaf fresh weight in 2018/19 and 60 kg P ha^{-1} for above ground fresh biomass in the pooled mean (Table 3).

Belstie *et. al*., (2017), in line with this study, reported that both leaf and stem fresh weight of Artemisia were significantly influenced by the interaction of nitrogen with phosphorus. In addition, in agreement with the findings of the two locations, Singh & Ganesha Rao, 2007; Singh, 2008; reported that KNO3 fertilizer increased fresh matter yield by an average of 60.5% compared with the control. Tanjia *et al.* (2009) noted that fresh herb yield increased with increasing N rates. The maximum value (103.54 g) of fresh herb product was obtained with the treatment of 120 kg N/ha. Generally, herb productivity increased as the level of N increased from 0 to 120 kg N/ha. On the other hand, in both testing locations and consecutive cropping seasons, the interaction of the two main effects didn't show significant (P >0.05) variation on leaf fresh weight, stem fresh weight and above ground fresh biomass (Table 2 and 3). The overall result of the two locations confirmed that nitrogen and phosphorus are one of the most essential elements for growth and development of sage.

Leaf and Stem dry weight (ton ha^{-1})

At Wondo Genet, in both consecutive cropping seasons and pooled mean, leaf and stem dry weight were significantly affected by nitrogen (Table 4). In 2017/18 cropping season, the highest leaf (5.03ton ha^{-1}) and stem (3.76ton ha^{-1}) were found at 46 kg N ha^{-1} though statistically similar with the highest two doses of nitrogen (92 and 138 kg N ha^{-1}). Similarly, in 2018/19 cropping season, maximum leaf (3.27ton ha^{-1}) and stem (0.97ton ha^{-1}) dry weight were found at 92 kg N ha^{-1} even though statistically at par with 46 and 138 kg N ha^{-1} (Table 4). Over year analysis confirmed that application of nitrogen at the rate of 46 kg N ha^{-1} gave maximum leaf (3.98ton ha^{-1}) and stem (2.33ton ha^{-1}) dry weight though statistically similar with 92 and 138 kg N ha^{-1}(Table 4). Silva and Uchida, (2000), In line with this study, reported that N improves the quality and quantity of dry matter in leafy plants and protein in grain crops.

On the same way, except stem dry weight in 2018/19 cropping season, application of phosphorus had significant effect on leaf and stem dry weight in both years and pooled mean (Table 4). In 2017/18 cropping season, application of phosphorus at the rate of 30 kg P ha^{-1} gave the highest leaf (5.13ton ha^{-1}) and stem (3.55ton ha^{-1}) dry weight. However, the significant variation was statistically similar with the highest rates of phosphorus (60 and 90kg P ha^{-1}). Similarly, in the second cropping season, phosphorus at the rate of 60 kg P ha^{-1} gave maximum leaf dry weight (3.14ton ha^{-1}) though statistically similar with 30 kg P ha^{-1} and the control treatment (Table 4). The over year analysis revealed that application of phosphorus at the rate of 30 kg P ha^{-1} gave maximum leaf (4.04 ton ha^{-1}) and stem (2.19 ton ha^{-1}) dry weight (Table 4).

Correspondingly, at koka the analysis of variance revealed that in both cropping seasons and pooled mean application of nitrogen gave significant effect on leaf and stem dry weight (Table 5). The highest leaf dry weight (5.41ton ha^{-1}) in 2017/18; (5.97ton ha^{-1}) in 2018/19; and (5.62ton ha^{-1}) in the pooled mean was found at 46,138 and 138 kg N ha^{-1} respectively (Table 5). Likewise, the highest stem dry weight (2.54 ton ha^{-1}) in 2017/18; (3.02ton ha^{-1}) in 2018/19 and (2.78 ton ha^{-1}) in the pooled mean was obtained at 138 kg N ha^{-1} though statistically similar with 46 and 92 kg N ha^{-1} in the second cropping season. In the same way, in the two consecutive cropping seasons and pooled mean, leaf and stem dry weights were significantly affected by different rates of phosphorus (Table 5). The highest leaf dry weight (5.43ton ha^{-1}) in 2017/18, (5.60ton ha^{-1}) in 2018/19 and (5.27ton ha^{-1}) in the pooled mean was found at 90, 30 and 90 kg P ha^{-1} although statistically at par with 60 kg P ha^{-1} in the two cropping seasons; 30 and 60 kg P ha^{-1} in the pooled mean (Table 5). Similarly, the highest stem dry weight (2.41ton ha^{-1}) in the first; (2.93ton ha^{-1}) in the second and (2.64ton ha^{-1}) over years was found at the rate of 30, 90 and 90 kg P ha^{-1} respectively though statistically similar with the lowest P rate (60 and 30 kg ha^{-1}) in 2018/19 and over years. This might be due to positive effect of nitrogen and phosphorus in promoting the vegetative growth and herbage yield, which consequently increased leaf and stem dry weight. Seyede Roghaye *et al.*, (2015), in agreement with this study, reported that application of organic and inorganic fertilizers increased both fresh and dry herbage yield of rosemary. However, at both testing sites, in both consecutive cropping seasons and pooled mean, the interaction effect didn't show any significant (P>0.05) effect on leaf and stem dry weight (Table 4 and 5).

Essential Oil Yield (EOY) (Kg ha^{-1})

At Wondo Genet, in both cropping seasons and pooled mean, essential oil yield was significantly affected by nitrogen and phosphorus (Table 4). However, the significant variation was observed compared with the control treatments. The highest EOY (70.09 kg ha^{-1}) in 2017/18; (55.66 kg ha^{-1}) in 2018/19 and (59.18 kg ha^{-1}) in the pooled mean was found at 138, 92 and 138 kg N ha^{-1} respectively. However, there was no statistical significant difference among 46 and 92 kg N ha^{-1} in the first year and pooled mean; 46 and138 kg N ha^{-1} in the second year. In the same way, maximum EOY (66.76 kg ha^{-1}) in 2017/18 and (54.89 kg ha^{-1}) in 2018/19 was found at 90 and 60 kg P ha^{-1} respectively though statistically similar with 60 and 30kg P ha^{-1} in 2017/18 and 30 kg P ha^{-1} in 2018/19 cropping season (Table 4). The over year analysis showed that maximum essential oil yield (58.53 kg ha^{-1}) was recorded at 60 kg P ha^{-1} though statistically at par with 30 and 90 kg P ha^{-1} (Table 4). The combined analysis of two years data confirmed that application of 30, 60, and 90 kg P ha^{-1}gave 12, 13 and 11% EOY increment over the control (Table 4).

At koka, similar to Wondo Genet, EOY was significantly affected by nitrogen and phosphors (Table 5). The highest EOY (93.97 kg ha^{-1}) in 2017/18; (108.27kg ha^{-1}) in 2018/19 was found at 46 and 138 kg N ha^{-1} respectively. The significant variation of EOY in 2018/19 cropping season was statistically similar with 92 kg N ha^{-1}. The combined analysis of two years data revealed that maximum essential oil yield (94.33 kg ha^{-1}) was obtained at 46 kg N ha^{-1} though statistically similar with 92 and 138 kg N ha^{-1} (Table 5). Likewise, application of phosphorus at 30 and 90 kg P ha^{-1} gave the highest essential oil yield (85.97 kg ha^{-1}) in 2017/18 and (111.02 kg ha^{-1}) in 2018/19 cropping season respectively (Table 5). However, there was no significant variation compared with 60 and 90 kg P ha^{-1} in 2017/18 and 60 kg P ha^{-1} in 2018/19 cropping season. The pooled mean analysis revealed that application of phosphorus at the rate of 90 kg P ha^{-1} gave maximum EOY (97.57 kg ha^{-1}) compared with 30 kg P ha^{-1}and the control treatment (Table 5). However, maximum essential oil yield obtained at 90 kg P ha^{-1} was statistically at par with 60 kg P ha^{-1}.

For both locations, Rao, (1989), in agreement with this study, reported that application of 100 kg N and 26kg P per hectare produced the highest biomass and essential oil yields of davana (Artemisia pallens Wall.). Similarly, Sharafzadeh, (2011) on thyme (Thymus vulgaris L.); Khalid, 2012 on some medicinal apiaceae (anise, coriander and sweet fennel) plants found that NP treatments produced the highest growth and essential oil yield compared with the control. According to Khalid, 2000, N fertilization increased the vegetative growth, essential oil, fixed oil, total carbohydrates, soluble sugars and NPK content of *Nigella sativa* L. plants.

However, at both testing sites, in both consecutive cropping seasons and pooled mean, the interaction effect didn't show any significant (P>0.05) effect on essential oil yield (Table 4 and 5).

Essential Oil Content (EOC) (%, w/w, wet based)

At Wondo Genet in all consecutive cropping seasons and pooled mean, both nitrogen and phosphorus and the interaction didn't significantly (P>0.05) affect essential oil content (Table 4). In the contrary, at koka in both consecutive copping season and pooled mean EOC was significantly affected by nitrogen and phosphorus except phosphorus in the first year (Table 5). Accordingly, application of nitrogen at the rate of 46 kg N ha^{-1}gave maximum EOC (0.58%) in 2017/18 cropping season. Similarly, in 2018/19 cropping season, the control treatment (unfertilized) produced the highest EOC (0.59%) compared with fertilized treatments (N inputs). The over year analysis on the other hand showed that control treatments gave maximum EOC (0.57%) compared with different rates of nitrogen (Table 5). Likewise, the highest essential oil content (0.56%) in 2018/19 and (0.56%) in the pooled mean was found at the rate of 90 and 30 kg P ha^{-1} respectively. N fertilization has been reported to increase total essential oil yield in thyme (*Thymus vulgaris* L.) (Baranauskienne *et al*., 2003) although it has been reported that essential oil content of creeping juniper *(Juniperus horizontalis*) was reduced in nitrogen fertilized plots (Robert, 1986).

The interaction effect in both testing location and cropping seasons, unlike to the main effects, didn't show significant (p>0.05) effect on essential oil content of sage (Table 4 and 5).

Table 4: Mean yield of Sage (*Saliva officinal's* L.) as affected by nitrogen and phosphorus rates at Wondo Genet in 2017/18, 2018/19 cropping seasons and pooled mean

TRT	2017/18				2018/19				Over years			
	LDW (ton/ha)	SDW (ton/ha)	EOY (kg/ha)	EOC (%, w/w, wet based)	LDW (ton/ha)	SDW (ton/ha)	EOY (kg/ha)	EOC (%, w/w, wet based)	LDW (ton/h a)	SDW (ton/ha)	EOY (kg/ha)	EOC (%, w/w, wet based)
Nitrogen												
0	3.38^{b}	2.74^{c}	48.99^{b}	0.51	2.50^{b}	0.69^{b}	47.95^{b}	0.568	2.94^{b}	1.72^{b}	48.47^{b}	0.543
46	5.03^{a}	3.76^{a}	64.36^{a}	0.54	2.94^{a}	0.89^{a}	52.65^{a}	0.540	3.98^{a}	2.33^{a}	58.50^{a}	0.543
92	4.19^{ab}	3.22^{bc}	61.80^{a}	0.56	3.27^{a}	0.97^{a}	55.66^{a}	0.530	3.73^{a}	2.09^{a}	58.73^{a}	0.547
138	4.38^{ab}	3.37^{ab}	70.09^{a}	0.55	2.98^{a}	0.96^{a}	48.26^{b}	0.533	3.68^{a}	2.16^{a}	59.18^{a}	0.544
LSD	1.09	0.51	8.65	ns	0.36	0.13	3.28	ns	0.57	0.28	4.21	ns
P value	*	**	***	ns	**	***	***	ns	**	***	***	ns
Phosphorus												
0	3.39^{b}	2.74^{b}	52.68^{b}	0.53	2.99^{a}	0.95	49.36^{b}	0.514	3.19^{b}	1.84^{b}	51.02^{b}	0.53
30	5.13^{a}	3.55^{a}	63.63^{a}	0.52	2.94^{ab}	0.84	52.80^{a}	0.548	4.04^{a}	2.19^{a}	58.22^{a}	0.54
60	4.03^{b}	3.39^{a}	62.16^{a}	0.54	3.14^{a}	0.92	54.89^{a}	0.557	3.58^{ab}	2.16^{a}	58.53^{a}	0.55
90	4.42^{ab}	3.41^{a}	66.76^{a}	0.56	2.61^{b}	0.80	47.47^{b}	0.553	3.52^{ab}	2.11^{ab}	57.12^{a}	0.56
LSD (0.05)	1.09	0.51	8.64	ns	0.36	ns	3.28	ns	0.57	0.28	4.21	ns
P value	*	*	*	ns	*	ns	***	ns	*	*	**	ns
N*P	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
CV (%)	30.87	18.72	16.91	13.39	14.85	17.72	7.71	10.09	19.21	15.96	8.98	7.32

*,**,*** Significant at p≤0.05, p≤0.01 and p≤0.001, respectively; ns= not significant. Means with the same letter in column are not significantly different at p<0.05; LSD: Least Significant Difference; PH: Plant height; LFW: Leaf dry weight; SFW: Stem dry weight, EOY: Essential oil yield; EOC: Essential oil content

Table 5: Mean yield of Sage (*Saliva officinal's* L.) as affected by nitrogen and phosphorus rates at koka in 2017/18, 2018/19 cropping seasons and pooled mean

TRT	2017/18				2018/19				Over years			
	LDW (ton/ha)	SDW (ton/ha)	EOY (kg/ha)	EOC (%, w/w, wet based)	LDW (ton/ha)	SDW (ton/ha)	EOY (kg/ha)	EOC (%, w/w, wet based)	LDW (ton/h a)	SDW (ton/ha)	EOY (kg/ha)	EOC (%, w/w, wet based)
Nitrogen												
0	4.57^{c}	2.07^{b}	74.98^{b}	0.55^{ab}	4.75^{bc}	2.34^{b}	101.21^{b}	0.59^{a}	4.66^{c}	2.21^{c}	88.09^{b}	0.57^{a}
46	5.41^{a}	2.04^{b}	93.97^{a}	0.58^{a}	4.52^{c}	2.88^{a}	94.70^{c}	0.50^{c}	4.96^{b}	2.46^{b}	94.33^{a}	0.54^{b}
92	4.92^{bc}	2.17^{b}	80.85^{b}	0.54^{ab}	5.09^{b}	2.74^{a}	107.30^{a}	0.55^{b}	5.00^{b}	2.45^{b}	94.08^{a}	0.55^{b}
138	5.27^{ab}	2.54^{a}	79.29^{b}	0.52^{b}	5.97^{a}	3.02^{a}	108.27^{a}	0.49^{c}	5.62^{a}	2.78^{a}	93.78^{a}	0.51^{c}
LSD (0.05)	0.41	0.25	5.97	0.04	0.35	0.32	4.12	0.03	0.26	0.20	3.22	0.02
P vale	***	***	***	*	***	**	***	***	***	***	***	***
Phosphorus												
0	4.85^{bc}	1.87^{b}	75.87^{b}	0.55	4.35^{c}	2.58^{b}	95.36^{b}	0.49^{b}	4.54^{b}	2.23^{b}	85.61^{c}	0.52^{b}
30	4.73^{c}	2.41^{a}	85.97^{a}	0.56	5.60^{a}	2.67^{ab}	97.28^{b}	0.55^{a}	5.23^{a}	2.54^{a}	91.63^{b}	0.56^{a}
60	5.16^{ab}	2.20^{a}	83.13^{a}	0.54	5.26^{ab}	2.80^{ab}	107.83^{a}	0.54^{a}	5.21^{a}	2.50^{a}	95.48^{a}	0.54^{ab}
90	5.43^{a}	2.34^{a}	84.13^{a}	0.53	5.11^{b}	2.93^{a}	111.02^{a}	0.56^{a}	5.27^{a}	2.64^{a}	97.57^{a}	0.55^{a}
LSD (0.05)	0.41	0.25	5.96	ns	0.35	0.32	4.13	0.02	0.26	0.20	3.22	0.02
P value	**	***	**	ns	***	*	***	***	***	***	***	*
N*P	Ns	Ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
CV (%)	9.75	13.44	8.69	8.71	8.28	14.14	4.81	5.59	6.05	9.55	4.17	5.23

*,**,*** Significant at p≤0.05, p≤0.01 and p≤0.001, respectively; nS= not significant. Means with the same letter in column are not significantly different at p<0.05; LSD: Least Significant Difference; PH: Plant height; LFW: Leaf dry weight; SFW: Stem dry weight, EOY: Essential oil yield; EOC: Essential oil content

CONCLUSION AND RECOMMENDATION

Nitrogen and phosphorus fertilizers play vital role in maximization of agronomic trait and economic yield of sage. The results of the study at Wondo Genet and koka revealed that most parameters (leaf and stem fresh and dry weight, above ground fresh biomass, essential oil yield) of sage was significantly higher in the fertilized plots compared to unfertilized plots. Essential oil content at Wondo Genet, on the other hand, didn’t show any significant variation while at koka it was significantly affected by unfertilized plots of nitrogen and 30 kg P ha^{-1}. Therefore,At Wondo Genet, application of 46 kg N ha^{-1} and 30 kg P ha^{-1} gave the highest plant height, leaf and stem fresh and dry weight, above ground fresh biomass and essential oil yield of sage. Similarly, at koka, the highest plant height, leaf and stem dry weight were obtained at 138 kg N and 30 kg P ha^{-1}; leaf fresh weight at 46 kg N ha^{-1} and 30kg P ha^{-1}; above ground fresh biomass at 138 kg N and 60kg P ha^{-1}; EOY at 46kg N and 60 kg P ha^{-1} and EOC at 0 kg N and 30kg P ha^{-1}. Therefore, at Wondo Genet and other similar soil type and agro ecologies N and P at the rate of 46 kg N and 30 kg P ha^{-1} could be recommended for maximum economic yield of sage. While at Koka and other similar soil type and agro ecologies, considering the interest of the producer, application of N and P at the rate of 46 kg N and 30 kg P ha^{-1} for leaf fresh weight; 138 kg N and 30 kg P ha^{-1} for leaf dry weight and 46 kg N and 60 kg P ha^{-1} for essential oil yield is recommended. Further validation and demonstration of this result around the study areas through the involvement of stakeholders is recommended. Additionally, bearing the economic profitability and sustainable use of the land, further research in an integrated approach with organic fertilizers is highly advised.

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