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Growth and marketable yield of lettuce (*Lactuca sativa* L.) as affected by bio-slurry and chemical fertilizer application

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ABSTRACT

The objective of this study was to evaluate the effects of bio-slurry (BS) and chemical fertilizer (CF) application on the growth and yield of lettuce (*Lactuca sativa* L. var. Parris Iceland Cos). Field experiment consisting of six treatments (100 % BS, 75 % BS + 25 % CF, 50 % BS + 50 % CF, 25 % BS + 75 % CF, 100 % CF and the control) was laid out in a randomized complete block design with three replications. Results showed that the combined application of BS and CF significantly increased lettuce yield and its constituents at $p < 0.05$. More specifically, the maximum plant height (31.4 cm), leaf area (4914.5 cm^2), and yield (38.34 ton ha^{-1}) were obtained with the combined application of 75 % CF and 25 % BS. Aside from that, yield and its components showed a positive correlation. Using BS alone or in combination with CF could increase lettuce yield while also potentially saving money on CF purchases. Overall, combining CF and BS in a 3:1 ratio could be an optimum rate for growing lettuce in the study area.

1. Introduction

Vegetables consist of more than 200 plant species worldwide. Various types of vegetables grow in Ethiopia under both rain-fed and irrigated systems [1]. The most economically important vegetables with increased attention in Ethiopian include Ethiopian mustard (*Brassica carinata*), tomato (*Solanum lycopersicum*), cabbage (*B. oleracea* var. *capitata*), cauliflower (*B. oleracea* var. *botrytis*), carrot (*Daucus carota*), asparagus (*Asparagus officinalis*) and broccoli (*B. oleracea* var. *italica*), among others [2]. Lettuce (*Lactuca sativa* L.), which is a test vegetable in this study, has not received much attention at present despite its currently increasing cultivation in Ethiopia. Its cultivation using small-scale irrigation and in home-gardens has been increasing in recent times. Moreover, seeds of various lettuce varieties are currently available in markets in Ethiopia where it is widely used as salad alone or together with other vegetables. Consequently, its demand in urban settings has been intensifying in the recent times.

Among salad crops, lettuce is one of the most widely grown and takes up the greatest amount of production space worldwide [3,4]. It is consumed primarily fresh and is rich in minerals, vitamins, phenolic compounds and fibers [4,5]. It grows in diverse climatic conditions and soil types. For it to thrive and be of high quality, the ideal mean temperature range is 15–25 °C [6]. It grows within an altitude of 1800–2100 m above sea level. Lettuce best grows in silt loams and sandy soils [7].

Agricultural practice in Ethiopia has faced a wider set of soil fertility deterioration, increasing price of chemical fertilizers, and poor

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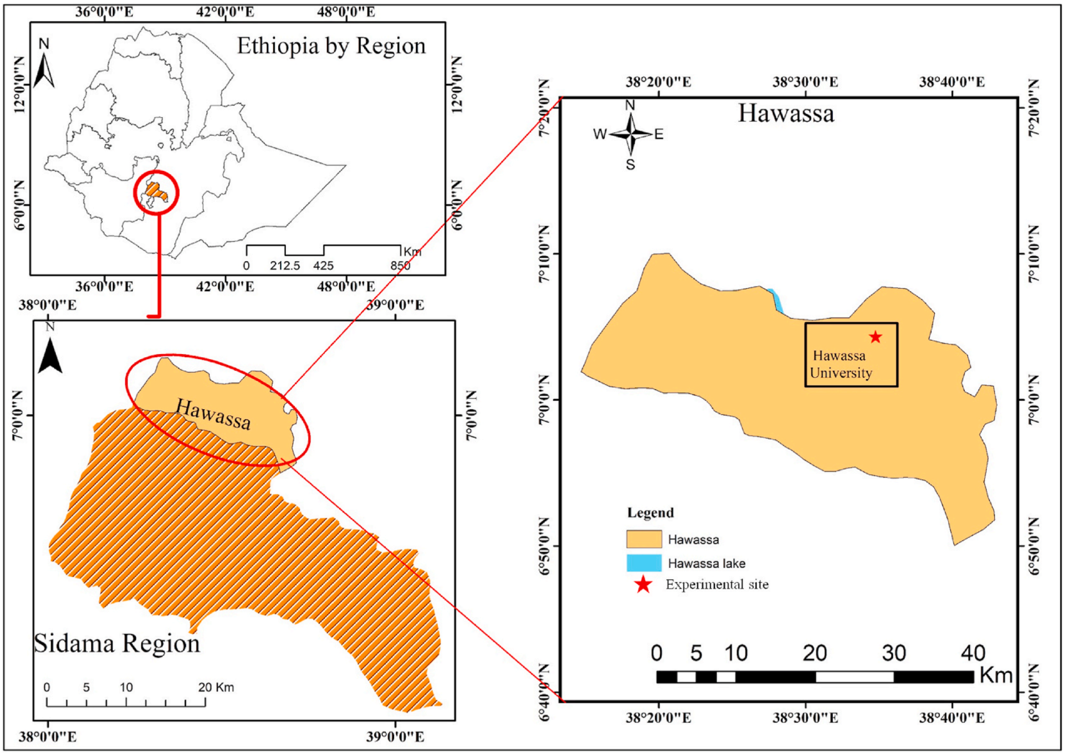

Fig. 1. Location map of the experimental site.

timeliness of fertilizer supply. Lack of appropriate fertilizer rates for most crops and agro-ecological conditions has become additional limiting variable in Ethiopia. Consequently, most farmers apply fertilizer rates different from the national recommendation in Ethiopia [8]. This works for the organic fertilizers as well, despite the increasing interest of applying them in agricultural productions, particularly in vegetable cultivation around home-gardens. One of the methods to reduce the dependence on chemical fertilizers is looking for alternative fertilizer sources such as organic fertilizers, which are cheap, locally available, environmentally friendly and productive.

Since organic fertilizers are a source and store of various vital plant nutrients, they have drawn interest from all over the world [9]. One type of organic fertilizer that is high in organic matter and nutrients (C, N, P, and K) is bio-slurry [10]. Its application improves soil pH, bulk density, porosity, and soil nutrient retention and water holding capacity. To improve soil fertility and agricultural productivity, it can be applied as a soil amendment [11]. Thus, in developing nations, it can serve as a substitute fertilizer to increase soil fertility and boost agricultural output [12].

Bio-slurry is available mostly with households installing biogas plants. Such installation has been undergoing since 2009/10 in Ethiopia as part of the National Biogas Program. However, applying bio-slurry as organic fertilizer is started only recently in the Ethiopian agricultural practices. Moreover, relevant empirical studies on its nutrient compositions and potential of substituting or supplementing chemical fertilizers and increasing agricultural productivity under varied agro-ecologies are lacking. Particularly, studies evaluating its potential use in vegetable cultivation as sole or combined with chemical fertilizers are scanty. Therefore, the objective of this study was to evaluate the effects of sole bio-slurry and chemical fertilizer, and their combined application on the growth and yield of lettuce.

2. Materials and methods

2.1. Description of the experimental site

The experiments were carried out at the Hawassa University Research Farm (Fig. 1). Hawassa is located at 273 km South of Addis Ababa (the capital city of Ethiopia) at 07°03′53.8″ N latitude and 038°28′59.2″ E longitude with an altitude of 1694 m above sea level.

Hawassa experiences bimodal rainfall distribution and a sub-humid climate [13]. The primary rainy season, which typically lasts from June to October, averages 996.29 mm of annual rainfall. February and March are the hottest months having an average annual temperature of 32.3 °C while December is the coolest month having an average annual temperature of 20.9 °C (9.4 °C) (Fig. 2 A).

During the cropping period, the mean monthly rainfall was 146.78 mm while the mean maximum and minimum temperatures respectively were 30.8 °C and 14.3 °C (Fig. B).

For most people who live in the Hawassa area, agriculture is their primary source of income. Major crops grown include vegetables,

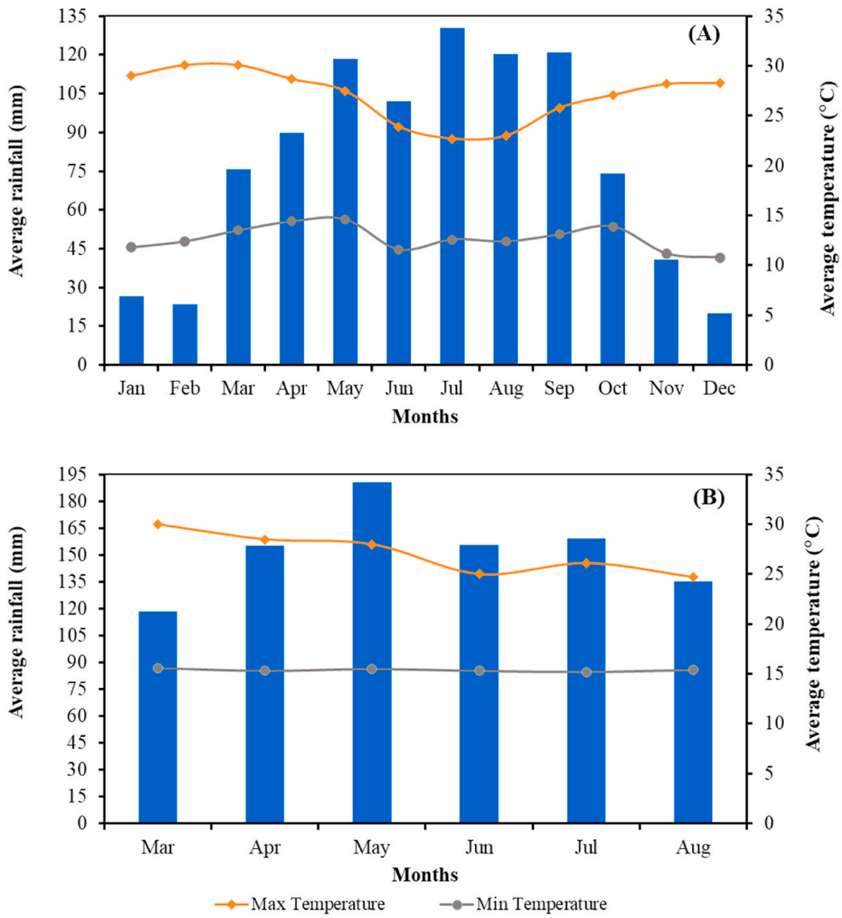

Fig. 2. The average monthly maximum and minimum temperatures and the average monthly rainfall in Hawassa from 1990 to 2019 (A) and during the experimental period (B) (Data source: National Metrology Service Agency (NMSA), Hawassa Branch, 2020).

Table 1
Treatments, fertilizer types and fertilizer rates.

Treatment	NPS (g planting hole^{-1})	Urea (g planting hole^{-1})	BS (g planting hole^{-1})
100 % (sole) BS	0	0	120
75 % BS+25 % CF	0.9	1.2	90
50 % BS+50 % CF	1.9	2.4	60
25 % BS + 75 % CF	2.8	3.6	30
100 % (sole) CF	3.8	4.8	0
Control with no fertilizer	0	0	0

CF – Chemical fertilizer (NPS and Urea), BS – bio-slurry.

haricot beans, coffee, and fruit trees [13]. The tropical andosol soils surrounding the experimental areas primarily have textural classes ranging from silty loam to sandy loam [13,14].

2.2. *Treatments and experimental design*

The treatments were composed of six fertilizers combinations having six levels of bio-slurry (0, 1.25, 2.5, 3.75 and 5 tonha^{-1}) and chemical fertilizers (0, 25, 50, 75 and 100 %) of the recommended NPS and urea fertilizers (Table 1). The experiment was laid out in a randomized complete block design with three replications. The recommended spacing between rows and plants was maintained at 60 cm and 40 cm, respectively [7]. The distance between plots and blocks were 0.5 and 1.0 m, respectively. Six rows per plot and five plants per row with a total of 30 plants per plot were established (Fig. 2). The plot size was 3.6 × 2 m, having a total area of 7.2 m^2. Following the recommendation for lettuce, urea (200 kg ha^{-1}), NPS (158 kg ha^{-1}) and bio-slurry rate (5 ton ha^{-1}) were adopted (Table 1).

Fig. 3. Field photos showing seedlings, seedbed preparation, and experimental plots.

2.3. Land preparation, planting and application of fertilizers

Lettuce (*L. sativa* var. Parris Iceland Cos) was used as a test plant. This lettuce variety is widely cultivated, for both food and market, in Ethiopia. Lettuce seeds were sown in nursery trays and were watered every two other days until the last four days to transplanting. Thinning of the seedlings was carried out two weeks after sowing.

Fig. 3 presents field photos showing seedlings, seedbed preparation, and experimental plots. The experimental field was prepared manually. Seedlings bearing five vigorous and healthy leaves were transplanted into the experimental plots 43 days after sowing. The NPS was applied at the time of planting while urea was applied 30 days after transplanting. The BS was applied just before planting incorporating into the soil at plow depth. Thinning of the transplanted seedlings was done one week after transplanting. Weeding and hoeing were carried out manually twice after transplantation. There was no infestation of pest in the experiment and hence, no chemicals were sprayed.

Harvesting was done 44 days after transplanting by uprooting the whole plant. The roots were removed with a knife. Finally, 20 plants in the central row of each plot were considered for the measurement of the weight of fresh marketable leaves.

2.4. Sampling and physico-chemical properties of the experimental soil

Before transplanting, soil samples were taken with a soil auger from the top 20 cm of the soil in a zigzag pattern. After the samples were well combined to create a composite sample, their physico-chemical properties were examined. The analysis's findings demonstrated that the soil had a pH H_2O of 5.6, 4.74 % OM, 11:01 C:N, 0.24 % TN, 2.73 % OC, 24.6 cmol kg^{-1} CEC, 49.6 ppm available P, 2.29 cmol kg^{-1} K, 0.21 cmol kg^{-1} Na, 46.15 cmol kg^{-1} Ca, 62.26 % porosity, 1 gm^{-3} bulk density, 42 % silt, 35.28 % sand, 22.72 % clay, and silt loam textural class.

2.5. Bio-slurry sample analysis

Following standard methods, a sample of fresh BS of 0.5 kg was examined for OC, CEC, TN, pH, and available P. The results of the analysis indicated that the BS had a pH of 7.52, 0.54 % TN, 6.24 % OC, 11.56C: N, 39 cmol kg^{-1} CEC and 262.2 ppm available P as well as 0.39, 52.34 and 10.3 exchangeable Na, K, Ca, respectively.

2.6. Data collection on growth and yield

Data on leaf number, leaf area and plant height (by measuring leaf height and leaf width using ruler and was then multiplied by the correction factor 0.587) were determined by taking five randomly selected plants for each treatment. Likewise, data on marketable yield were taken for each treatment at harvesting from the five randomly selected plants in the central row of each treatment and was then weighted using hanging digital meter.

2.7. Statistical data analysis

The growth and yield data were tabulated correctly and then subjected to one-way analysis of variance (ANOVA) using the GLM Procedure of SAS software [15]. The Least Significant Difference (LSD) test was performed at $p \leq 0.05$ to compare all significant treatment means. To ascertain the correlation between yield and its component, Pearson correlation was employed.

Table 2
Vegetative growth and yield of lettuce as affected by chemical fertilizer and bio-slurry.

Treatment	Leaf area (cm^2)	Leaf number	Plant height (cm)	Marketable yield ($t\ ha^{-1}$)
0 % BS	3666.6^{d}	31.47^{c}	28.2^{c}	31.41^{de}
25 % CF + 75 % BS	4226.1^{c}	32.47^{bc}	29.47^{b}	33.12^{cd}
50 % CF + 50 % BS	4896.9^{ab}	35.02^{a}	29.5^{b}	34.14^{bc}
75 % CF + 25 % BS	4914.5^{a}	34.47^{ab}	31.4^{a}	38.34^{a}
100 % CF (NPS + Urea)	4498.6^{bc}	34.73^{a}	28.9^{bc}	36.12^{b}
Control with no fertilizer	3068.9^{e}	27.7^{d}	27.2^{d}	29.65^{e}
CV	**13.1**	**8.8**	**4.7**	**17**

There is no significant difference between the same letters in the same column at $p \leq 0.05$.

3. Results and discussion

3.1. Vegetative growth as affected by application of chemical fertilizer and bio-slurry

3.1.1. Plant height

The integrated and sole application of chemical fertilizer and bio-slurry significantly increased height over the control. Apart from that, all the integrated application significantly increased height over the application of sole bio-slurry. Whereas, among the integrated applications, only the application of 25 % bio-slurry and 75 % chemical fertilizer significantly increased height over the sole chemical fertilizer application. The integrated application of 25 % bio-slurry and 75 % chemical fertilizer had the highest height (31.4 cm) while the control had the smallest height (27.2 cm). Height decreased with an increase in bio-slurry and a decrease in chemical fertilizer in the integration (Table 2). Collectively, the integrated application of chemical fertilizer and bio-slurry increased height over their separate application. Findings from previous studies indicated that the use of chemical fertilizer and bio-slurry gives premier height over the control in lettuce [16,17], in tomato [14] and okra [18]. This might attribute to the high nutrient and organic matter contents of bio-slurry, which optimize both the deficit and the excess nutrients in the soil [19,20].

3.2. Leaf number per plant

When compared to the control, the integrated and separate applications of chemical fertilizer and bio-slurry significantly boosted the number of leaves. Statistically, every other integrated application—aside from the combined 75 % bio-slurry and 25 % chemical fertilizer application—significantly increased leaf number compared to the sole application of bio-slurry. The application of the integrated 25 % bio-slurry and 75 % chemical fertilizer, sole chemical fertilizer, and integrated 50 % bio-slurry and 50 % chemical fertilizer increased leaf number by 24.44 %, 25.38 %, and 26.43 % over the control, respectively. The application of the 100 % chemical fertilizer significantly increased leaf number over the sole bio-slurry and control, which is 10.36 % and 25.38 % higher, respectively. Similarly, compared to the control, the sole application of bio-slurry significantly boosted the leaf number, which is 13.6 % higher (Table 2). Comparatively, the integrated application of bio-slurry and chemical fertilizer influences lettuce leaf number over their individual application. This result is consistent with that of an earlier study that combined the use of bio-slurry and chemical fertilizers gave significantly higher leaf number in cabbage production [21]. The leaf number in lettuce increased with the application of organic and chemical fertilizers [22,23]. The higher leaf number with the application of the 50 % bio-slurry and 50 % chemical fertilizer could attribute to a higher possibility for the bio-slurry and chemical fertilizer supplying balanced plant nutrients to the soil or optimizing soil nutrients and promoting lettuce lateral shoot growth.

3.3. Leaf area per plant

In comparison to the control, the individual and combined applications of chemical fertilizer and bio-slurry significantly increased lettuce leaf area. Apart from that, all the integrated application significantly The integrated application of 25 % bio-slurry and 75 % chemical fertilizer significantly increased leaf area over increased leaf area over the separate bio-slurry. All other fertilizer applications except the 50 % chemical fertilizer and 50 % bio-slurry. Besides, compared to the sole application of bio-slurry, the separate application of chemical fertilizer significantly increased leaf area. The highest leaf area (4914.5 cm^2) was also obtained through the combined application of 25 % bio-slurry and 75 % chemical fertilizer, with the control yielding the lowest (3068.9 cm^2). The leaf area shrank with an increase in bio-slurry and a decrease in chemical fertilizer in the integrated application (Table 2). When chemical fertilizer and bio-slurry were applied together, lettuce leaf area was generally affected more than when they were applied separately. This might be that the integrated application offers more nutrients, and could create synergistic effects and increase leaf area. When bio-slurry and chemical fertilizers are applied together, the leaf area of okra is larger than when inorganic fertilizer and bio-slurry are applied separately [18].

3.4. Marketable yield as affected by chemical and fertilizer bio-slurry application

Compared to the control, the yield of lettuce increased significantly with both the integrated and separate application of chemical fertilizer. With the exception of the 75 % chemical fertilizer and the 25 % bio-slurry, the full integrated fertilizer application

Table 3
The correlation coefficient between yield and its components.

	Leaf number	Leaf area	Plant height	Yield
Leaf number	1			
Leaf area	0.78481***	1		
Plant height	0.52014***	0.66486***	1	
Yield	0.53467***	0.53386***	0.46375***	1

*** Significant at $P < 0.001$,** Significant at $P < 0.01$, *Significant at $p < 0.05$

significantly improved fresh yield in comparison to the bio-slurry alone. Furthermore, compared to using only chemical fertilizer, the application of 25 % bio-slurry and 75 % chemical fertilizer significantly boosted yield. In turn, the application of sole chemical fertilizer significantly increased yield in comparison to the application of both sole bio-slurry and integrated 25 % chemical fertilizer and 75 % bio-slurry. The highest yield was obtained by applying 25 % bio-slurry and 75 % chemical fertilizer together (38.34 ton ha^{-1}) (Table 2) and increased yield by 6.15 %, 12.3 %, 15.76 %, 22.06 % and 29.31 % over sole chemical fertilizer, 25 % chemical fertilizer and 75 % bio-slurry, 50 % bio-slurry and 50 % chemical fertilizer, sole bio-slurry and control, respectively. This demonstrates that when chemical fertilizer and bio-slurry are applied together, yields seem to increase more often than when bio-slurry or chemical fertilizers are applied alone. Previous research revealed that applying bio-slurry and chemical fertilizers together has synergistic effects and improves the timing of nutrient release and uptake by plants, which in turn increases yields [24–26]. The highest yield in maize cultivation is achieved when bio-slurry and chemical fertilizer are applied together [27]. Research conducted by Iqbal et al. [28] also shows that the rice yield was enhanced by the combined application of chemical and organic fertilizers. In the present study, nevertheless, the proportion of chemical fertilizer in the integrated application becomes more influential in increasing yield compared to the proportion of the bio-slurry. The higher the proportion of the chemical fertilizer, the more becomes the yield of lettuce.

3.5. *Correlation between growth parameters and yield*

The yield and its components showed a significant ($p < 0.05$) positive correlation as follows: yield-plant height ($r = 0.464$***), yield-leaf number ($r = 0.535$***), yield-leaf area ($r = 0.534$***), plant height - leaf number ($r = 0.520$***), plant height - leaf area ($r = 0.665$***) and leaf area - leaf number ($r = 0.785$***) (Table 3). Thus, the application of chemical fertilizer and bio-slurry, as sole or integration, increased both growth and yield of lettuce. A prior study found that when chemical fertilizer and bio-slurry were applied together, there was a significant positive correlation between the overall fruit yield and yield components in tomatoes [14] and in maize [27].

4. Conclusion and recommendation

Compared to the control, the sole application of bio-slurry or in combination with chemical fertilizers significantly enhanced the growth and yield of lettuce. Besides, compared to their single application and the control, the combined application of chemical fertilizers and bio-slurry generated a significantly higher growth and yield of lettuce. The integrated application strategy that yielded the highest yields, consisting of 25 % chemical fertilizers and 75 % bio-slurry, seems to be the most effective for growing lettuce in the study area. Additionally, the growth and yield of lettuce tended to increase as the percentage of chemical fertilizers increased. Therefore, the higher the percentage of the chemical fertilizer, the more becomes the yield of lettuce. In conclusion, it may be suggested that the best rate for growing lettuce in the research area be a 3:1 ratio between chemical fertilizers and bio-slurry.

Data availability statement

It is contained within the manuscript in the form of Tables and Figures.

Research support for this reported work

No further assistance has been provided by any organization for us to declare.

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CRediT authorship contribution statement

Tsigereda Meskelu: Writing – original draft, Software, Methodology, Investigation, Formal analysis. **Abate Feyissa Senbeta:** Writing – review & editing, Validation, Supervision, Software, Resources, Project administration, Methodology, Funding acquisition, Data curation, Conceptualization. **Yadessa Gonfa Keneni:** Writing – review & editing, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Getachew Sime: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that none of their known financial conflicts or interpersonal connections could have had an impact on the work presented in this paper.

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