EFFECT OF DIFFERENT RATE OF VERMICOMPOST AND INORGANIC FERTILIZER APPLICATION ON AGRONOMIC PERFORMANCE, BIOMASS YIELD AND CHEMICAL COMPOSITION OF PANICUM COLORATUM GRASS IN JIMMA, SOUTH WEST ETHIOPIA

BY

LEMESA TILAHUN TSIGE

JUNE 2020

JIMMA, ETHIOPIA.

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A THESIS

SUBMITTED TO THE DEPARTMENT OF ANIMAL SCIENCE, COLLEGE OF AGRICULTURE AND VETERINARY MEDICINE IN FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN ANIMAL PRODUCTION

MAJOR ADVISOR: TAYE TOLEMARIAM (PhD, PROFESSOR)

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POST GRADUATE STUDIES

Jimma University College of Agriculture and Veterinary Medicine

Department of Animal Science

Thesis Submission for External Defense Request Form (F-08)

Name of Student: Lemesa Tilahun Tsige ID No RM 7983/11

Title: Effect of Different Rate of Vermicompost and Inorganic Fertilizer Application on Agronomic Performance, Biomass Yield and Chemical Composition of Panicum Coloratum Grass in Jimma, South West Ethiopia. I have incorporated the suggestions and modifications given by my advisors and got the approval of my advisors. Hence, I hereby kindly request the department to allow me to submit my Thesis for external defense.

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We, the thesis advisors have verified that the student has incorporated the suggestions and modifications given by us and the Thesis ready to submit. Hence, we recommend the Thesis to be submitted for external defense.

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Decision/suggestion of Department Graduation Council (DGC)

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DEDICATION

I dedicate this Thesis paper to my wife Burtukan Wonber for her enthusiastic partnerships in the success of my life.

STATEMENT OF THE AUTHOR

I declare that this Thesis is my work and that all sources of materials used for this Thesis have been duly acknowledged. This Thesis has been submitted in partial fulfillment of requirements for MSc degree at Jimma University and is deposited at University library to be made available to readers under the rules of library. I truly declare that this Thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate. Brief quotations from this Thesis are acceptable without special permission on condition that accurate acknowledgement of the source is made. Request for permission for extended quotation from or reproduction of this Thesis in whole or in part may be approved by the head of Animal Science or Coordinate of Post graduate Studies his or her judgment the proposed used of material in the interest of scholarship. In all other circumstance, however, permission must be obtained from the author.

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Place: Jimma University, Jimma.

Date of Submission ____________/_____________/______________

BIOGRAPHICAL SKETCH

The author, Lemesa was born from Tilahun Tsige and Workinesh Oljira on August 13, 1992 in Gimbi District, Western Wollega Administrative Zone, and Oromia Regional State. He attended his elementary education in Geba-senbata and Jogir Kebele Primary Schools. He continued his high school studies at Biftu Gimbi Senior Secondary and completed preparatory school at Gimbi compressive High school. After passing the Ethiopian entrance Examination successfully, he joined Wollega University in 2009/2010 academic year and graduated with a B.Sc. degree (in Distinction) in Animal Science in July 2012. Soon after his graduation, the author was employed by the Oromia Regional State, Agency of Livestock and Health office and assigned at Meko Livestock and Health Agency Office. Lemesa was transferred to Becho Woreda Livestock and Health Agency Office and assigned as an expert on Livestock and fishery extension at the Department of Animal Sciences in 2016. Finally, after he worked for five years and eight months, he joined Jimma University College of Agriculture and Veterinary Medicine, Department of Animal Sciences in October 2018/19 to pursue his MSc in Animal Production. At present the author is married and has a four years Son.

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ABBREVIATIONS

ADF	Acid detergent fiber
ADL	Acid detergent lignin
ADMY	Average dry matter yield
AGDP	Agricultural gross domestic product
AADMY	Average adjusted dry matter yield
ANOVA	Analysis of variance
AOAC	Association of Official Analytical Chemists
CEC	Cation exchange capacity
CP	Crude protein
CPY	Crude protein yield
CSA	Central statistical agency
DF	Date of flowering
DG	Date of germination
DIF	Date of initial flowering
DM	Dry matter
DMY	Dry matter yield
DWss	Dry weight sub-sample
ETB	Ethiopian birr
FAO	Food and Agriculture Organization of the United Nations
FBY	Fresh biomass yield
FWss	Fresh weight sub-sample
GB	Gross benefit
GDP	Gross domestic product
LLPP	Leaf length per plant
LSR	Leaf to steam ratio
MRR	Marginal rate of return
NDF	Neutral detergent fiber
NI	Net income

NLPP	Number of leaf per plant
NPSB	Nitrogen, phosphorus, sulfur and boron
NTPP	Number of tiller per plant
OC	Organic carbon
OM	Organic matter
PBA	Partial budget Analysis
PH	Plant height
TA	Total ash
TC	Total variable cost
TFC	Total fixed cost
TR	Total revenue
TVC	Total variable cost
VC	Vermicompost
VCPC	Vermicompost preparation cost

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Effect of Different Rate of Vermicompost and Inorganic Fertilizer Application on Agronomic Performance, Biomass Yield and Chemical Composition of Panicum Coloratum Grass in Jimma, South West Ethiopia

ABSTRACT

The study was carried out in Jimma University College of Agriculture and Veterinary Medicine, at Eladale research site with the objectives of evaluating different rates of vermicomposts and inorganic fertilizer application on agronomic performance, biomass yield, and chemical composition of Panicum coloratum grass. The experiment was planned in a randomized complete block design with three replications. The treatments were T1= sole application of inorganic fertilizer (100 kg/ha), T2 = 25% vermicompost (VC) and 75% NPSB (nitrogen, phosphorus, sulphur and boron), T3 = 50% VC and 50% NPSB, T4 = 75% VC with 25% NPSB, T5 = 100% (5 ton/ha) VC with 100% (100 kg/ha) NPSB and T6 = 100% VC& 0% NSPB. The data on 50% flowering, agronomic performance, biomass yield and chemical composition were collected. The agronomic performance, biomass yield, and laboratory analytical data were subjected to one-way ANOVA and correlation analysis of SAS software 9.3 versions. Tukey's Honest Significant Test was used to separate means that showed significant difference. The result revealed that combined application of vermicompost and inorganic fertilizer significantly (P<0.05) affected phonological variables, agronomical performance, biomass yield and chemical composition of Panicum coloratum. Early full germination date was 10.33±0.67, early days to initial flowering was 50.33±0.88 and 50% flowering days was 68.78±0.29obtained due to the application of 100% each of VC and inorganic fertilizer. The highest plant height, leave length, number of tiller per plant and number of leaves per plant for Panicum coloratum grass at 1, 2 and 2.5 months were recorded for T5 followed by T3 while the lowest was from sole inorganic fertilizer. The overall mean fresh biomass yields were 1421.07, 146.41 and 154.80 ton/ha while the dry matter yields were 8.72, 9.42 and 9.94 ton/ha at 1st, 2ndand 3rd stages of cutting, respectively. Application of vermicompost and inorganic fertilizer increased CP and OM content, but NDF, ADF and ADL contents decreased at balanced rate of both fertilizers. The study results showed that combined application of vermicompost and inorganic fertilizer was economically feasible at 50% each sources (T3). Besides, with 100 ETB cost, a 301 ETB extra income was attained from T3 when compared with sole application of inorganic fertilizers. In summary, application of 50%each source (T3) improved agronomic performance, biomass yield, and nutritional quality as well as economic benefit in production of Panicum coloratum grass. In future, application of vermicompost with inorganic fertilizer should be verified at on farm conditions, at different season and agro-ecology conditions.

Keyword: Agronomy, Biomass yield, Chemical composition, Fertilizer, *Panicum coloratum*, Vermicompost.

1 INTRODUCTION

Ethiopia has the largest livestock population in Africa and cattle populations become estimated about 60.39 million (CSA, 2018). Livestock in Ethiopia contribute considerably to the national economy and the lively hood of citizen. This is because about 85% of population of the country farming for their livelihood (CSA, 2018) and oxen are the main sources of traction power. The subsector also contributes 15 to 17% of national gross domestic product (GDP) and 35 to 49% of agricultural GDP and 37 to 87% of household incomes (GebreMariam *et al*., 2013; Gelayenew *et al*., 2016). The crop livestock system in Ethiopia highlands and mid latitude area are under stress because of shrinking of grazing lands due to cultivation for crops and coffee, high rate of population growth, land degradation (Funtea et al., 2010).

The major available feed resources in Ethiopia are natural pasture, crop residues, aftermath grazing, and agro-industrial by-products (Adugna, 2007; Firew and Getnet, 2010; Yaynshet, 2010). The current report of CSA (2018) revealed that 55.96, 30.12, 0.32, 6.55, 1.61 and 5.44% of the total livestock feed supply of the country is derived from grazing on natural pasture, crop residues, improved forage, hay, agro industrial byproducts and others respectively. The fibrous agricultural residues contributes a major parts of livestock feed especially in the populated countries where land is prioritized for crop cultivation. Assefa *et al.*,(2013), Gebremichael(2014) and Kassahun *etal* (2016) reported that natural pasture, weeds, aftermath grazing, crop residues and maize thinning in wet season and crop residues, aftermath grazing, hay and supplements were the major feed resources in dry season. Their contribution to the total feed resource base varies from area to area based on cropping intensity (Seyoum *et al*., 2001).

At present, livestock are fed almost entirely on natural pasture and crop-residues. Use of improved forages and agro-industrial by products is minimal and most of agro industrial byproducts are concentrated in urban and peri-urban areas (Alemayehu, 2005). Those available feed resources are characterized by their inherent nutritional deficiencies, and are generally low in nitrogen, energy, vitamin and minerals (Solomon *et al*, 2003). These constraints result in low milk and meat yields, high mortality of young stock and retarded growth, longer parturition intervals, and low animal weights. Availability of quality livestock feed is important for improving the productivity of the livestock sector.

The use of improved forage like *Panicum coloratum* is important to increase the productivity of the livestock due to their better nutritive value. The grass is among the targets under consideration under livestock master plan of Ethiopia during 2015-2020 (Shapiro *etal*, 2015). *Panicum coloratum* is one of the grass species recommended for production in sub humid tropical areas of the western zones of Ethiopia (Diriba *et al*., 2013**).** Hidosa *et al.* (2017) showed that *Panicum coloratum* produced higher fresh and dry matter yields. *Panicum coloratum* is a perennial grass of warm climates, native of Africa. Depending on soil fertility and rainfall, dry matter production varies from 4 to 7tons/ha/year. It can be efficiently produced with 500mm of annual rainfall and it is highly palatable (Ramirez, *etal*. 2002). *Panicum coloratum* is palatable, high quality forage when green, tolerant of temporary water logging and flooding, drought tolerant, tolerant to soil salinity, very persistent, even in heavy soils with low soil N (Belete. *et al*., 2018).

Nitrogen is an important element in grass production due to its role in photosynthesis and influence in the chlorophyll molecule (Oliveira *et al.,* 2016). Where available N from soil is not sufficient for forage production, application of N-fertilizer may provide immediate responses in forage grasses (Batista *et al.,* 2011). *Panicum coloratum* grass performs much better on acid soils than other grasses, such as Panicum species (Dhakal, 2019).

On the other hand, proper growth of the grasses requires appropriate agronomic management including fertilizer application and/ or the use of vermicomposts. Vermicomposts are the product of the aerobic microorganism degradation of organic materials by integrated actions of various microorganisms and earthworms. Vermicomposts are major source of plant nutrients to reduce chemical fertilizer input there by minimize the cost of crop production (Adhockery, 2012; Lazcano *et al*., 2013). Vermicompost contain large amounts of inorganic and organic form of nitrogen (N), which is immediately available for plant uptake (Lazcano *et al*., 2013). Available N in vermicomposts found in the forms of nitrate (NO3-) and ammonium (NH4+) (Alemneh and Ygrem, 2017).

Vermicompost produces readily available nutrients for plants due to microbial activity within the compost. Through the process of mineralization, microorganisms in vermicompost release nutrients into plant available form which are essential for the growth of plants. Bacteria and fungi initiate this process, mineralizing large amounts of organic material (Condron, 2017). Mineralization is greatly enhanced by other organisms grazing on the bacteria and fungi (Parfitt *et al*., 2004). Red worms (*Eisenia foetida*) graze on these microorganisms and turn over large areas of vermicompost through bioturbation. Nematodes contained in the vermicompost also influence mineralization and immobilization. Griffiths (1986) study found, the nitrate concentration was increased by 0.286 µg N per gram in the rhizosphere after the introduction of nematodes.

The red worms (*Eisenia foetida*) process the vermicompost by shedding the organic material into finer fragments which increases the surface area exposed to microorganisms (Orgiazzi *et al*., 2016). This accelerates mineralization by the microbes, converting a great quantity of the nutrients held in the vermicompost into plant available form. Red worms *(Eisenia foetida)*, consume each layer of vermicompost, and excrete vermicast which are rich in bioavailable nutrients. Once the material is broken down, it's spread across fields to amend crop and soil health as an organic fertilizer or as an alternative source of energy (Singh *et al*., 2016). Temperature of the vermicompost must be kept below 25°C to prevent worm fatality (Orgiazzi *et al*., 2016). Thus, inputs may require pre-composting to bring the temperature down.

Replacing vermicompost with mineral fertilizer may lift nutrient levels which are lacking in the organic material (Abernethy, 2017). Bajracharya *et al*. (2007) studied on the effect of vermicompost in combination with bacteria and mineral fertilizers on soybean found applying amendments together showed increase in shoot and root dry weight. Despite vermicompost treatment applied alone reaching the highest yield for the soybean crop; the total root dry weight peaked when vermicompost was applied in combination with fertilizer. Thus, the research suggests vermicompost alone may give the highest overall yield, however to achieve higher root and shoot dry weight, vermicompost should be applied in combination with fertilizer for best results.

Looking at the livestock production potential, feed shortage around Jimma and the ecological range of adaptation of a grass mentioned above, trials on adaptation and performance of the grasses used vermicompost as an alternative fertilizer source had valuable before widely extending to the farmers. Therefore, study was aimed to evaluate the impact of different levels of vermicomposts integrated with different levels of inorganic fertilizer application on agronomic performance, biomass yield and chemical composition of *Panicum coloratum* grass.

1.1 Statement of Problem

Duguma *et al*. (2012) stated that low quality and quantity of livestock feed is one of impediments for low productivity of livestock in Ethiopia. Feed shortage and low in quality of available feeds have become the major constraint for livestock production of Ethiopia. The most common type of animal feeds is predominantly high fiber feeds, which are incomplete in nutrients (nitrogen, sulfur, phosphorus, etc) necessarily for microbial fermentation (Solomon, 2003). Sun *et al* (2012) reported that Chemical fertilizers are a vital role to meet the nutrient requirement for plants and thereby increase their production.

However, in the present scenario the non-judicious use of fertilizers is posing both economic and ecological problems which are often difficult to face, particularly in developing countries (Sutton *et al*., 2011; Sun *et al*., 2012). Widespread nutrient deficiency in soils disturbed soil reaction, development of nutrient imbalance in the plant, increased susceptibility of plants to diseases, reduced soil organic matter, the lesser occurrence of beneficial soil microorganism and increased environmental pollution, as well as human health hazards, are the key problems associated with indiscriminate and overuse of synthetic fertilizers (Mengistu *et al*., 2017).

Besides, the ecological concerns, the rising cost of chemical fertilizers coupled with the low affordability to smallholder farmers has led to growing interests among the scientific and farming community to shift their attention from chemical alone agriculture to integrated nutrient management strategy which utilizes both organic and inorganic nutrient forms (Singh *et al*., 2010). Since the nutrient turnover in the soil-plant system is considerably high in intensive farming, neither the chemical fertilizers nor the organic and biological sources alone can achieve production sustainability (Javaria and Khan, 2011). Sole application of organic sources cannot maintain and synchronize the required nutrient supply to the growing plant due to a lesser quantity of mineral nutrients or time needed for their mineralization to release nutrients for plant uptake (Akhtar *et al*., 2011).

Thus, the integrated use of organic and inorganic nutrient sources has assumed great significance in recent years (Prativa and Bhattarai, 2011). In addition to the supply of nutrients, organic sources improve the physical condition and biological health of the soil, which improves the availability of applied and native nutrients. Integrating chemical fertilizer along with composted organic materials could be more effective, economical and sustainable for both agriculture and environment (Reddy, 2011; Koushal *et al*., 2011).

However, different work has been done to study the effect of vermicompost on different vegetables and cereal crops, to determine the extent of reduction of inorganic fertilizer by applying vermicompost as an organic source for grass production are limited. Therefore, there is a need to elucidate the appropriate combinations of these nutrient sources to obtain financially viable grass production.

1.2 Objective

The study designed with the following specific objectives;

- To evaluate the effect of applying combined vermicomposts and inorganic fertilizer in different proportions on agronomic performance and biomass yield of the *Panicum coloratum* in Jimma area.
- To investigate applying combined vermicomposts and inorganic fertilizers in different proportions on chemical composition of *Panicum coloratum* forage.
- To examine economic feasibility of combined application of vermicomposts and inorganic fertilizers on *Panicum coloratum* forage production.

1.3 Research Questions

- ❖ What were the effects of different rate of vermicompost and inorganic fertilizer application on agronomic performance, biomass yield and chemical composition of *Panicum coloratum* grasses?
- ❖ Was there any economic advantage of replacing some levels of inorganic fertilizer by vermicompost in using *Panicum coloratum* grass?

2 LITERATURE REVIEW

2.1. Feed Resources in Ethiopia

There are different types of livestock feed resources in Ethiopia, most of which are subjected to seasonal availability. Feed sources vary with the form of agricultural activities (mode and intensification of crop production), populace strain, agro-ecology, a season of the year and environmental situations which include rainfall distribution (Seyoum *et al*., 2001). Alemayehu (2005) grouped the Ethiopian livestock feed resources into grazing land (natural pasture), crop residues, improved pasture, fodder trees and browse, forage crops and agro-industrial by-products. Moreover, there are also feed resources such as byproducts of vegetables, kitchen wastes, etc generally known as non-conventional feeds.

2.1.1. Natural Pasture

Natural pasture is a critical supply of ruminant cattle feed in growing countries (FAO, 2001; Solomon *et al*., 2008). In addition the important contributor to cattle feeds in Ethiopia is natural pasture or grazing lands (Mekasha *et al*., 2015) and it is mentioned that approximately 55.96 % of the overall feed sources is derived from grazing on natural pasture (Table 1). Natural pastures encompass annual and perennial species of grasses and herbaceous legumes (FAO, 2001).

The supply of natural pasture in the highlands of Ethiopia relies upon on the intensities of crop production, population strain, the amount of rainfall, and distribution pattern of rainfall and seasons of the year (Abate and Mohammed, 1995). The contribution of those elements to the full feed useful resource base varies from place to vicinity based on cropping intensities (Seyoum *et al.,* 2001). The reliability of natural pasture as a supply of feed in Ethiopia is limited to the moist season (Zinash *et al*., 1995). And yet grazing lands play a large role in cattle feeding and help a diverse variety of grasses, legumes, shrubs and trees.

Feed values of natural pasture fluctuate considerably in quality based on components such as protein and fiber, which are generally inversely proportional to each other. Natural pastures are categorized as poor quality roughage with a low intake (Berhanu *et al*., 2009), tough texture, poor digestibility, and nutrient deficiency, particularly that of crude protein and metabolizable energy concerning the requirements of the animals (Mupangwa *et al*., 2002)

Table1: The proportion of Animal Feed Resources in Ethiopia

No	Feed type	Percentage
1	Grazing	55.96
2	Crop residue	30.12
3	Hay	6.55
4	Agro-industrial by product	1.61
5	Other feed/ concentrated feeds	5.44
6	Improved fodder or Pastures	0.32

Source: CSA (2018)

In Ethiopia, the available grazing land diminished faster for the duration of the previous last few of years and is probably to continue within the future. The elevated population stress, growth of crop farming, and emerging urbanization result in similarly shrinkage of the prevailing natural pasture land. It has been mentioned that the percentage of natural grazing pasture on the country wide degree has been decreased from 90% (Alemayehu, 1985), to about 55.96% (CSA, 2018). The productivity of the available grazing lands is predicted to variety among 0.5 and 6 tons of DM/ha, the worth of that is characterized as low productivity compared to the yield from the improved pasture (Adane and Berhan, 2005; Alemayehu, 2006).

2.1.2. Crop Residue

In the mixed cereal dominated crop and farm animals farming system of the Ethiopian highlands, crop residues offer about 50% of the overall ruminant cattle feed useful resource. The contributions of crop residues can be as high as 80% at some point of the dry seasons of the year (Adugna, 2007). The excessive dependency on crop residues as farm animals feed is expected to be higher and higher, as increasingly more of the grazing lands are cultivated to satisfy the grain needs of the increased developing human population. The contribution of crop residues to the national feed resource base is good sized (Solomon *et al.*, 2008), for the reason that to be had evidence has a tendency to suggest that (Lemma, 2002), below the modern Ethiopian condition, crop residues offer 40%-50% of the once a year farm animals feed requirement. Consistent with Gashaw (1992), in most components of the significant highlands of Ethiopia, crop residues account for approximately 27% of the full annual feed supply for the duration of the dry intervals.

On average, crop residues offer 10-15% of the full feed consumption within the mixed crop-cattle producing areas (Alemayehu, 2004) in the valuable highlands of Ethiopia. It has been mentioned that, in most intensively cultivated regions, crop residues and aftermath grazing account for greater than 60-70% of ruminant animal's basal food plan (Seyoum *et al*., 2001). The general tendency is that the function of crop residue as livestock feed is increasing once in a while at the expense of shrinkage of grazing lands (CSA, 2018). Teff, barley, wheat, and pulse straws are stacked after threshing and fed to animals for the duration of the dry season when the first-rate and amount of the available natural pasture declines considerably in special components of the Ethiopian highlands (Solomon *et al*., 2008). The supply of these crop residues is without delay proportional to the land location used for cropping the grains (Daniel, 1988). Cereals account for greater than 75% of the entire crop residue yield inside the crucial highlands of Ethiopia (Yoseph, 1999).

Crop residues are an increasing number of becoming the main basal feed for livestock within the crop-cattle mixed farming systems of Ethiopia. The most suitable usage of crop residues is limited through their low feed fine as measured in phrases of protein content and digestibility (Daniel, 1988; Kassahun *et al,* 2016). Furthermore, most of the crop residues used as cattle feed are subjected to seasonal fluctuation in availability and used with none treatment or strategic supplementation (Solomon *et al*., 2008). Crop residues are of very terrible in feeding value attributed to low metabolizable power, to be had protein and a serious deficiency in mineral and vitamins (Staniforth, 1979).

Crop residues range substantially in chemical composition and digestibility relying on varietal differences (Reed *et al*., 1986) and agronomic practices (Staniforth, 1979). The feeding value of crop residues is also confined through their poor voluntary intakes and occasional digestibility. The crude protein content of crop residues grades among 2.4 and 7% and their IVDMD stages among 34 and 52% (Gashaw, 1992). Cereal straws have a mean CP, NDF, and IVDMD values of 4.5, 79.4 and 51.1%, respectively as compared to pulse straws, which have an average CP, NDF and IVDMD values of 7, 62.9 and 63.5%, respectively. Straws of oil plants have CP and NDF values 5.4 and 66.4%, respectively (Alemu *et al*., 1991). Crop residues are normally characterized by high fiber content material and low digestibility and intake (Zewdie *et al*., 2011). Most cereal straws and stovers are recognized for his or her lower nutritive value as compared to haulms of grain legumes and vines from root crops such as candy potato.

The haulms of leguminous crops were reported to represent good quality roughages with CP contents ranging between 5 and 12% (Adugna, 2007). Within the highland mixed crop-farm animals farming systems of the Ethiopian highlands, the cereal crop residues provide approximately 50% of the total feed supply for ruminant farm animals. The contributions of crop residues reach as much as 80% all through the dry seasons of the year (Adugna, 2007). Further increased dependence on crop residues for livestock feed is expected, as more and more of the native grasslands are cultivated to satisfy the grain food needs of the rapidly increasing human population in the country.

The whole annual production of crop residues in Ethiopia is estimated to be 30 million tons of DM (Adugna *et al*., 2012), of which 70% is utilized as livestock feed. Primarily based on the present trend of conversion of grazing land into cropping land, crop residues primarily based farm animals production system is anticipated to increase proportionally (Peter *et al.,* 2010). However, crop residues tradeoffs (using crop residues for different uses) such as household energy source, house construction and other related industrial use may lead to serious competition with livestock production. Crop residues are also encouraged inside the context of soil conservation and it is advocated that approximately 30% of the whole crop residues produced on a given plot of land need to be left on the land for soil amelioration and protection from erosive losses. The combinations of these crop residues tradeoffs will in general reduce the contributions of crop residues to livestock feed resources (Angaw *et al*., 2011). For this reason, there's a need to search for other alternative feed sources as complementary feeds to crop residues.

2.1.3. Agro-industrial By-Products

Feed resources of agro-industrial origin include by-products of cereal milling and by-products cooking oil extractions, both of which are a good source of easily fermentable energy and protein. Agro-industrial by-products that are once categorized as wastes are now considered valuable livestock feeds (Ensminger *et al.,* 2002). Almost all plant material produced or processed for food or feed yields one or more by-products that can be utilized as animal feed. Under the modern-day Ethiopian situations the main agro-commercial with the aid of-products include residues final behind oilseed and grain processing. Residues from the processing of the various agricultural by-products should become a more important element in ameliorating inadequate feed supplies.

Oilseed cakes (oilseed meals) are byproducts generated from the processing of oil crops such as groundnut, sunflower and soybean (Firew and Getnet, 2010). Ibrahim (1998) pronounced that oilseed cakes are rich in protein quality and quantity and fatty acids. Oilseed cakes commonly used as protein concentrates on animal feeding are soybean meal, coconut meal, cottonseed meal, linseed (flax) meal, noug seed cake, sesame meal and sunflower meal. Using oilseed cakes in animal feeding is stricken by the availability and digestibility of amino acids, the concentrations of minerals and vitamins and the level of moisture, fiber and urease. The feeding value of oilseed food additionally varies consistent with the method of extraction (Ensminger *et al*., 2002).

In Ethiopia, oil extraction is done almost entirely by a mechanical pressing method with the use of old machines in the oil milling industries (CSA, 2015). It has been indicated that sunflower seed cake was utilized effectively by Menz sheep in the Ethiopian highlands in terms of rumen microbial nitrogen synthesis, nitrogen retention and growth (Osuji, 1993). The addition of small amounts of energy which include overwhelmed maize grain at the pinnacle of the oilseed cake, in addition increased microbial nitrogen synthesis, nitrogen retention and live weight gain. Solomon (1992) reported a significant increase in growth rates of sheep fed on ration supplemented with groundnut seed cake. Based on feed conversion efficiency, oilseed cakes could be ranked on descending order as cottonseed cake, noug cake and groundnut cake. The other essential agro-industrial by-products normally used as animal feed are by-product acquired from flour milling, brewery and sugar industries.

Agro-industrial by-products could either be protein concentrate, energy concentrate or both. Local brewer's byproducts (brewer's grains) are a good source of protein for livestock feeding in Ethiopia (Solomon, 2007). They are low in fiber content material, high in digestibility and energy value for ruminant animal feeding compared with poor quality tropical feed resources (Seyoum and Zinash, 1989). Alemu *et al*. (1991) suggested extra than 35% crude protein and 50-70% in-vitro organic matter digestibility for oilseed cakes and 18-20% crude protein and more than 80% in-vitro organic matter digestibility for flour milling with the aid of-products. Supplementing low-quality ruminant feeds with agro-industrial by-products improves animal performance attributed to the higher nutrient density of the supplement to correct the nutrient deficiencies in the basal diet.

2.1.4. Indigenous Fodders

Shrubs and fodder tree play an enormous role in livestock production in all agro-ecological zones of tropical Africa. The fodder tree foliage is commonly browsed directly on trees, or after lopping by livestock herders. They are also offered as cut-and-carry feed install-fed situations (Atta-Krah, 1990). The importance and availability of fodder trees in tropical Africa are influenced by several factors such as the natural distribution of trees within the agro-ecological zones, the distribution, types, and importance of livestock, the integration, and role of livestock within the farming system, and the availability of alternative sources of fodder in livestock feeding in the agro-ecological zone (Atta-Krah, 1990). The productivity of the fodder trees in terms of foliage production consistent with unit region is linked with habitat and soil texture.

Some fodder trees in humid and sub-humid climate had been reported to supply 2.3 to 4.69 tons of forage DM/ hectare/year (Baumer, 1992). Fodder trees contain medium to an excessive stage of CP ranging from 120-250 g per kg, indicating that they are a precious source of protein in cattle feeding within the tropics (Solomon, 2001). Le Hoearou (1980) reported that fodder trees contain 26-95% DM and 10-30% CP. Perennial fodder trees retain high CP content for a longer period than annual shrubs. However, the CP digestibility of certain fodder species was found to be low and several cases of livestock death have been associated with their high tannin content in foliage. The role of fodder trees in ruminant nutrition has not been truly defined and is likely to be different depending on whether they are used as a strategic supplement or basal feed source.

Indigenous fodder trees and shrubs are important feeds of ruminant animals due to their appreciable nutrient content that is deficient in ordinary feed resources such as crop residues and natural pasture (Aberra, 2011; Firisa *et al*., 2013; Awoke, 2015). Most browse plants are high in crude protein content, ranging between 10 and 25% on a dry matter basis. Indigenous fodder trees could be considered as reliable feed resources to develop a sustainable livestock feeding system due to their ability of remaining green for a longer period (Okoli *et al.*, 2003 cited in Aynalem and Taye, 2008; Ashenafi *et al*, 2016). The ability of most browse species to remain green for a longer period is attributed to deep root systems, which enable them to extract water and nutrients from deep soil profile which in turn contributes to the increased crude protein content of the foliage (Le Houérou, 1980). There is a very critical need to evaluate the feed values of the indigenous browse plants and develop sustainable feeding standards in the tropics. A wide range of indigenous trees and shrubs are grown in Ethiopia. To mitigate the problem of ruminant animal feed availability and quality in the tropics, the use of browse plants as an option has been sought (Enideg, 2008; Aberra, 2011).

2.1.5. Improved Forages

Introduction, popularization and utilization of improved multipurpose forage crops and trees such as Sesbania spp., *Leucaena leucocephala*, Calliandra spp. and *Chamaecytisus palmensis* through integration with food crops cultivation in the mixed crop-livestock system in Ethiopia started in the 1970s aimed at supplementing the widely available roughage feed resources (Alemayehu, 2006). Unsatisfactory and limited success rates have been reported from the attempts made in the establishment of improved forages (Abebe *et al*., 2008) with less than one percent contribution (CSA, 2015) which calls for further effort in extension and research activities in the area. Cultivated fodder crops such as oats, vetch, alfalfa, and fodder beet are not well developed under the present Ethiopian conditions (Alemayehu, 2005).

Shortage of land in the mixed crop-livestock production system, technical problems such as planting and managing the seedlings, insect damage and low interest of farmers were some of the reported reasons for poor adoption of improved forage production (Abebe *et al*., 2008). In the highland of Ethiopia, immediate response to population pressure is targeted towards an expansion of the cultivated area to maintain per capita crop output. Thus, livestock and crop activities may become competitive for land resources (McIntire *et al.*, 1992). Although the demand for feed may increase under these conditions, competition with food crops is unfavorable to forage adoption, particularly because farmers tend to be unwilling to sacrifice food production to produce fodder for animals (McIntire *et al*., 1992). Some potential contribution of indigenous multipurpose plants such as Vernonia amygdalina,

Buddleja polystachya, Maesa lanceolata, Ensete ventricosum, and Bambusa spp. as a livestock feed resource in the smallholder traditional farming systems have been reported in different parts of the country (Aynalem and Taye, 2008; Beyene. *et al*., 2010). Abebe *et al*. (2008) noted that farmers showed more interest in multipurpose indigenous fodder trees than exotic ones. This indicates that the potential of improved forage adoption is limited under subsistence-oriented livestock production as the economic incentives are low. In contrast, the potential for adoption of improved forages could be higher under market-oriented livestock production systems, such as dairying with crossbreds or improved breeds, and fattening of large and small ruminants (Gebremedihin *et al*., 2003).

2.1.6. Non-Conventional Feed Resources

Non-conventional feed resources refer to feeds that have not been traditionally used for feeding livestock and are not commercially used in the production of livestock feeds. Feedstuffs such as fish offal, duckweed and kitchen leftovers (i.e., potato peel, carrot peel, onion peel, and cabbage leftover), poultry litter, algae, local brewery, and distillery by-products, sisal waste, cactus, coffee parchment, and coffee pulp are commonly used in Ethiopia and could be invaluable feed resources for small and medium-size holders of livestock (Negesse *et al*., 2009).

A common feature about feeds is that the traditional feeds of tropical origin tend to be mainly from annual crops and feeds of animal and industrial origin. Due to their low cost and availability of nonconventional feed resources such as by-products from local brewery and distillery are widely used by smallholder farmers (Nurfeta, 2010). According to, Negesse *et al*. (2009), non-conventional feeds could partly fill the gap in the feed supply, decrease competition for food between humans and animals, reduce feed cost, and contribute to self-sufficiency in nutrients from locally available feed sources. It is therefore imperative to examine for cheaper non-conventional feed resources that can improve the intake and digestibility of low-quality forages.

2.2 *Panicum Coloratum* Grass

Panicum coloratum grass is a warm-season, perennial bunchgrass native to Africa (Dhakal, 2019). It begins green up in late winter or early spring and continues to grow until late fall (Alderson and Sharp, 1994). Plants grow with erect stems ranging from 50.8 to 119.38 cm from a knotty base. The seed head is a fan-shaped, fine-branched panicle similar to switchgrass. *Panicum coloratum* grass reproduces by seed and rhizomes (Hatch *et al*., 1993). Breeding and selection programs have utilized the variability in *Panicum coloratum* grass germplasm to expand the area of adaptation and use in the southern plains (Holt and Conrad, 1966).

Panicum coloratum is one of the grass species recommended for production in sub-humid tropical areas of the western zones of Ethiopia (Diriba *et al*., 2013). Hidosa *et al*. (2017), show that *Panicum coloratum* grass produced higher fresh and dry matter yields. *Panicum coloratum* is a perennial grass of warm climates, a native of Africa. Depending on soil fertility and rainfall, dry matter production varies from 4 to 7tons/ha/year. It can efficiently produce with 500mm of annual rainfall and it is highly palatable (Ramirez *et al.*, 2002). Also *Panicum coloratum* grass is a tufted perennial grass with a variable habit, up to 150 cm high. It is adapted to drier (400 mm) low land alluvial flood plains at an altitude range of 500 to 2000 m.a.s.l. Yields are usually around 12 t/ha DM but ranges of 5.8 to 18 t/ha DM have been reported (Alemu, 2008).

*Panicum coloratum*grass is palatable, high-quality forage when green, tolerant of temporary water logging and flooding, drought-tolerant, tolerant to soil salinity, very persistent, even in heavy soils with low soil N (Belete *et al*., 2018). It is an excellent complement for the short-cycle cutting systems. Different parts of the plant differ in nutritional qualities. In grasses, leaves generally have better nutritional quality than stems (Ramirez *et al*., 2002).

Panicum coloratum grass, a warm-season C4 perennial grass, is cross-pollinated species and appears to be adapted to a wide range of soil conditions that make it attractive for forage production in marginal areas. In particular, *P. coloratum* can tolerate periods of drought followed by flooding (Tischler and Ocumpaugh, 2004).

Panicum coloratum grass has many other conservation benefits including soil stabilization and re-vegetation on depleted soils or range conditions. It can also be used to prevent soil erosion on embankments, ditches, and other highly erodible sites (Dhakal, 2019). Photosensitization is a disease associated with hypersensitivity of small ruminants such as sheep and goats to sun light (Carr, 2014). The disease has been linked to small ruminants grazing Panicum species, including *Panicum coloratum* grass. Re-growth following defoliation or from favorable moisture conditions has shown to be more toxic than older or dormant foliage. Symptoms include discharges from the eyes and nose and sunburn and edema of skin on the muzzle and must be removed immediately from the pasture to avoid death. Signs in horses are more difficult to detect and Cattle appear to be unaffected from this toxin (Ziehr, 2014).

2.3 Vermicomposts Preparation and Application

Vermicomposting: Vermicomposting is a method of making compost, with the use of earthworms, which eat biomass and excrete it in a digested form. This compost is generally called vermicompost or worm compost.

Vermicompost is living organic material produced through the mutual association of microorganisms and worms. Vermicompost produces readily available nutrients for plants due to microbial activity within the compost. Through the process of mineralization, microorganisms in vermicompost release nutrients into plant available form which are essential for the growth of plants. Bacteria and fungi initiate this process, mineralizing large amounts of organic material (Condron, 2017).

Mineralization is greatly enhanced by other organisms grazing on the bacteria and fungi (Parfitt *et al*., 2004). Red worms (Eisenia foetida) graze on these microorganisms and turn over large areas of vermicompost through bioturbation. Nematodes contained in the vermicompost also influence mineralization and immobilization. Griffiths (1986) study found the nitrate concentration was increased by 0.286 µg N g-1in the rhizosphere after the introduction of nematodes.

The red worms (Eisenia foetida) process the vermicompost by shedding the organic material into finer fragments which increases the surface area exposed to microorganisms (Orgiazzi *et* *al.*,2016). This accelerates mineralization by the microbes, converting a great quantity of the nutrients held in the vermicompost into a plant-available form. Red worms (Eisenia foetida), consume each layer of vermicompost and excrete vermicast which is rich in bioavailable nutrients. Once the material is broken down, it's spread across fields to amend crop and soil health as an organic fertilizer or as an alternative source of energy (Singh *et al.*, 2016).

2.3.1 Mechanism of Vermicomposting

Materials consumed by worms undergo physical breakdown in the gizzard resulting in particles <2µ, giving thereby an enhanced surface area for microbial processing. This finely ground material is exposed to various enzymes such as protease; lipase, amylase, cellulase and chitinase secreted into the lumen by the gut wall and associated microbes. These enzymes breakdown complex biomolecules into simple compounds. Only 5-10% of the ingested material is absorbed into the tissues of worms for their growth and rest is excreted as cast. Mucus secretions of the gut wall add to the structural stability of vermicompost (Rana *et al.*, 2014).

Organic wastes used in the production of vermicompost may consist of green leaf, sewage sludge and milk sludge. Other sources of inputs have been trialed including grape pulp, seaweed, septic tank sludge, paper waste and other nutrient-rich alternatives. Sawdust is another source of waste, which is incorporated into the vermicompost as a bulking agent to assist in the retention of leachate (Tejada & Gomez, 2015). The inputs are collected from various sectors and are arranged in layers in a random sequence. The temperature of the vermicompost must be kept below 25°C to prevent worm fatality (Orgiazzi *et al.*, 2016). Thus, inputs may require pre-composting to bring the temperature down.

This is especially important in trials involving vermicomposting of septic tank waste, as E-coli pathogens contained in the waste area of higher temperatures, beyond what the red worms may tolerate. Therefore, pre-pasteurization is required to breakdown the E-coli pathogens (Singh *et al.*, 2011). Moreover, vermicompost beds should be kept moist at 50% moisture content and machinery may be required to break down raw materials (Abernethy, 2017). Vermicompost may consist of wastes from many different sources. However, the material used in vermicompost must be of organic origin, contain no sharp items and be within the range of temperatures the worms can tolerate. There are many sources of organic waste produced on-farm which may be suitable for vermicompost, thus it may act as a waste disposal option (Abernethy, 2017).

2.3.2 Role of Vermicompost in Soil Fertility

According to Singh *et al*. (2016) Vermicomposts can influence the growth and productivity of plants due to their micro and macro elements, vitamins, enzymes and hormones. Vermicomposts contain nutrients such as nitrates, exchangeable phosphorus, soluble potassium, calcium, and magnesium in plant-available forms (Ibrahim *et al*., 2016) and have a large particular surface area that provides many microsites for microbial activity and the strong retention of nutrients (Singh *et al*., 2016). Uptake of nitrogen (N), phosphorus (P), potassium (K) and magnesium (Mg) by rice (Oryza sativa) plant was highest when fertilizer was applied in combination with vermicompost. Nitrogen uptake by ridge gourd (*Luffa acutangula*) was higher when the fertilizer mix contained 50 % vermicompost (Ibrahim *et al*., 2016).

Singh *et al.* (2008) reported that adding vermicomposts to soil improves soil structure, fertility, plant growth and suppresses diseases caused by soil-borne plant pathogens, increasing biological yield. On the other hand, Adhikary (2012) reported the nutrient status of vermicomposts with organic carbon 284.83–288.17g/kg, total nitrogen 22.1—24.1g/kg, available phosphorus 9.75–9.95g/kg, available potassium 15.01—15.39g/kg, calcium 20.9—26.7g/kg, and magnesium 6.64–6.84g/kg, copper 0.93—1.01g/kg, zinc 16.73—17.07g/kg, organic mater 492.8—498.2g/kg and exchangeable C/N ratio 12.17—12.43g/kg that nutrient status of vermicompost listed in the table-2. Besides, Vermicompost application increases the macro pore space ranging from 50 to 500 (μm), resulting in an improved air-water relationship in the soil, favorably affecting plant growth (Marinari *et al.* 2000). Evaluation of various organic and inorganic amendments on the growth of raspberry proves that vermicompost has the beneficial buffering capability and ameliorates the damage caused by an excess of nutrients that may otherwise cause phytotoxicity (Joshi *et al*., 2015).

Table 2: Nutrient content of vermicomposts

No	Parameters	Vermicomposts
1	pH	7.78—7.86
2	TotC(g/kg)	284.83—288.17
3	TotN(g/kg)	22.1—24.1
4	AvailableP(g/kg)	9.75–9.95
5	Organic matter(g/kg)	492.8—498.2
6	ExchC/N ratio	12.17—12.43g
7	ExchK (g/kg)	15.01—15.39
8	ExchCa (g/kg)	20.9—26.7
9	ExchMg (g/kg)	6.64–6.84g
10	ExchCu (g/kg)	0.93—1.01
11	ExtFe (g/kg)	8.54—8.82
12	ExtZn (g/kg)	16.73—17.07
13	Total Sulphur g/kg	3.21—3.23

Source: Adhikary (2012)

2.3.3 Agronomic Value of Vermicomposts Use in Agriculture

Increased rate of germination: According to Arancon (2012) Vermicompost encourages early germination due to the increased supply of nutrients and improvement of the environment's physical conditions. It was found, the seedlings germination rate increased considerably, even at 0-12% concentration of vermicompost extracts on tomato and lettuce. Similarly, Ievinsh (2011) reported that the germination percentage of 0 and 3% plants, showed increased germination of 7 and 13% when vermicompost extract was applied. According to Ievinsh (2011) this was associated with the improvement of soil conditions and increased availability of mineral nutrients after vermicompost application. The early emergence of seedlings is beneficial as it may encourage suppression of weeds and strong initial growth.

Increased canopy cover: Vermicompost may increase the leaf area and canopy size of leaves which consequently increases photosynthetic potential and yield. Vermicompost contains a high amount of nitrate which may move to the growth areas of the plant and increase the leaf area index (Abernethy, 2017). This in turn can increase the absorption of light, enabling the plant to undergo photosynthesis. This leads to a dry matter yield increase in plants. Papathanasiou et al. (2012) compared applications of fertilizers and compost on the yield of lettuce. It was found; the highest leaf number (23.67) was recorded in the 10% vermicompost treatment and highest leaf dry weight (7.8 g) in the 20% vermicompost treatment.

Shoot and root elongation: Crops supplied with vermicompost may have strong early development due to an increased supply of nutrients. Vermicompost contains high availability of nitrate and potassium, allowing ready absorption of nutrients and shoot elongation. Vermicompost may encourage strong initial growth of seedlings by enhanced root formation, elongation of stem and production of biomass (Chavda & Rajawat, 2015). Similarly, Bajracharya et al. (2007) found, application of vermicompost in combination with fertilizer, increased the shoot dry weight of soybean. Suthar's (2009) study revealed that after the application of vermicompost, the yield of garlic plants was increased compared to the application of fertilizers. Leaf length was 0.6% higher, shoot dry weight was 31.4% higher and root length was 74.6% higher compared to mineral fertilizer application.

2.3.4 Effect of Vermicompost on Dry Matter Production

The application of vermicompost can accelerate pasture production due to the increased supply of nutrients. This may encourage the early establishment and greater root growth to increase the plants access to nutrients (Abernethy, 2017). Sabrina *et al*. (2013) assessed the effectiveness of phosphorus enriched vermicompost on the DM production of Setaria grass and after assessment the treatment which has vermicomposts increases DM production of the grass. This led to an increased root mass of 163 cm and subsequently increased DM yield (5.75 g pot-1 to 6.46 g pot 1). Many researchers have studied the effects of vermicompost on various crops (Atiyeh *et al.*,2000; Bajracharya *et al.*, 2007; Chavda & Rajawat, 2015). However, these studies haven't assessed the effect on pasture uptake and production. The influence of vermicompost applied to perennial ryegrass will be quantified in the Abernethy (2017) study.

2.3.5 Vermicomposts Reduction in Plant Toxicity and Deterrence of Pests

Vermicompost can improve crop yield due to the reduction of plant toxicity and the deterrence of insects. Phytotoxicity is a plant injury inflicted by compounds added to the soil, such as phenolic acid. This often occurs when chemicals are applied to regulate growth or fertilize plants (Ievinsh, 2011). Vermicompost however, produces a stable product and reduces phenol acids in the waste material. In the study of Masciandaro *et al*. (2010) assessed the ability of worms to reduce phenolic compounds, and found they decreased the phytotoxicity by 50%.

This increased germination by 70% under vermicompost addition compared to 43% germination in the conventional compost. Besides, other literature suggests the presence of phenolic compounds provides a benefit to plant growth, as it acts as a deterrent to pests. Edwards *et al*. (2002) research found aphid populations were suppressed in vermicompost treated tomato and cucumber plants. Abernethy (2017) reported that twenty-five aphids were released in each treatment and after two weeks, the population increased up to 40 in the control. Whereas in the 20% substituted vermicompost treatment, the populations continually decreased over the next 14 days, reducing the overall damage to the crops. Consequently, there were significant increases in shoot weight and leaf area of tomato plants.

2.3.6 Role of Inorganic Fertilizer for Plant Production

Inorganic fertilizers are good for the rapid growth of plants because the nutrients are already water-soluble. Therefore the effect is usually immediately and fast, contains all necessary nutrients that are ready to use. Inorganic fertilizers are quite high in nutrient content and only relatively small amounts are required for productivity. The correct amount of applications of inorganic fertilizer can increase soil organic matter through higher levels of root mass and crop residues. There are numerous building blocks of life that plants need for healthy and optimum growth(Chen, 2008).

Chemical fertilizers are rich in three essential nutrients nitrogen, phosphorous, and potassium and/or sulfur. Without these nutrients, plants cannot grow to their full potential, will provide lower yields, and be more susceptible to disease (Grant *et al*., 2001). The cost of inorganic fertilizers is increasing enormously, to the extent that they are out of reach for small and marginal farmers. The benefit of inorganic fertilizer plays a significant role in increasing agricultural production and productivity over the last half-century. However, the productivity boost provided by fertilizer technology may be reaching a point of diminishing return (Gruhn *et al*., 2000), with industrial fertilizer use becoming increasingly unsustainable and environmentally damaging.

Nitrogen is an integral component of many compounds such as chlorophyll, nucleotides, alkaloids, enzymes, hormones, and vitamins and these are essential for plant growth processes (Brady and Weil, 2008). However, the application of fertilizer alone is not sustainable solution to improve soil fertility and maintain yield increases (Gruhn, 2000), rather, it has been widely realized that application of excessive inorganic fertilizer, especially N, may Couse soil deterioration and other environmental problems due to more rapid organic matter mineralization. Application of vermicompost in combination with mineral fertilizers can also be of economic benefit. According to Abernethy (2017) supplementing vermicompost with mineral fertilizer may lift nutrient levels which are lacking in the inorganic material. Despite vermicompost treatment applied alone reaching the highest yield for the soybean crop; the total root dry weight peaked when vermicompost was applied in combination with fertilizers. Thus, the research suggests vermicompost alone may give the highest overall yield, however, to achieve higher root and shoot dry weight, vermicompost should be applied in combination with fertilizers for best results.

2.3.7 Effect of Vermicompost Combined With Fertilizer

Application of vermicompost in combination with mineral fertilizers can also be of economic benefit. Nutrients contained in the vermicompost, may not match the requirements of the plant. Supplementing vermicompost with mineral fertilizer may lift nutrient levels which are lacking in the organic material (Abernethy, 2017). Bajracharya *et al*. (2007) study on the effect of vermicompost in combination with bacteria and mineral fertilizers on soybean found applying amendments together showed an increase in shoot and root dry weight. Despite vermicompost treatment applied alone reaching the highest yield for the soybean crop; the total root dry weight peaked when vermicompost was applied in combination with fertilizer. Thus, the research suggests vermicompost alone may give the highest overall yield, however, to achieve higher root and shoot dry weight, vermicompost should be applied in combination with fertilizer for best results.

Aisha *et al*. (2007) declared that, chemical fertilizers alone generate several deleterious effects to the environment and human health and they should be replenished in every cultivation season because, the synthetic N, P and K fertilizer is rapidly lost by either evaporation or by leaching in drainage water and it causes dangerous environmental pollution. Generally N, P and K uptakes were significantly higher in both organically and inorganically fertilized plants than their unfertilized counterparts (Babajide *et al*., 2008). The role of nutrients is one of paramount importance in boosting productivity and quality of plant which is a heavy feeder of mineral elements and continuous use of inorganic fertilizers resulted in deficiency of micronutrients, imbalance in soil physicochemical properties and unsustainable crop production (Jeyathilake *et al*., 2006).

3 MATERIALS AND METHODS

3.1 Description of Study Area

The experiment was conducted at Jimma University College of Agriculture and Veterinary Medicine (JUCAVM), research field (Eladale) in the year 2019 through rain condition which is located at 7km towards north of Jimma. Jimma is located at 346 km in south western of Addis Ababa, an elevation of 1710 m.a.s.l, (Ebisa *et al.*, 2018). The mean annual maximum and minimum temperature are 26.8 and 11.4 ^{o}C and the mean annual maximum and minimum relative humidity are 91.4 and 39.9 respectively (Ebisa *et al.,* 2018). The average annual rainfall of the area is 1250 mm. It lies in the climatic zone locally known as "Weyna-dega (1500-2200 m above sea level) which is considered ideal for agriculture as well as human settlement.

3.2 Experimental Fertilizer Preparation

Vermicomposting was conducted on the small area land of JUCAVM sheep farm. Vermicompost was prepared in four boxes. The boxes were 1 m in length and 30 cm in width. The duration of the culture was for 2 months from May, up to July, 2019 as per the recommendation of Jaganathan *et al*. (2013).

Beddings were material like cow dung and green leaf specifically castor oil leaf (*ricinus communis*) brought to the area and equally distributed and filled the bedding boxes. Seventy two kilograms of bedding material was provided for vermicomposting. Cow dung and leafy materials was mixed in the proportion of 3:1 or 54 kg: 18kg and were kept for partial decomposition for 5 days. Verrmiculture or worm compost of 'Eisenia foetida species' was obtained from Jimma agricultural research center (JARC). About two hundred Eisenia foetida species was stocked in each of bedding boxes.

The boxes containing the compost were checked every day. For the purposes of culture management and different physicochemical parameters such as moisture, aeration, temperature, pH etc were checked and maintained properly. Daily water was sprayed on the worm compost and moisture of the bedding material maintained. 0.36 m2 (1.2m x 0.4m) of plastic sheet was placed above each of the bedding boxes. Harvesting was done on 60th day, and the worms were separated from the vermicast. The young worms and cocoons were separated from the compost by hand as soon as the harvest and using 3 mm sieves after the moisture was removed. Finally, fifty four kilograms ‘of blackish, odorless and crumbly substrate vermin compost was harvested and kept for one week under the shade until applied to soil. The current finished product was 3/4th of the raw material used and 1/4th of the raw material consumed by the worm compost.

3.3. Land Preparation and Sowing

About 5 kg Seed of *Panicum coloratum* was obtained from Bako agricultural research center. Seeds of *Panicum coloratum*grass were planted on well prepared seed beds at a seed rate of 10 kg/ha which was 0.108 kg for all plots in late days of the weeks of 22 June, 2019. The seeds were drilled in rows of 2m long with 30 cm inter row spacing, with plot size of 6m2 (2m× 3 m), each plot consisting of 9 rows. Space between replications and plots was 1 m and 0.5 m respectively. Vermin composts were applied at rate of 5000 kg ha-1 to all plots ten (10) days before planting Before drilling the seeds, fertilizer was applied in the form of NPSB (Nitrogen, Phosphorus, Sulphur and Boron) in different level at a rate of 100 kg/h and worked in to the upper soil layer using hand rakes to enhance vigorous growth of the seedlings and improve their resistance to weed suppression.

Weeding was practiced by hoeing and hand weeding during the seedling establishment stage, and subsequently as needed. Moreover; after the seedling well established, the above ground biomass was uniformly cut at about 4cm height above the ground on October 1, 2012, November 15, 2012 and December 30, 2012, and cut biomass was raked out of the plot. This was done with the target to increase stand uniformity for the subsequent re-growth cutting stage. Finally, three re growth times were conducted at 10, 16 and 22 weeks for subsequent evaluation of dry matter yield and nutritional quality.

3.4. Treatment and Experimental Design

The experimental design was randomized complete block design (RCBD) where 6 treatments were randomized within a block and there were three blocks (6 treatments × 3 replications = 18 plots). Six treatments consisted different rates of vermicomposts (0%, 25%, 50% and 75%, 100% kg/h of the recommended base @ 5 ton/ha used by Joshi *et al.* (2013)

and were partially substituted this different rate of vermicomposts with inorganic fertilizers specifically NPSB 100kg/ha by Diriba *et al.* (2013) shown in Table 3.

Table 3: Treatment and replication

L/No	Treatment	Amount of Application	
		NPSB (kg)	Vermicompost (ton)
1	Treatment one	100% (100 kg/h)	0% (0 ton/h)
2	Treatment two	75% (75kg/h)	25% (1.25 ton/h)
3	Treatment three	50% (50 kg/h)	50% (2.5 ton/h)
4	Treatment four	25% (25 kg/h)	75% (3.75 ton/h)
5	Treatment five	100% (100 kg/h)	100% (5 ton/h)
6	Treatment six	0% (0 kg/h)	100% (5 ton/h)

*NB: L/No = list of numbers; NPSB = nitrogen, phosphorus, sulfur and boro*n Adapted from Joshi *et al*. (2013) applied on wheat.

3.5 Data Collection

3.5.1 Soil Sample Collection

The composite soil sample was collected from nine points in diagonal pattern before forage planting and eighteen plots after harvesting from depth of 0-20 cm using auger. The sample was air dried, crushed using mortar and pestle and passed through a 2 mm sieve (Anderson, 2010).The composite samples of soil were analyzed for selected physico-chemical properties for soil pH and texture, nitrogen, Organic Carbon, available phosphorus and cations exchange capacity (CEC).

Soil pH was measured using glass electrode pH meter in the suspension of 1: 2.5 mixture of soil to distilled water. Soil organic Carbon was determined using Walkley and Black method (1934). Total N was analyzed using the Kjeldhal method by oxidizing the Organic Matter in 0.1N H2SO4 as described by Black (1965). The available phosphorus was determined from the soil sample by extracting with solutions of 0.03 Ammonium fluorides in 0.1M hydrochloric acid following Olsen II methods (Olsen, 1954). Organic matter (OM) was estimated indirectly from the organic carbon determination OM%=1.72X%OC. The soil samples were analyzed at JUCAVM, soil science laboratory.

3.5.2 Agronomic Parameters Collection

For agronomic parameters, ten sample plants were selected from fourth and sixth rows of each plot area, and tagged using string which was slightly tied on plant to determine various morphological and phonological characteristic. Morphological characteristic such as plant height, tiller number, leaf lengths and leaf per plant were recorded at 1, 2 and 2.5 months after planting. Plant height (cm) was determined using steel ruler and measured vertical from the ground to the tip of the plant. The leaf length (cm) was measured from the node to the tip of the leaf. Number of leaf per plant was determined by counting total number of leaf from the main ten plants randomly selected on the fourth and sixth rows in each plot. Number of tillers per plant also determined by counting visible tillers in each of ten plants randomly selected plant on the fourth and sixth rows of each plot. Leaf to stem ration was determined by separating leaf and stem from ten randomly selected plants and dried in oven for 72 hour at 65^{o}c independently and evaluate ratio of leaf to stem. For all agronomic parameters, the mean of ten randomly selected plants were taken for each plot determination (Tibebu *et al*., 2018).

3.5.3 Germination and Flowering Determination

For germination and flowering determination, the fourth and sixth rows of *Panicum coloratu*m grass species from the first days of germination and inflorescence appearance in each plot was determined using continuous visual observation. Date of full germination (DG), date of initial (DIF) and 50% flowering were recorded with daily follow-up. Time of full germination of *Panicum coloratum* grass was determined by continuously visual observation in recording the number of days post-planting when all of the plants were germinated.

Date of initial flowering (DIF) was determined at the time when the ten sample plants of the two middle rows started to give flowers. Days to 50% are number of days from planting to the date on which 50% of the ten sampled plants produce flowers. Time to initial and 50% flowering date for *Panicum coloratum* grass was determined by continuous visual observation and recording the number of days planting when a first and 50% of the plants were flowering (Tibebu *et al*., 2018).

3.5.4 Biomass Yield Evaluation

Biomass yield of forage per plot was evaluated under successive cuts at 50% of flowering based on continuous follow up. Samples were collected from fourth and sixth rows (1.2 m2) area of each plot and harvested at stubble 4 cm of cutting. The harvested green forage was weighed plot wise using sensitive field balance. The fresh sub-sample were measured from the fourth and sixth rows from each plot weighed and chopped into small pieces using sickle (2.5 cm), labeled and kept in separate perforated bags. Fresh weight of sub-samples (FWss) of 300 gm was taken from each plot and dried in an oven at 65 oC for 72 hours to constant weight. Dry weight of sub-samples (DWss) reinterred for 30 minute into Oven and weighed to have an estimated of dry matter production. The following formulas were employed to obtained dry matter yield estimation.

1) Dry matter yield kgha-1 = 10 x Tot FW x (DWss/HA x FWss) (Tarawal, 1995)

Where:

Tot FW = total fresh weight from plot in (kg)

DW ss = dry weight of the subsample (grams)

HA = Harvesting area in (m2)

FW ss = fresh weight of the subsample (grams)

10 = a constant for conversion of yields kg/m2 to ton/ha

2) The fresh biomass yield ton/ha was determined by using the flowing formula;

Fresh biomass yield (tonha-1) = $\frac{Total\ fresh\ biomass\ weight\ (kg)}{harvested\ area\ in\ m2}\ x\ 10$

3) Dry matter (%) = For dry matter determination, 300 gm grass sample could be weighted in each container and placed in an oven at 65 oC for 72 hours still constant weight attained. Dry matter percentage was calculated by the following formula.

Dry matter (%) = $\frac{Wt.of\ oven\ dried\ sample\ (gram)}{Sample\ fresh\ weight\ (gram)}$

3.5.5 Chemical Analysis

The forage was harvested from fourth and six rows (1.2 m2) at 50% flowering. The samples of harvested forage from each plot were chopped into small pieces using sickle, weighed, labeled and kept in separate perforated bags of sub-sample of 300 gram. For each plot sample of Panicum coloratum grass was taken and dried in forced dry oven at 65 oC for 72 hours and samples was ground using Wiley mill to pass through 1mm sieve screens for chemical analysis. Dry matter (DM), Ash, and crude protein (CP) was determined by using AOAC (1995).

The total DM content was determined by oven drying at 105 oC for 24 hours. The Ash content was determined by igniting the dried sample in muffle furnace at 550 oC overnight (AOAC, 1990). The residual after burning in muffle furnace was the Ash. The OM was determined by subtracting the ash component from 100. Nitrogen (N) content was determined by Kjeldhal method and CP was calculated as 6.25 x Nitrogen. The methods of van Soest and Robertson (1985) were used to determine neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL). The sample was analyzed at JUCAVM Animal nutrition and post-harvest laboratories.

3.5.6 Partial Budget Analysis

The economics of various treatments was calculated by taking into account the existing price of inputs and produce. The investment for organic and inorganic fertilizers, labor, and power for performing different operations such as ploughing, weeding and harvesting etc were worked out ha-1 as per rate prevalent at the Jimma and around Jimma town. The considered cost of labor for vermicompost preparation, cultivation and harvest of grass were thirty birr. Besides, the cost of produced dry matter yield was 2.25 birr per kg at study area. The cost of cultivation was taken into account for calculating economics of treatments and expressed as net return (ha-1) and marginal rate of return (CIMMYT, 1998).

3.5.6.1 Total return (revenue) (ha-1)

The dry matter biomass yield was converted into gross income or total revenue in ton per hectare on the basis of current price of the produced.

3.5.6.2 Net return (ha-1)

This is the amount of money which is left when total costs (TC) are subtracted from the total return (TR):

NI = TR –TC (TR – (FC + VC)), whereas NI = net income, TR = total return, TC = total cost, fixed cost and variable cost. Marginal net benefit (MNB) increase in change in net income (▲NI) which is the difference between the change in total returns (▲TR) and the change in total variable costs (▲TVC), and total fixed cost (▲TFC) of the first and new technology according to formula (CIMMYT, 1998).

MNB = ▲NI = ▲TR – (▲TFC + ▲TVC); Fixed costs are, by definition, the same for all technologies:

▲FC = 0: Thus formula can be simplified to: MNB = ▲NI = ▲TR - ▲TVC. Net-income changes of all treatments could be done from control treatment or sole inorganic application. This could be due to different rates of vermicompost incorporated in 100% recommended inorganic fertilizer on Panicum coloratum applicable (CIMMYT, 1998).

3.5.6.2.1 Total costs (TC):-

Included here were the costs of all inputs, such as organic fertilizer, inorganic fertilizer, labor and power for different duties. For purposes of PBA, total cost has been separated into two groups: fixed costs (FC) and variable costs (VC): TC = FC + VC (Upton, 1979), if FC =0 or common for all; TC = VC. Marginal cost is increase in changes of total variable cost (▲TVC) which is a difference between the first and new technology. MC = ▲TVC

3.5.6.3 Marginal rate of return

In addition to change in net income, the marginal rate of return (MRR) was used for evaluating the economics of adopting a new technology. MRR measures the increase or decrease in net income.

MRR = ▲NI/▲TVC or MNB/MC (Upton, 1979)

In other words, (MRR) measures the net return on additional capital invested in a new technology, compared to the farmer’s present one. If the new technology costs less than the farmer’s present technology, it is not necessary to calculate the marginal rate of return (MRR). If the alternative technology is more costly, the marginal rate of return (MRR) must be; higher than those of other possible investments, and high enough to cover risks associated with adoption. According to the CIMMYT, (1998), in the partial budget analysis three criteria can be applied:

- If the net income remains the same or decrease the new technology should be rejected because it is not more profitable than the farmer’s present technology.

- If the net income increase and variable costs remains the same or decrease the new technology should be accepted because it is more profitable than the farmer's present technology.
- If both net income and variable costs increase, the marginal rate of return (MRR) should be looked at, the greater increase in net income and the higher marginal rate of return, the more economically an alternative technology is, the new technology should be accepted only if its marginal rate of return is higher than 1.0.

For the current study, in all treatments marginal rate of return could be calculated from the T1 (0 ton/ha VC with 100 kg/ha NPSB) net-income changes (▲NI), because different rate of vermicompost substituted in 100% (100 kg/ha) recommended inorganic fertilizers.

3.6 Statistical Analysis

The data were analyzed by using GLM (ANOVA) with SAS software (SAS, 2011 version 9.3). Significantly different means were separated and compared using Tukey's HSD test at 5% significance level.

The model used for data analysis was:-Yij = μ + Ʈi + βj + £ij

Where Yij = All dependent variables (Phonological data, Morphological, Biomass yield and analytical data) were collected.

μ = Overall mean effect.

Ʈi = the treatment effect

βj =Block effect

£ij = Experimental error (random error) for treatments i^{th} in block j^{th}.

4. RESULTS AND DISCUSSION

4.1 Soil Composition.

The result for chemical properties of the vermicompost, soil sample before and after harvesting of a grass is presented on Table 4. The pH of the composite soil sample before planting was very strong acidic based on the rating suggested by Landon, (2014). There was improvement of the soil pH after harvesting grass in all treatments probably attributed to the various rate of vermicompost application and change in soil characteristics.

The available phosphorous (4.69 ppm) of the soil before planting the forage was rated as very low based on classification made by Black, (2013) as a relative range of extractable phosphorous (P) of 0-5ppm, 6-10ppm, 11-15ppm, 16-20ppm and 21-25 ppm as very low, low, medium, high and very high, respectively. The total nitrogen, organic carbon, organic matter and cations exchange capacity (CEC) content of the study soil before planting were 0.168(medium), 1.95 (low), 3.36 (low) and 25.8 (high) respectively. Analyzed composite soil texture before planting and after application of the compost was clay and clay loam, respectively. The pH of prepared vermicompost was found to be 7.85 which is slightly alkaline. The available phosphorous, total nitrogen, organic carbon, organic matter and cations exchange capacity (CEC) content of the prepared vermicompost were 139.8 (very high), 0.42 (very high), 4.85 (high), 8.4 (medium) and 33.72 (high) (Table 4), respectively.

Soil pH, available phosphorous, organic carbon, organic matter, total nitrogen and cations exchange capacity of soil were significantly ($P<0.05$) affected by different rate of vermicompost and inorganic fertilizer application after harvest of the grass. The pH value of post-harvest soil was presented on Table 4. The soil pH value after application of vermicompost increased from 4.4 up to 5.97. A plot treated with T5 and T6 showed a 23.12% and 20.86% higher pH value over sole application of inorganic fertilizer (T1), respectively. The lowest pH value observed from a plot amended in sole inorganic fertilizer application (T1) followed by 1.25 ton/ha VC and 75 kg/ha inorganic fertilizer application (T2). There were insignificant difference of pH value among T4, T5 and T6. Similarly, a plot amended with T2 and T3 were not statistical difference in pH value from T1. The acidity of soil decreased with increasing rate of vermicompost under integrated rate of vermicompost and inorganic fertilizer application. In line with the current result, Zaman *et al*. (2018) reported that combined application of vermicompost and inorganic fertilizer increased soil pH after harvest of stevia grass. Similarly, Sailaja and Usha (2000) implied that the pH of the acid soil was increased due to vermicompost application.

Soil organic carbon (OC) after harvesting of *Panicum coloratum* was significantly ($P<0.05$) influenced with increased rate of vermicompost under integrated application of vermicompost and inorganic fertilizer. A plot amended with a higher rate of vermicompost (T5 and T6) scored highest OC than sole applied inorganic fertilizer (T1) and T2. The lowest OC observed from sole application of inorganic fertilizer (T1), followed by a plot treated @ 1.25 ton/ha vermicompost with 75 kg/ha inorganic fertilizer (T2). There were insignificant difference between T5 and T6. Besides, there was no statistical difference between T1 and T2 as well as T3 & T4.

Total 'N' from soil after harvesting of *Panicum coloratum* was significantly ($P<0.05$) enhanced with increasing rate of vermicompost under integrated rate of vermicompost and inorganic fertilizer application (Table 4). The highest value of total 'N' observed from a plot amended with T5 and the lowest values were from the sole inorganic fertilizer (T1) application. A treatment supplied with T5 and T6 showed a 58.33% and 57.14% higher total 'N' over sole application of inorganic fertilizer (T1), respectively. Lower total 'N' in soil after harvesting the grass was recorded from a plot applied in T1, followed by T2. There were insignificant differences between T5 and T6 as well as between T2 and T3.

The current result indicated that, the residual soil of total 'N' values of plot which received sole inorganic fertilizer was lower than those plots receiving increased rate of vermicompost under integrated rates of vermicompost and inorganic fertilizer. This might be due to the fact that vermicompost, by virtue its increased nutrient retention capacity, might have reduced the nitrogen losses and thus, increased the availability of 'N' in the soil to improve the fertilizer use efficiency (Prativa and Bhattarai 2011). In line with this result, Zaman *et al.* (2015) found that the highest values of the total 'N' in post-harvest soil were obtained when vermicompost was applied @ 10 ton/ha. Manivannan *et al*. (2009) also found that increased growth of the plant due to the use of vermicompost which indirectly influenced the physical conditions of the soil and supported better aeration to the plant roots and absorption of water.

Available ‘P’ in soil after harvesting of *Panicum coloratum* was significantly ($P<0.05$) increased with the increased rate of vermicompost and inorganic fertilizer application (Table 4).A plot treated with T5 and T6 showed a 44.09% and 43.52% more available phosphorus, respectively over sole inorganic fertilizer (T1) application. The lowest available ‘P’ was obtained from T1, followed by a treatment supplied @1.25 ton/ha vermicompost with 75 kg/ha inorganic fertilizer (T2). There was insignificant difference of available ‘P’ between T5 and T6 as well as T3 and T4.

The current result showed that, the available ‘P’ in the soil sample after harvesting of Panicum coloratum grass was increased with increasing rate of vermicompost under integrated rate of vermicompost and inorganic fertilizer application. This might be due to the increased availability of ‘P’ in plots receiving integrated nutrition attributed to the fact that vermicompost in combination with mineral fertilizer and might have helped the solubilization of unavailable ‘P’ to easily available for the plant. In line with the current result, Azarmi *et al*. (2008) reported that, in response to the added vermicompost, the solubilization of ‘P’ was increased either by microorganism activation with excretion of organic acids or by higher phosphatase activity. Moreover, the results are similar with the findings of Prativa and Bhattarai (2011) who reported that higher available ‘P’ content was observed with increased vermicompost rate through the integrated use of organic and inorganic fertilizers.

Organic matter content after harvest of Panicum coloratum grass significantly ($P<0.05$) increased with increased rate of vermicompost and inorganic fertilizer application that shown at (Table 4). A plot applied withT6 and T5, OM content increased over sole application of inorganic fertilizers (T1) that ranged from 35.95% to 38.27%, respectively. The lowest OM content scored from a treatment supplied by sole inorganic fertilizer application (T1) and T2. There were insignificant difference between T5 and T6. There were significant difference between a plot applied @1.25 ton/ha vermicompost with 75 kg/ha inorganic fertilizer (T2) from T1. The current result indicated that organic matter of soil sample after harvest of Panicum coloratum grass increased with increased rate of vermicompost application. This might be due to the high availability of organic matter content in the applied vermicompost.

The CEC of post harvested soil sample was significantly influenced ($P<0.05$) by application of integrated rate of vermicompost and in organic fertilizer (Table 4). The CEC soil increased with increment of integrated rate of vermicompost and inorganic fertilizer application as ranged 25.8 up to 32.74 from before and after harvest of the grass, respectively. T5 and T6 showed a 21.35% and 14.82%, respectively more CEC over independent inorganic fertilizer (T1). The CEC of soil after harvest of the grass increased with increased rate of vermicompost over independent inorganic fertilizer application. This might be due to the greater availability of the exchangeable bases such as (Ca, MG, K and Na), and the increased cations exchange capacity (CEC) resulted from the added vermicompost. Vermicompost has high cations exchange capacity, thus the application of vermicompost might have helped to increase the CEC of the soil and thereby to retain more of the cations in harvested sites (Nada *et al*., 2011).

Table 4: Chemical properties of the soil, vermicompost and the influence of the treatments before and post-harvest of Panicum coloratum grass.

TRT	pH	%OC	% TN	Av.P (ppm)	% OM	CEC
BP soil sample	4.40	1.95	0.168	4.69	3.36	25.8
Vermicompost	7.85	4.85	0.42	139.8	8.4	33.72
Treatment			Post-harvest soil			
T1	4.59±0.12^{c}	1.98±0.02^{d}	0.15±0.01^{d}	41.94±0.71^{d}	3.42±0.15^{d}	25.75±0.15^{c}
T2	4.74±0.06^{c}	2.34±0.05^{dc}	0.23±0.01^{c}	53.02±0.96^{c}	4.56±0.06^{c}	26.92±0.08^{bc}
T3	4.94±0.07^{bc}	2.71±0.11^{bc}	0.24±0.00^{c}	59.44±0.29^{b}	4.63±0.16^{ba}	27.32±1.37^{bc}
T4	5.66±0.14^{ba}	2.78±0.09^{bc}	0.32±0.01^{b}	60.27±0.57^{b}	4.88±0.08^{bc}	29.04±1.06^{bac}
T5	5.97±0.24^{a}	3.33±0.16^{a}	0.36±0.01^{a}	75.01±0.30^{a}	5.54±0.11^{a}	32.74±1.20^{a}
T6	5.80±0.24^{a}	3.2±0.12^{ba}	0.35±0.01^{a}	74.26±0.61^{a}	5.34±0.07^{ba}	30.23±0.44^{ba}
CV	5.30	6.64	3.90	1.77	4.12	5.33
P-value	0.0001	<.0001	<.0001	<.0001	<.0001	0.0013
overall mean	5.28	2.72	0.28	60.66	4.73	28.70

Means with the different superscript letter in the same column are significantly different at (PV<0.05). BP = before planting; TRT = treatment; OC = organic carbon; Av.P=available phosphorous; OM = organic matter; TN = total nitrogen; CEC = cations exchange capacity; VC = Vermicompost; T1 = control treatment (VC0ton/ha: NPSB100kg); T2 = VC 1.25ton/ha: NPSB75kg/ha; T3 = VC5 2.5ton/ha: NPSB50kg/ha; T4 = VC3.75: NPSB25kg/ha; T5 =

VC5ton/ha: NPSB100kg/ha; T6 = VC5ton/ha: NPSB0kg; M = month; CV = coefficient of variation; PV = probability value.

4.2. Phonological Variables

The result of vermicompost and inorganic fertilizer application on germination date, date of initial flowering and 50% flowering of *Panicum coloratum* were shown in Table 5. There were significantly different results ($P<0.05$) due to different rates of vermicompost and inorganic fertilizer application on early germination, initial and 50% flowering dates.

4.2.1. Date of Full Germination

There was significant ($P<0.05$) difference among the treatments on full germination for *Panicum coloratum* grass post-planting date. T1 and T2 took 3 - 4 days longer to fully germinate as compared to T5 and T6. There was insignificant difference of full germination date between T5 and T6. Moreover, there were no statistical difference among T1, T2, T3 and T4.The current result indicated that *Panicum coloratum* grass seed germination has been enhanced with increased rate of vermicompost under integrated rates of vermicompost and inorganic fertilizer application.

The delay in full germination with sole application of inorganic fertilizer could be due to low amount of major nutrients, when compared with integrated vermicompost and inorganic fertilizer application (Fernandez *et al*., 2010). Similarly, Arancon (2012) reported that vermicompost application encourages early germination date due to the increased supply of nutrients and an improvement of the environments physical conditions. Moreover, Tolera *et al*. (2018) noted that the integration rates of vermicompost stimulated seed germination in cereal plant such as barley and wheat. Atiyeh *et al*. (2000) reported that vermicompost stimulates the emergence of plants because of the presence of major nutrients and other essential nutrients like N, P, K, and improves soil structure due to organic matter present in it. As mentioned by Bewley *et al.* (2012) during vermicomposting, nitrogen is not lost; rather some nitrogen gets added in the form of earthworm mucus. As both nitrate and ammonium are efficient breakers of seed dormancy, their enrichment in vermicompost makes the early a facilitator of germination.

4.2.2. Days to Initial Flowering (DIF) and 50% Flowering

The integration rates of vermicompost and inorganic fertilizers had brought significant ($P<0.05$) effect on days to initial as well as 50% flowering. Initial flowering of a plot applied with sole inorganic fertilizer (T1) was 61.67 after planting *Panicum coloratum*, which is about 10 days delayed as compared to T5 and T6. Furthermore, T5 and T6 have shortened initial flowering by 6days compared to T3 and T4, while there was no statistical difference between T5 and T6 as well as among T2, T3 & T4. Moreover, date of initial flowering of T2 was not statistical different from T1. The current result indicated that the initial flowering date early occurred with increased rates of vermicompost under integrated rates of vermicompost and inorganic fertilizer application, which could be related to early full germination date.

The achievement of early flowering of *Panicum coloratum* was due to the highest rates of vermicompost under integrate rate of vermicompost and inorganic fertilizers application might have encouraged the grass for early emergence, rapid growth and development. In line with this result, Kinfe *et al*. (2019) had found that application of vermicompost and nitrogen, phosphorus and sulfur (NPS) fertilizers hastened days to initial flowering and 50% flowering as compared to low fertilized plots on Teff. Taleshi *et al*. (2011) also reported that increase in N-levels, and microbial activity by adding vermicompost leads to greater root expansion, which in turn leads to greater uptake of nutrients, water and rate of photosynthesis, ultimately leading to better flowering and maturity. Similarly, Mitiku *et al*. (2014) reported that application of farmyard manure, vermicompost and nitrogen, phosphorus and potassium (NPK) fertilizers resulted quick days to early flowering and maturity as compared to low fertilized plots. This result is also in agreement with findings of Sewnet (2005) who reported early flowering of rice with an increased level of N-fertilizer application.

The 50% flowering date of *Panicum coloratum* grass was significantly ($P < 0.05$) affected by integrated use of vermicompost and inorganic fertilizer application. The earlier 50% flowering of *Panicum coloratum* recorded at T5, followed by T6 that achieved 68.78±0.29 and 69.04±0.54 days, respectively after planting. Thus, prolonged days of 50% flowering recorded from T1 that achieved 75.05±0.58 days. There were insignificant different between T1 and T2 indicating zero and 25% of vermicompost with inorganic fertilizer had little impact in improving the days to 50% flowering. Likewise, a plot applied with T3, T4, T5, and T6 remained the same in 50% flowering of *Panicum coloratum* after planting.

The current result showed that increased rate of vermicompost under integrated rates of vermicompost and inorganic fertilizer applications shorten 50% flowering of *Panicum coloratum* grass. Early flowering of *Panicum coloratum*grass could be due to highest rate of vermicompost and nitrogen, phosphorus, sulfur, and Boron (NPSB) fertilizers which encourage the grass in early emergence, rapid growth and development. Moreover, some possible reasons for the relative earliest of *Panicum coloratum* grass in vermicompost incorporated treatments could be due to biological effects such as increases in beneficial enzymatic activities, increased population of beneficial microorganisms, or the presence of biologically active plant growth influencing substances such as plant growth regulators or plant hormones and humic acids in the vermicompost (Atiyeh *et al*., 2001; Singh *et al*., 2008).

In line with this result, Mitiku *et al*. (2014) reported that application of farmyard manure, vermicompost and nitrogen, phosphorus and potassium (NPK) fertilizers hastened days to flowering as compared to unfertilized plots on teff. This result is also in agreement with findings of Sewnet (2005) who reported early flowering of rice with an increased level of N-fertilizers application. Similarly, Woubshet *et al*. (2014) found that application of different rate of organic matter with inorganic fertilizer speedup days of heading and maturity of barley.

Table 5: Effect of integrated application of vermicompost and inorganic fertilizer on days to full germination, initial and 50% flowering of *Panicum coloratum* grass

Treatment	Days to full germination	Days to initial flowering	Days to 50% flowering
T1	14.67±0.33[a]	61.67±1.45[a]	75.05±0.58[a]
T2	14.00±0.58[a]	57.67±0.88[ba]	72.69±0.46[a]
T3	13.75±0.14[ba]	56.00±1.15[b]	69.09±0.22[b]
T4	13.33±0.33[ba]	56.00±0.58[b]	69.42±0.97[b]
T5	10.33±0.67[c]	50.33±0.88[c]	68.78±0.29[b]
T6	11.33±0.88[bc]	50.67±0.67[c]	69.04±0.54[b]
CV	7.35	3.07	1.38
P-value	0.0007	<.0001	<.0001
Mean	12.90	55.39	70.68

Means with the different superscript letter in the same column are significantly different (P<0.05). T1 = control treatment (0ton/haVC: 100kg/haNPSB); T2 = 1.25ton/haVC: 75kg/ha NPSB; T3 = 2.5ton/haVC: 50kgNPSB; T4 = 3.75ton/haVC: 25kg/haNPSB; T5 = 5ton/haVC: 100kg/haNPSB; T6 = 5ton/haVC: 0kg/haNPSB; CV = coefficient of variation; PV = probability value.

4.3. Agronomic Parameters

Significant difference was observed (P<0.05) on the plant height, leaf length, number of leaf per plant, number of tiller per plant and leaf to stem ration of *Panicum coloratum* grass when the field was incorporated with different rate of vermicompost and inorganic fertilizer at 1, 2 and 2.5 months measurement (Figure 1 &Table 6).

4.3.1. Plant Height

A significant variation was observed among the treatments on the plant height of *Panicum coloratum* grass when the field was incorporated with different rates of vermicompost and inorganic fertilizer. The tallest plant height (156±0.58cm) was observed from T5, and the second tallest plant height achieved 151±1cm by application of 2.5 ton/ha vermicomposts and 50 kg/ha inorganic fertilizer (T3) application. The shortest plant height was observed from 5ton/ha vermicompost exclusively (T6) fertilizer, followed by (T1) sole application of 100 kg/ha inorganic fertilizer which recorded (131cm). The shortest plant height was recorded from the sole application of vermicomposts for *Panicum coloratum* grass in all months of measurements, followed by T1 (sole application of 100 kg/ha inorganic fertilizer).

There was insignificant difference between the plot treated with T5, and T3. A plot supplied with T5, and T3 showed a 16.03 and 13.25% greater plant height, respectively over T1at 50% flowering. There were no statistical differences in plant height T4 and T6 from T1 at 50%flowering. A plot treated with only 5 ton/ha vermicompost (T6) scored 124±0.58 which showed that a 5.34% lower than the sole application of 100% inorganic fertilizers (T1). For *Panicum coloratum* grass, plant height increased with advanced months of measurement from T1 to T6. Moreover, plant height increased with the increased rate of vermicompost and inorganic fertilizer application and vice versa. The overall mean plant height obtained was 38.45, 67.28, and 138.33 for *Panicum coloratum*grass recorded at 1, 2, and 2.5 months of measurements, respectively.

The current result showed that *Panicum coloratum* grass height increased at equal proportion of the two types of fertilizer under combined rate of vermicomposts and inorganic fertilizer application. Besides, the current finding also indicated that *Panicum coloratum* grass height decreased at lower proportion of each sources fertilizer application. This might be due to the amending vermicompost and inorganic fertilizer together could lift-up nutrient levels which are lacking in one of the two fertilizers. In agreement with current result, Li and Li (2010) stated that the humic acids in humus of vermicompost are essential to plants in helping chemical fertilizers to effect better. Similarly, Abernethy (2017) pronounced that incorporating vermicompost with mineral fertilizer intensified major nutrient uptake which are lacking in one of the two types of fertilizers. Besides, applying the essential nutrients, the positive effect of vermicompost on the growth of *Panicum coloratum* grass might be related to the presence of plant growth regulators, humic acids, increased microbial diversity and activity and improvement of the physical structure of the soil (Arancon *et al.,* 2005; Llaven *et al*., 2008; Singh *et al*., 2010). Thus, vermicompost might have an additive effect in enhancing the growth and development of the plant when integrated with the inorganic fertilizer.

This result in line with Ashik *et al*. (2016) who found that combined application of different rates of vermicompost and NPKS fertilizer had a significant effect on plant height of rice. Sarker *et al*. (2004) reported that the variation in plant height observed were due to nutrient sources varied in the availability of major nutrients. Chemical fertilizer offers nutrients that are readily soluble in soil solution and thereby occurring available to plants at early time. Nutrient availability from organic sources is due to microbial action and improved physical condition of soil not available for immediate use; release nutrients after the expected time.

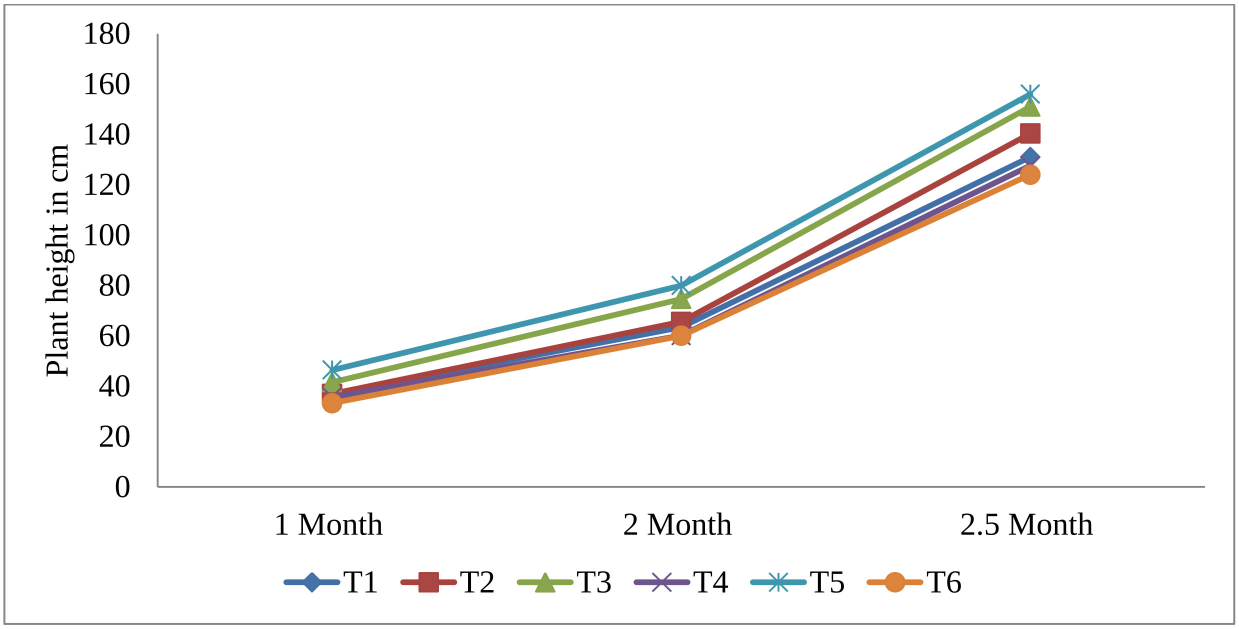
Likewise, Tolera *et al.* (2018) reported that using of 50% vermicompost in combination with50% inorganic fertilizer increased the growth and early flowering of barley. In the same way, Shrivastava *et al.* (2018) studied that the application of farmyard manure and vermicompost with inorganic fertilizers resulted in better cell division, cell expansion, and enlargement that led to a higher plant height at different cereal plant height development stages. Moreover, Assefa *et al.* (2016) found that combination of compost and NP fertilizer did show a significant effect on plant height of teff.

Table 6: Least square means and standard errors for Plant height (cm), leaf length (cm), number of leaf per plant, numbers of tiller per plant and leaf to stem ratio of grass measured at 50% of flowering.

TRT	PH	LLPP	NLPP	NTPP	LSR
T1	131.00±5.57^{dc}	43.00±0.58^{b}	5.33±0.33^{c}	25.33±0.33^{c}	1.10±0.05^{cb}
T2	140.33±1.20^{bc}	43.00±1.00^{b}	6.17±0.44^{bc}	27.00±0.58^{bc}	1.11±0.04^{cb}
T3	151.00±1.00^{ba}	48.00±0.58^{a}	7.33±0.33^{ba}	29.00±0.58^{ba}	1.22±0.03^{b}
T4	127.60±3.76^{dc}	41.00±0.58^{cb}	6.00±0.58^{bc}	27.00±0.58^{bc}	1.06±0.04^{cb}
T5	156.00±0.58^{a}	50.00±0.58^{a}	7.67±0.33^{a}	31.00±0.58^{a}	1.59±0.03^{a}
T6	124.00±0.58d	38.00±0.58^{c}	5.67±0.33^{bc}	25.00±0.58^{c}	1.04±0.03^{c}
CV	3.55	2.63	10.96	3.10	5.14
P-value	<.0001	<.0001	<0.0080	<.0001	<.0001
Mean	138.33	43.83	6.36	27.39	1.19

Means with the different superscript letter in the same column are significantly different at (PV<0.05). VC=Vermicompost; PH = plant height; LLPP = leaf length per plant; NLPP =

number of leaf per plant; NTPP = number of tiller per plant; LSR = leaf to steam ratio; T1= control treatment (VC0ton/ha:NPSB100kg); T2 = 1.25ton/haVC:75kg/ha NPSB; T3 = 2,5ton/ha VC: 50kg/ha NPSB; T4 = 3.75/ha VC: 25kg/ha NPSB; T5=5ton/ha VC: 100kg/ha NPSB; T6 = 5ton/ha VC: 0kg/ha NPSB; NPSB = nitrogen, phosphorus, sulfur and boron; CV = coefficient of variation; PV= probability value; LSD= Least Significant Difference.



NB: T1 = control treatment (100kg NPSB/ha); T2 = treatment two (1.2 ton/ha VC and 75kg/ha NPSB); T3 = treatment three (2.5ton/ha VC and 50kg/ha NPSB); T4 = treatment four (3.75ton/ha VC and 25kg/ha NPSB); T5 = treatment five (5ton/ha VC and 100kg/ha NPSB); T6 = treatment six (5ton/ha VC and 0kg/ha NPSB); VC = vermicompost; NPSB = (nitrogen, phosphorus, sulfur, boron).

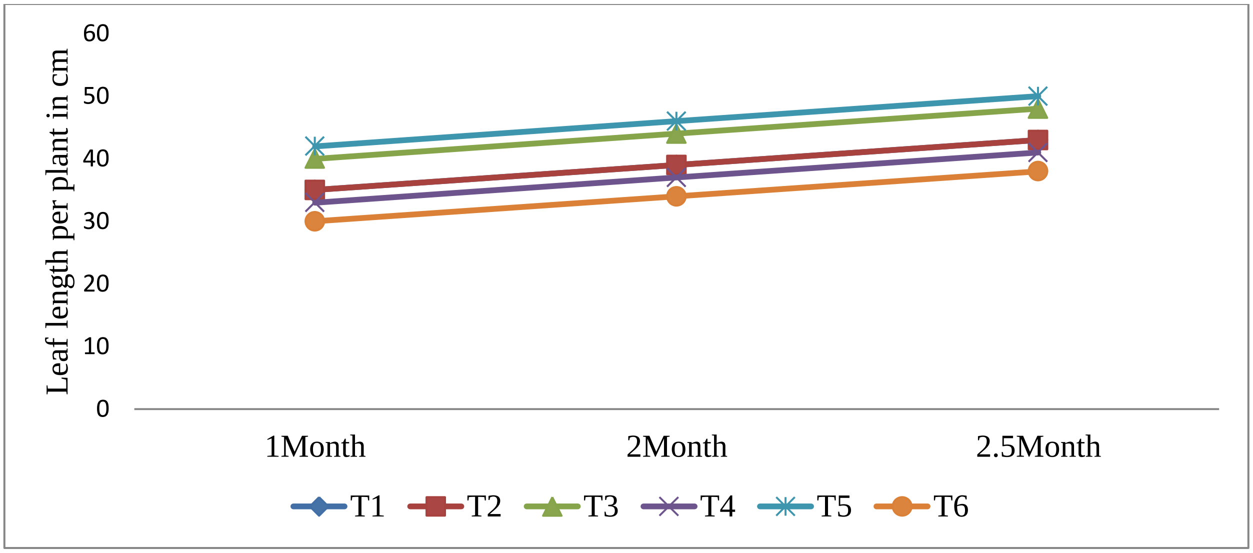
Figure 1: Effect of vermicompost and inorganic fertilizer application on the height of *Panicum coloratum* grass in three consecutive measurements (from July 22 up to October 1).

4.3.2. Leaf Length

The analysis of variance showed that the leaf length of *Panicum coloratum* grass was significantly ($P<0.05$) affected by different rates of vermicompost and inorganic fertilizer at 1, 2, and 2.5 months after planting (Figure 2 & Table 6). The tallest leaf length was recorded at T5followed by T3 while the shortest leaf length was obtained from T6 at all months of growth, followed by T4. The maximum leaf length (50±0.58cm) was observed from T5 which was statistically similar to T3. There was no significant difference among T2, T4, and T1 as well as between T4 and T6.

The current result showed that lower leaf length of *Panicum coloratum* grass observed at a lower ratio of inorganic fertilizer at T4 as well as sole application of vermicompost (T6), and higher leaf length recorded at equal proportion of the two types of fertilizers, specifically in T3 and T5 rate of vermicompost and inorganic fertilizer application. This might be due to the lower ratio of inorganic fertilizer incorporated at T4 and T6 in the proportion, rather than the rest of treatments. Moreover, this might be applying vermicompost and inorganic fertilizer together at equal proportion could lift-up nutrient levels which are lacking in each source of fertilizers. In line with the current result, Abernethy (2017) pronounced that incorporating integrated rates of vermicompost with mineral fertilizer could be lift up-nutrient levels which are lacking in organic material. Similarly, Li and Li (2010) stated that the humic acids in humus of vermicompost are essential for plants in helping chemical fertilizers to effect better. Leaf length of *Panicum coloratum* grass increased with advanced months of measurement (figure 2). The overall mean leaf length 35.83, 39.83, and 43.83 *Panicum coloratum* grass were recorded at 1, 2, and 2.5 months of measurements, respectively.

The possible reason for the longest leaf length found from the rate of combined application of vermicompost and inorganic fertilizer was due to the ability of vermicompost to increase the supply of nitrogen and made more available of nitrogen nutrient to plant and this nitrogen is very important for the growth of leaf the length as the result higher supply of photosynthesis. In line with this result, Taleshi *et al*. (2011) reported that available N is greater in vermicompost and N-fertilization increased growth and leaf length of the plant which in turn increases absorption of light leading to more dry matter and yield. Similarly, Ashik *et al*. (2016) found that increased leaf length of rice by application of different doses of vermicompost with nitrogen, phosphorus, potassium, and sulfur (NPKS).



NB: M = month; T1 = control treatment (100kg NPSB/ha); T2 = treatment two (1.2 ton/ha VC and 75kg/ha NPSB); T3 = treatment three (2.5ton/ha VC and 50kg/ha NPSB); T4 = treatment four (3.75ton/ha VC and 25kg/ha NPSB); T5 = treatment five (5ton/ha VC and 100kg/ha NPSB); T6 = treatment six (5ton/ha VC and 0kg/ha NPSB); VC = vermicompost; NPSB = (nitrogen, phosphorus, sulfur, boron).

Figure 2: Effect of combined rate of vermicompost and inorganic fertilizer application on leaf length of *Panicum coloratum* grass in three consecutive measurements (from July 22 up to October 1).

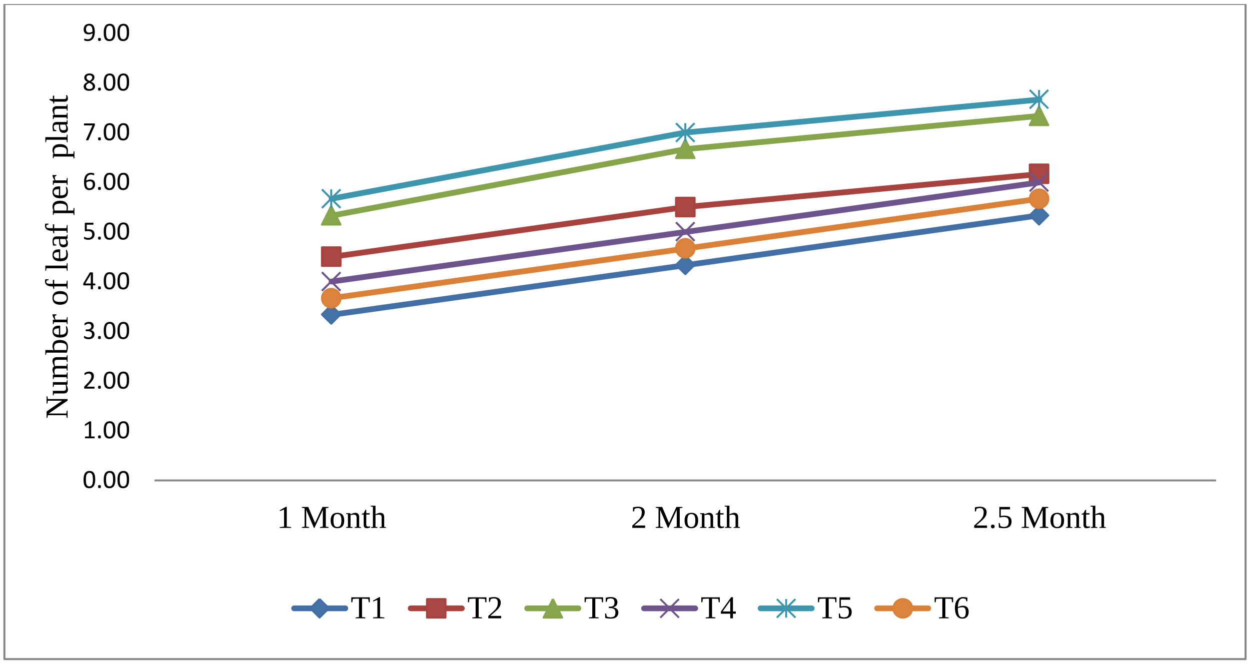
4.3.3. Number of Leaf per Plant

The statistical analysis showed that the number of leaves per plant were significantly affected ($P<0.05$) by a different rate of vermicompost and inorganic fertilizer application (Table 6). The highest number of leaf per plant was found in a plot supplied with T5, followed by T3 while the lowest number of leaf per plant was recorded in T1 which was statically similar with T6 at 1, 2 and 2.5 months of growing period (Figure 3). There was an insignificant difference between T5 and T3. Besides, there were no statistical differences among T2, T4, and T6 from T1. Leaf per plant of *Panicum coloratum*grass increased with enhanced time of measurement (figure 3 & Table 6). The overall mean leaves per plant were 4.22, 5.33, and 6.36 for *Panicum coloratum*grass at 1, 2, and 2.5 months of measurement, respectively.

The current study indicated that the number of leaf per plant was increased, at the equal proportion of both vermicompost and inorganic fertilizer application, and when each source of fertilizers decreased in the proportion, number of leaf per plant was lowered. This might be due to the nutrients contained in the vermicompost, may not compensate the requirements of the plant or provide nutrient in inorganic fertilizer all in all. Besides, applying integrated rates of vermicompost and inorganic fertilizer together might be chemical fertilizer to effect better rather than independent amendments.

In agreement with current finding, Li and Li (2010) stated that the humic acids in humus of vermicompost are essential to plants in helping chemical fertilizers to effect better. Similarly, Bajracharya *et al*. (2007) reported that amendment of vermicompost and inorganic fertilizer together showed an increased shoot of plant other than applying both of the fertilizer independently. Despite vermicompost treatment applied alone reaching the highest yield, the total shoot and root dry weight peaked when vermicompost was applied in combination with fertilizer. Thus, Bajracharya *et al*. (2007) suggested that vermicompost alone may gave the highest overall yield, however, to achieve higher shoot or number leaf per plant, vermicompost should be applied in combination with fertilizer for best results.

Moreover, this result indicated that vermicompost might have added beneficial microbes and nutrients in the soil and also modulates soil's Physico-chemical properties which stimulate better growth and development of plants. This result is in agreement with Buli (2019) who reported that an increase in fertilizer levels to increase the average number of leaf per plant. Similarly, Arancon *et al*. (2008) found that humic acid fraction in vermicompost can trigger plant growth and increase plant height, leaf numbers, and area, shoot and root dry weight by applying 50-500kg vermicompost on plant in the greenhouse. Likewise, Singh and Agarwal, (2001) stated that the increase in leaf number as well as size due to enough nutrition could be explain in terms of the possible increase in nutrient absorption capacity of the plant as a result of better root development and increased translocation of carbohydrates from source to growing points. In the same way, Fathi (2007) reported that an increase in fertilizer level led to an increase the average number of leaves per plant. This is due to the fact that nitrogen increases plant growth and plant height, and this resulted in more nodes and internodes and consequently more leaves.



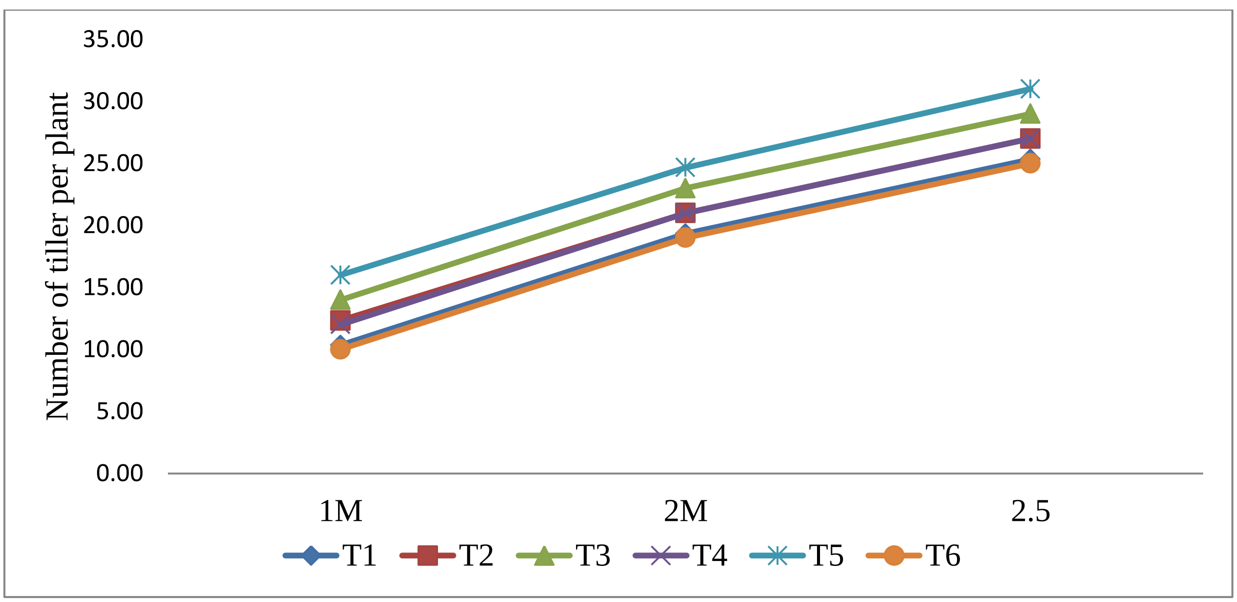
NB: M = month; T1 = control treatment (100kg NPSB/ha); T2 = treatment two (1.2 ton/ha VC and 75kg/ha NPSB); T3 = treatment three (2.5ton/ha VC and 50kg/ha NPSB); T4 = treatment four (3.75ton/ha VC and 25kg/ha NPSB); T5 = treatment five (5ton/ha VC and 100kg/ha NPSB); T6 = treatment six (5ton/ha VC and 0kg/ha NPSB); VC = vermicompost; NPSB = (nitrogen, phosphorus, sulfur, boron).

Figure 3: Effect of combined rate of vermicompost and inorganic fertilizer application on number of leaf per plant of *Panicum coloratum* garss in three consecutive measurements (from July 22 up to October 1).

4.3.4. Number of Tiller per Plant

The numbers of tiller per plant were significantly affected ($P<0.05$) by integrated rates of vermicompost and inorganic fertilizer application after planting in T6 & Figure 4. The greatest number of tillers (31) was observed from T5 which was followed by T3, whereas the lowest (25) was obtained from T6 which was statistically similar to T1 at 50% flowering. A plot at T3 and T5 recorded a 12.66% and 18.30% more tiller per plant respectively over T1 at 50% flowering. A plot which amended with a rate of 5 ton/ha vermicompost (T6) showed a 1.32% lower tiller per plant than T1. There was insignificant difference in tiller numbers between T3 and T5. Moreover, T2, T4, and T6 were no statistical differences in number of tiller per plant from T1. The number of tillers per plant was enhanced with advanced months in growth period within treatment (Figure 4).

The current study showed that the number of tillers per plant was increased at equal proportion of vermicompost and inorganic fertilizer, specifically at T5 and T3, and didn't show significant difference at lower proportion of each source fertilizers applications. In agreement with the current result, Singh *et al*. (2016) reported that nutrients contained in the vermicompost or inorganic fertilizer may not compensate for the requirements of the plant independently. Applying both of them at the same time could be lift-up nutrient levels which lacking from each source fertilizers. This might be due to the nitrogen obtained from vermicompost and inorganic fertilizer application together improved vegetative activity of plants. This is in agreement with other reports for other grass species by Ashik *et al*. (2016) who reported that the application of vermicompost and inorganic fertilization (NPKS) significantly affects the appearance of new tillers and increases the dynamics of tiller population of rice.



NB: M = month; T1 = control treatment (100kg NPSB/ha); T2 = treatment two (1.2 ton/ha VC and 75kg/ha NPSB); T3 = treatment three (2.5ton/ha VC and 50kg/ha NPSB); T4 = treatment four (3.75ton/ha VC and 25kg/ha NPSB); T5 = treatment five (5ton/ha VC and

100kg/ha NPSB); T6 = treatment six (5ton/ha VC and 0kg/ha NPSB); VC = vermicompost; NPSB = (nitrogen, phosphorus, sulfur, boron).

Figure 4: Effect of different rate of vermicompost and inorganic fertilizer application on number of tiller per plant of *Panicum coloratum* grass in three consecutive measurements (from July 22 up to October 1).

4.3.5. Leaf to Steam Ratio.

Leaf to stem ratio of *Panicum coloratum* grass significantly varied (P<0.05) by incorporation of different rates of vermicompost and inorganic fertilizer (Table 6). The current result showed that leaf to the stem ratio (LSR) of *Panicum coloratum* grass ranged from 1.04 to 1.59 with overall mean of 1.19. A plot incorporated with T5 scored the highest LSR followed by T3. A plot that incorporated with T3 and T5 showed a 9.84% and a 30.82% higher LSR than independent inorganic fertilizer (T1). The lowest LSR was obtained from 5 ton/ha vermicompost application (T6) followed by T4. There were insignificant difference in leaf to stem ratio among T1, T2, T4 and T6.

This corresponds to the findings of the number of leaves per plant reported in this study, leaf to the stem ratio of *Panicum coloratum*grass increased at balanced rate of two sources' fertilizer application specifically in T3and T5. Besides, the current finding also indicated that *Panicum coloratum* grass LSR decreased at lower proportion of each sources' fertilizer application. This might be due to the fact that integrating vermicompost with mineral fertilizer could lift-up nutrient levels which are lacking in the organic material and inorganic fertilizer (Abernethy, 2017; Singh *et al*., 2016).Moreover, amendment of soil by vermicompost and inorganic fertilizer together enhanced the shoot, root and leaf canopy area of plant and achieved higher shoot dry weight of leaf while applying vermicompost with inorganic fertilizer for best result (Bajracharya *et al*., 2007) and uptake of nutrients such as nitrogen (N), phosphorus (P), potassium (K) and magnesium (Mg) by the plant was intensified when fertilizer was applied in combination with vermicompost (Ibrahim *et al*., 2016).

Besides, vermicompost enhances growth parameters such as tillering performance, plant height, shoot, and canopy of a leaf that may affect the proportion of leaf and stem of the plant (Ibrahim *et al*., 2016; Singh *et al*., 2016). Similarly, Smart *et al.* (2004) reported that, the LSR has significant implications on the nutritive quality of the grass as leaf contains higher levels of nutrients and less fiber than stems. Likewise, Tudsri *et al.* (2002) indicated that, the leaf is higher nutritive value and the performance of animals is closely related to the amount of leaf in the diet.

4.5. Biomass Yield

4.5.1. Fresh Biomass Yield

The fresh biomass yield of *Panicum coloratum* grass at 1st, 2nd, and 3rd cutting after planting that tested in different rates of vermicompost and inorganic fertilizer was summarized in Table 7 and Figure 5. A plot treated with T5 recorded higher fresh biomass yield (FBY) by 27.29%, 29.36%, and 27.32% than T1 at 1st, 2nd, and 3rd harvest, respectively at 50% flowering. The second highest FBY was recorded from a plot incorporated with T3 resulted in 21.31%, 23.72%, and 21.76% more FBY over T1 at three cutting stages during 50% flowering.

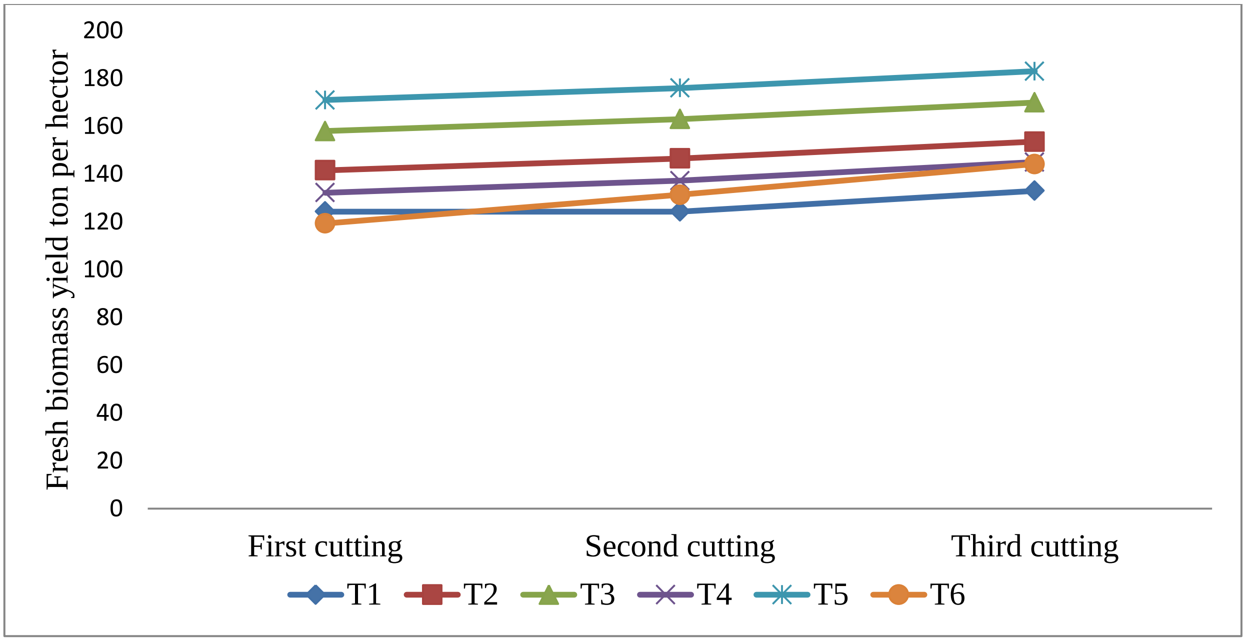
There was an insignificant difference between treatment five (T5) and (T3) at all cutting time. Similarly, there was no statistical difference among T2, T4, T6, and T1 at 1st and 2nd cutting time. Besides, there were no significant differences among T2, T3, T4, and T6 from T1 at 3rd cutting time. The lowest fresh biomass yield was recorded from treatment with pure inorganic fertilizers (T1) and organic fertilizer (T6) for *Panicum coloratum*grass during all cutting time at 50% flowering. The current finding showed that at equal proportion of two source's fertilizer under combined application of vermicompost and inorganic fertilizer could result in better biomass yield associated with better agronomic performance indicated above.

On the other hand, a plot treated by T1 had greater FBY over T6 at first harvest, whereas the cutting stage advanced FBY of the grass with pure vermicompost (T6) was greater than T1. This result might be due to vermicomposts had low mineralization and leaching ability when compared with inorganic fertilizer at early time and vice versa (Ibrahim *et al*., 2016). This result is in line with Zaman *et al.* (2018) who reported that the highest biomass yield was in the treatment with the highest integrated level of vermicompost and chemical fertilizer application and the lowest biomass yield was from the non-application of integrated vermicompost and chemical fertilizer in stevia grass.

Similarly, Azarpour *et al*. (2013) obtained the highest fresh biomass yield of other grass from the treatment where 10 ton per hectare vermicompost was applied than chemical fertilizers. The highest fresh biomass yield of *Panicum coloratum* grass was obtained from the third harvest followed by the second harvest over the first harvest shown in (Figure 5). *Panicum* coloratum grasses', fresh biomass yield was increased with an advanced stage of cutting from 1st to 3rd. Third harvest of a plot incorporated by T5 showed 6.56 and 3.83% of FBY over a first and second harvest, respectively. Besides, third harvest of a plot amended by T3 recorded 7.06 and 4.12% of FBY than a first and second harvest, respectively. This might be due the enhanced mineralization rates of vermicompost that could leads increased number of tillering and leaf per plant in regard to advanced time.

In the current study, FBY of the grass was enhanced at equal proportion of two source's fertilizer under integrated rate of vermicompost and inorganic fertilizer application and when each source fertilizers lowered in the proportion, FBY of a grass decreased. This result might be due to the effect of amending the soil by vermicompost and inorganic fertilizers together have enhanced the shoot, leaf canopy area of the plant, and achieved higher shoot dry weight of leaf (Bajracharya *et al*., 2007). Besides, uptake of nutrients such as nitrogen (N), phosphorus (P), potassium (K), and magnesium (Mg) by the plant was intensified when fertilizer was applied in combination with vermicompost that forced to enhanced biomass yields (Ibrahim *et al*., 2016). Moreover, Singh *et al*. (2016) reported that, vermicompost enhances growth parameters such as tillering performance, plant height, shoot, and canopy of the leaf that may affect the proportion of leaf and stem of the grass.

The overall mean of FBY obtained from the current study at all cutting times of grass were higher than previously reported values 40.8ton/ha by Denbela (2015) in the rain-fed condition. The higher, fresh biomass yield from this study than the author reported values might be due to the effect of the application of different rates of vermicompost and inorganic fertilization and difference in agro-ecology of the study sites.



NB: T1= control treatment (VC0 ton/ha: NPSB100 kg); T2 = VC 1.25 ton/ha: NPSB 75 kg/ha; T3=VC5 2.5 ton/ha: NPSB50 kg/ha; T4=VC3.75: NPSB 25kg/ha; T5=VC5 ton/ha: NPSB 100 kg/ha; T6=VC5 ton/ha: NPSB0 kg.

Figure **5**: Effect of different rate of vermicompost and inorganic fertilizer application on fresh biomass yield (FBY) of Panicum coloratum grass in three consecutive harvests.

Table 7: Effect of integrated rates of vermicompost and inorganic fertilizer application on fresh yield, dry matter yield and Crude protein yield of three consecutive harvest of *Panicum coloratum* grass at 50% flowering

Treatment	Fresh biomass yield (ton/ha)			Dry matter yield (ton/ha)			CPY (ton/ha)
	1st cutting at 10 week	2nd cutting at 16 week	3rd cutting at 22 week	1st cutting at 10 week	2nd cutting at 16 week	3rd cutting at 22 week	1st cutting at 10 week
T1	124.33±6.19[bc]	124.33±4.50[c]	133.00±8.33[b]	7.67±0.32[bc]	8.05±0.24[c]	8.17±0.32[c]	0.74±0.03[c]
T2	141.56±14.73[bc]	146.56±14.73[bc]	153.56±14.73[ba]	9.0467±0.97[bc]	9.54±0.97[bc]	9.98±.94[bc]	1.07±0.06[b]
T3	158.00±3.46[ba]	163.00±3.46[ba]	170.00±3.46[ba]	9.74±0.02[ba]	10.23±0.02[ba]	11.23±0.02[ba]	1.45±0.03[a]
T4	132.22±3.78[bc]	137.22±3.78[bc]	145.00±8.33[b]	7.75±0.13[bc]	9.01±0.06[bc]	9.52±0.27[bc]	1.05±0.03[b]
T5	171.00±0.58[a]	176.00±0.58[a]	183.00±0.58[a]	10.95±0.21[a]	11.44±0.21[a]	12.44±0.21[a]	1.63±0.04[a]
T6	119.33±6.19[c]	131.33±6.19[bc]	144.22±3.78[b]	7.18±0.32[c]	8.24±0.13[bc]	8.54±0.01[c]	0.80±0.05[c]
CV	8.97	8.40	8.93	8.91	7.75	7.419	6.45
P-value	0.0021	0.0018	0.0080	0.0005	0.0008	0.0001	<.0001
Overall Mean	141.07	146.41	154.80	8.72	9.42	9.98	1.12

Means with the different superscript letter in the same column are significantly different at (PV<0.05). CPY = Crude protein yield; NPSB = nitrogen, phosphorus, sulphur and boron; VC = vermicompost; T1 = control (0 ton/ha VC and 100 kg/ha NPSB; T2 = 1.25 ton/ha VC and 75 kg/ha NPSB; T3 = (2.5ton/ha VC and 50 kg/ha NPSB); T4 = 3.75 ton /ha VC and 25 kg/ha NPSB; T5 = 5 ton/ha VC and100 kg/ha NPSB); T6 = 5 ton/ha VC and 0kg/ha NPSB; CV = coefficient of var*iation; PV = probability value*

4.5.2. Dry Matter Yield (DMY)

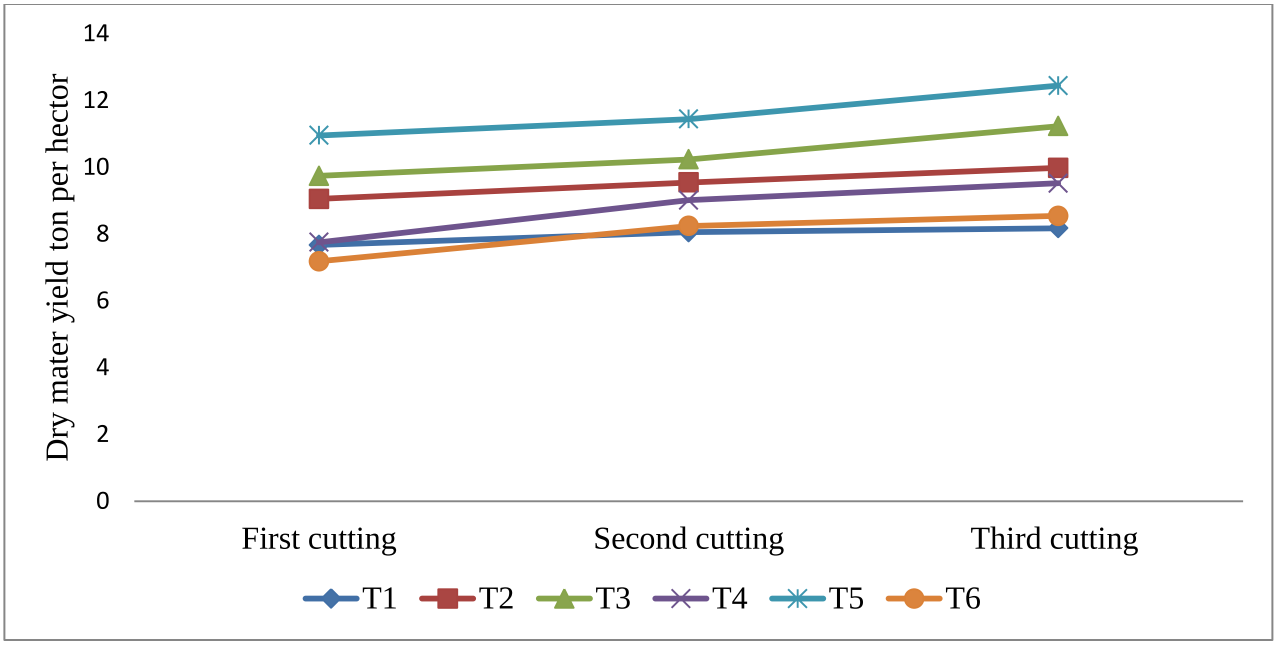
The dry matter yield of *Panicum coloratum* grass at 1st, 2nd, and 3rd cutting after planting that investigated under integrated rates of vermicompost and inorganic fertilizer application was summarized in Table 7 and Figure 6. The result obtained on dry matter yield from this study indicated that similar trends as fresh biomass yield among the six rates of fertilizer. The highest dry matter yield obtained from T5which was statistically similar with T3.A plot amended with T5 showed a 29.95%, 29.63% and 34.32% DMY over T1, during the first, second and third harvest, respectively at 50% flowering, followed by T3 which has scored 21.25%, 21.31% and 27.25% DMY than T1, at first, second and third cutting stage of 50% flowering. Generally, the lowest DMY was obtained from plots treated with both sole application of inorganic fertilizers (T1) and vermicompost (T6) at 50% flowering; which corresponds to the above finding on fresh biomass yield.

The results revealed that dry matter yield progressively increased at equal proportion of two source fertilizers under integrated rates of vermicompost with inorganic fertilizer application and then declined with sole applications of vermicompost (T6) and inorganic fertilizer (T1). This result might be due to the effect of amending the soil by vermicompost and inorganic fertilizers together enhanced the growth parameters like the height of the plant, leaf length, and numbers of tillers, shoot, and leaf canopy area of plant and to achieve higher dry matter yield of grass applying vermicompost with inorganic fertilizer for best result (Bajracharya *et al*., 2007). Likewise, Ibrahim *et al.* (2016) stated that uptake of nutrients such as nitrogen (N), phosphorus (P), potassium (K) and magnesium (Mg) by the plant was intensified when fertilizer was applied in combination with vermicompost those nutrients enhances growth parameters and tillering performance of the plant. Moreover, Singh *et al*. (2016) reported that vermicompost enhances growth parameters such as tillering performance, plant height, shoot and canopy of the leaf that may affect the proportion of leaf and stem of the plant that pushed the increments of dry matter yield (DMY).

A plot treated only by inorganic fertilizer (T1) has recorded greater dry matter yield (DMY) than pure vermicompost (T6) application at first harvest, whereas as the cutting stage advanced dry matter yield (DMY) of the grass from pure vermicompost (T6) was greater than sole inorganic fertilizer application (T1). The highest dry matter yield of *Panicum coloratum* grass was obtained from the third harvest followed by the second harvest over the first harvest shown in (Figure 6) which corresponds to FBY of the above. *Panicum coloratum* grass's, DMY increased with an advanced stage of cutting from 1st to 3rd. Third harvest of a plot incorporated by T5 showed 11.97 and 8.04% of DMY over a first and second harvest, respectively. Besides, third harvest of a plot amended by T3 caused 13.27 and 8.90% of DMY than a first and second harvest, respectively. This might be due the enhanced mineralization rates of vermicompost that leads increased number of tillering and leaf per plant in regard to advanced time.

There was an insignificant difference between T5 and T3 at all harvesting times. Similarly, there was no statistically significant difference among T2, T4, and T6 from the control treatment (T1) at all harvesting time. The overall mean of dry matter yield for *Panicum Coloratum*grass of the current study at all cutting times were higher than the result reported by Denbela (2015) who obtained 7.6 ton/ha DMY. This might be, due to a significant increase in growth parameters of grass after application of vermicompost and the earthworms might have stimulated microbial activities, metabolism and also influenced microbial populations while more available nutrients and microbial metabolites are released into the soil (Tomati *et al*., 1990).

In line with current result, application of different rate of vermicompost with inorganic fertilizers increased leaf area and canopy size of leaves and this, in turn, can increase the absorption of light, enabling the plant to undergo photosynthesis which consequently increases dry matter production of the plant (Papathanasiou *et al.*, 2012). Similarly, Singh *et al*. (2008) reported that adding vermicomposts to soil improves soil structure, fertility, plant growth parameters such as shoot of the plant, leaf area and length of the plant, tillering performance and suppresses diseases caused by soil-borne plant pathogens that lead increment of above-ground biomass yield.



T1= control treatment (VC0 ton/ha: NPSB100 kg); T2 = VC 1.25 ton/ha: NPSB 75 kg/ha; T3=VC2.5 ton/ha: NPSB50 kg/ha; T4=VC3.75: NPSB 25kg/ha; T5=VC5 ton/ha: NPSB 100 kg/ha; T6=VC5 ton/ha: NPSB0 kg.

Figure 6: Effect of different rate of vermicompost and inorganic fertilizer application on dry matter yield (DMY) of *Panicum coloratum* ton/ha at three consecutive harvests.

4.5.3. Crude Protein Yield (CPY)

The crude protein yield of *Panicum coloratum* grass in the study area was presented in Table 7. The highest crude protein yield per hectare was obtained from T5 followed by T3. T5 and T3 affected more CPY by 54.60 and 48.97%, respectively over T1. The lowest CPY (0.74 ton/ha) for *Panicum coloratum* grass was obtained from T1, which was statistically similar to T6. There was an insignificant difference between plots supplied with T5 and T3. Similarly, there was an insignificant difference between T1 and T6 as well as at T2 and T4. The current result showed that CPY ton/ha enhanced at the rates of 2.5 ton/ha vermicompost with 50 kg inorganic fertilizer (T3) and 5 ton/ha vermicompost with 100kg inorganic fertilizer (T5) application regardless of other treatment. Besides, the current result showed that CPY ton/ha lowered at the sole organic (T6) and inorganic fertilizer (T1) application. This might be due to the highest crude protein content was recorded at T5 and T3; however CP content was lowered at T1 and T6. This could be due to the more number of leaf and tiller per plant were obtained from T5 and T3, respectively, but at T1 and T6 number of leaf and tiller per plant was lowered other than all treatment.

4.6. Chemical Composition of *Panicum Coloratum* Grass

The CP content observed for *Panicum coloratum* grass has shown a significant (P<0.05) difference at a different rate of vermicompost and inorganic fertilizers (Table 8). The highest crude protein content 13.06±0.09 was recorded from a plot treated with T5 followed by T3 that obtained 12.48±0.37 crude protein content.

T5 and T3 resulted in more CP content by 30.70% and 27.48%, respectively over T1. The lowest CP content 9.05±0.04 for *Panicum coloratum* grass was recorded from the sole application of inorganic fertilizer (T1), followed by the sole application of vermicompost (T6). There was an insignificant difference between plots incorporated with T5 and T3. Similarly, there were no statistical differences between the sole applications of vermicompost (T6) and inorganic fertilizers (T1). The current result showed that, different rates of vermicompost and inorganic fertilizer application affected the CP content of the grass and increased (P<0.05) with an increasing rate of vermicomposts and inorganic fertilizer. This might be due to the increased rate of combined organic and inorganic fertilization, allowed continuous growth of the vegetative part of a grass-like leaf and tillering per plant, which was fresh even during the harvest of forage biomass.

This result is in line with Buli (2019) who reported that organic and inorganic fertilization affect CP content and the highest crude protein content (13.05) was obtained from 5ton/ha organic and 100kg/ha inorganic application while the lowest CP content (9.28) was obtained from unfertilized plot for *Panicum coloratum* grass. Similarly, this result is in agreement with Abdi *et al*. (2015) who reported that a significant difference in the increased level of fertilizer application affected the CP content of the grass and increased (P<0.05) with increasing level of fertilizer. Moreover, Yuksel (2010) reported in other grasses that nitrogen fertilization affected the crude protein content of grasses and the highest crude protein content (11.11 to 12.17%) was obtained from nitrogen application while the lowest crude protein content (8.26 to 9.41%) was obtained from the unfertilized treatment.

The current finding showed that the CP content of the grass was greater than the critical level of 7.2% which is optimum for microbial rumen function (Van Soest, 1982). Since, the required maintenance range of CP content is from 7.2 up to 15 percentages, supplementation is not as such required to satisfy the maintenance requirements of animals. The current result can be categorized into quality forage. Hence, top-quality forage contains a minimum of crude protein content (CP) (10%-14%) in the DM basis to meet the maintenance and production requirement of dairy cattle (Miller, 2012; SNV, 2017). Likewise, a minimum of 15% CP is required for lactation and growth of ruminants (Norton, 1982). Hence, the CP content of the current result obtained from both T5 and T3 was 12.93% up to 16.80% far from the required CP content for lactation and growth of ruminants, respectively so that there is a need for few supplementations of other protein sources in the ration.

The grasses that have high DM content are likely to boost energy in forage for cattle (Meissner, 2000). Insignificant variation was observed between the treatments on the dry matter (DM) percentage of *Panicum coloratum* grass when the field was incorporated with different rates of vermicompost and inorganic fertilizer (P>0.05). In line with the current result, Buli (2019) observed that non-significance differences in DM content of the same grass varieties by application of different levels of organic and inorganic fertilization. Similarly, Sodeinde *et al*. (2006) reported that non-significance differences in DM content of the same grass species with the increased fertilizer levels.

Application of different rates of vermicompost and inorganic fertilizer on Ash had significant (P<0.05) difference in *Panicum coloratum*grass. The highest ash percentage was observed at T1 (13.22±0.21) and the lowest ash percentage was recorded from application of T5 (11.00±0.01) which is opposite to the result obtained for DM and CP content form this study. The ash content in the current result decreased with an increasing rate of combined vermicompost and inorganic fertilizer application. The current result is in agreement with Abdi *et al*. (2015) who reported that ash content decreases with increased nitrogen fertilizer level. The present result also, agrees with Manaye *et al*. (2009) who noted decreased ash percentage of grass as a result of an increase in the level of N-fertilizer application.

The organic matter content (OM) was conversely of ash value and the lowest ash value content has the highest OM% and vice versa. The effect of the integrated rate of vermicompost and inorganic fertilizer application had shown a significant difference ($P<0.05$) on organic matter concentration (OM %) of *Panicum coloratum*grass at the study area. A treatment incorporated with a rate of 5 ton/ha vermicompost and 100 kg/ha inorganic fertilizer (T5) and by application of 2.5 ton/ha vermicompost with 50 kg/ha inorganic fertilizer (T3) scored highest OM% (89.00) and (87.96) respectively, compared to sole application of inorganic fertilizer (T1). The organic matter content (OM) increased as the rate of vermicompost and inorganic fertilizer increased. This result might be due to the high availability of major nutrients (like nitrogen, available phosphorus, etc) in the vermicomposts.

The effect of different rates of vermicompost and inorganic fertilizer application on NDF content had shown significant differences ($P<0.05$) among treatment. The highest mean NDF 71.14±0.76 and 68.57±0.43 respectively was recorded for the sole application of inorganic fertilizer (T1) and vermicompost (T6). On the other hand, the plots treated with T5 and T3 recorded the lowest NDF by 13.54% and 13.11%, respectively than the sole application of inorganic fertilizer (T1). There was an insignificant difference among treatments T3, T4, and T5. Besides, there was no statistical difference among plots treated in sole inorganic fertilizer (T1), organic fertilizer (T6) and (T2).

The current result indicated that as the rate of integrated vermicompost and inorganic fertilizer increased, the NDF content decreased. This might be due to vermicompost increases vegetative part of grass such as tillering performance, shoot height, and canopy of the leaf that may affect the proportion of leaf regardless of the stem of the grass and decreased NDF content (Ibrahim *et al.,* 2016; Singh *et al.,* 2016). The result obtained in this study is in line with Abdi *et al.* (2015) who stated a significant decrease in NDF concentration of plants as N-fertilization levels increased. The current result also supported by Van Nieker *et al*. (1993) who reported that a significant decrease in NDF concentration of plants as N-fertilization levels increased. They reasoned out the decrease in NDF to the increased growth rate of new leaves and shoot which are lower in plant structural components as a result of N-fertilization.

According to Singh and Oosting (1992), the NDF content of roughage feeds with less than 45% was grouped as a high-quality feed, while feed with NDF content of 45-65% was categorized as medium quality feed. Therefore, the current result showed that all treatments can't be grouped as high quality whereas only T3, T4, and T5 had less than 65% of NDF content and can be categorized as medium quality feed. The current result didn't realize the recommendation made by Meissner *et al*. (1991) who noted that the threshold level of NDF that affects dry matter intake of forage is ≤ 60% beyond which voluntary feed intake is decreased and rumination time increased. The current result was lower than the result reported by Diriba (2013) the herbage value of neutral detergent fiber content varied from 74 to 77 %. This could be due to application of vermicompost and inorganic fertilizers encouraged the plant to leave growth and decreased the lignin content of the plants. NDF peaked at the low fertilization rate and then decreased with increasing fertilizer rates.

Acid detergent fiber (ADF) is a sub-fraction of NDF, but only consists of cellulose, lignin, and ash, and knowledge of it helps for prediction of the energy value of forages. Different rates of vermicompost and inorganic fertilizer application had shown significant differences ($P<0.005$) on ADF and ADL contents shown in (Table 7). T5 and T3 lowered ADF content by 20.16 and 16.09% folds respectively than sole inorganic fertilizer (T1). The treatments T2, T4, and T6 were not significantly different from the sole application of inorganic fertilizer (T1). Besides, there was no statistical difference between T3, T4, T5, and T6

The current result showed that as an integrated rate of vermicompost and inorganic fertilizer increased, the ADF content decreased. In line with this result; Magani *et al.* (2010) stated that increased nitrogen fertilization significantly decreased ADF content. The ADF content of the present study especially with a plot amended by T3 and T5 can be categorized as medium quality forage as per Kellems and Church (1998) who categorized roughages with less than 40% ADF as high quality.

The highest and lowest mean of the ADL contents, respectively were obtained from the treatments applied sole 100% inorganic fertilizer rate (T1) and 5 ton/ha VC with 100 kg/ha NPSB (T5). A plot treated with T5 and T3 showed 38.13% and 33.57% lower than T1. There was an insignificant difference between T3 and T5. Besides, T2, T4, and T6 were no statistically different in lignin content from T1. Therefore, the current result showed that all treatments can be partly inhabited feed intake voluntary of ruminants whereas only T3 and T5 had less than 7% of ADL content and can't hinder feed intake voluntary. The lignin content of T1, T2, T4 and T6 were not achieved the recommendation made by Reed *et al*. (1986) who noted that the threshold level of lignin content which affect dry matter intake voluntary and increased rumination time is greater than 7%.

As the combined vermicompost and inorganic fertilizer rate increase, the ADL content decreased. This result is an agreement with Buli (2019) who reported that the effect of organic and inorganic fertilizer rate has revealed a significant difference in ADL and as the level of organic and inorganic fertilizer increased the ADL content decreased. Similarly, Abdi *et al*. (2015) stated that lignin content of a grass decreased, under increased level of nitrogen fertilizer application. This might be due to the N-fertilizer promotes the growth of new leaves and shoots resulting in low lignin, which compensates for the increase in lignin content of other tissues. When lignin is lowered it has always produced a marked increase in the digestibility of the plants and lignin are highly resistant to chemical and enzymatic degradation and are not appreciably broken down by the micro-flora in the ruminant digestive tract (Ranjhan, 1993).

Table 8: Effect of integrated rates of vermicompost and inorganic fertilizer application on chemical composition (as % DM basis) of *Panicum coloratum* grass at 50% flowering

TRT	DM%	%CP	%Ash	%OM	%NDF	%ADF	%ADL
T1	95.82±0.10	9.05±0.04^{d}	13.36±0.35^{a}	86.64±0.35^{c}	71.14±0.76^{a}	45.38±0.99^{a}	10.07±0.52^{a}
T2	95.90±0.01	10.81±0.47^{c}	13.00±0.01^{ba}	87.00±0.01^{bc}	67.52±0.71^{ba}	44.85±1.64^{a}	9.43±0.72^{ba}
T3	96.27±0.33	12.48±0.37^{ba}	12.04±0.47^{bc}	87.96±0.47^{ba}	61.81±1.08^{c}	38.083±0.67^{b}	6.69±0.27^{bc}
T4	96.23±0.12	11.00±0.08^{bc}	12.43±0.23^{ba}	87.57±0.23^{bc}	64.96±0.77^{bc}	40.47±2.23^{ba}	7.87±0.92^{ba}
T5	96.40±0.13	13.06±0.09^{a}	11.00±0.01^{c}	89.00±0.01^{a}	61.51±1.65^{c}	36.23±0.62^{b}	6.23±0.41^{c}
T6	95.88±0.16	9.40±0.56^{dc}	13.22±0.21^{ba}	86.78±0.21^{bc}	68.57±0.43^{ba}	41.54±0.68^{ba}	9.25±0.61^{ba}
CV	0.31	5.37	3.74	0.54	2.58	5.42	12.86
P-value	-	<.0001	<0.0004	<0.0004	<.0001	<0.0016	0.004
Overall mean	96.08	10.97	12.51	87.49	65.92	41.09	8.26

Means with the different superscript letter in the same column are significantly different (PV = 0.05); TRT = treatment; DM = dry matter; OM = organic matter; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; ADL = acid detergent lignin; T1 = control (0 ton/ha VC and 100 kg/ha NPSB; T2 = 1.25 ton/ha VC and 75 kg/ha NPSB; T3 = (2.5ton/ha VC and 50 kg/ha NPSB); T4 (3.75 ton /ha VC and 25 kg/ha NPSB; T5 = 5 ton/ha VC and100 kg/ha NPSB); T6 = 5 ton/ha VC and 0kg/ha NPSB;VC = vermicompost; NPSB = nitrogen, phosphorus, sulfur and boron; CV = coefficient of variation; PV = probability value.

4.7 Correlation of Morphological and Nutritional Parameters of *Panicum Coloratum* Grass

Table 9 shows that simple linear bivariate correlation analyses among morphological, quality and yield parameters of *Panicum coloratum* grass. Dry matter yield of *Panicum coloratum* grass were negatively correlated with NDF, ADF and ADL and had positive association with some of the morphological parameters (plant height, leaf length per plant, number of tiller per plant and number of leaf per plant). This might be due to increments of DMY and all morphological parameters and decreased fiber content (NDF, ADF and ADL) related to the increased rate of combined vermicompost and inorganic fertilizer application. Likewise, there were significant correlation of all morphological parameters and fiber content with DMY except acid detergent fiber (ADF).

Crude protein content and yield of *Panicum coloratum* grass were negatively correlated with all fiber contents (NDF, ADF and ADL).This indicated that as the cell wall contents contributed for increment of plant parts which eventually lead to decrement in total crude protein content (CP) and yield (CPY). Moreover, as plant matures, it increases the stem portion regardless of leaf portion which has less crude protein content (CP) and yield (CPY) than in the leaf part. Crude protein content and yield of *Panicum coloratum*grass significantly ($P<0.001$) and positively correlated with leaf to steam ratio (LSR) and negatively associated with fiber component (NDF). In line with this finding, Tessema *et al.* (2002) reported that there were direct association between leaf to stem ratio and CP content and the inverse association of leaf to stem ratio and fiber content observed in Napier grass.

The fiber components of *Panicum coloratum*grass NDF, ADF and lignin (ADL) were positively correlated with each other's. This indicated that there was a high relationship among the different cell wall contents. This component of cell wall decreased as the rate of fertilizer increased. There was significant association of neutral detergent fiber (NDF) with acid detergent lignin (ADL) at ($P<0.05$) and acid detergent fibers (ADF) with acid detergent lignin (ADL) ($P<0.001$). Neutral detergent fiber (NDF) component is negatively correlated with PH, NLPP, LLPP, NTPP and LSR. This result might be due to the fact that all agronomic parameters increased with increased rate of vermicompost and inorganic fertilizer and decreased fiber components among the treatments with increased rate of fertilizers.

Table 9: Correlation coefficient among morphological parameters, chemical composition and yield of Panicum coloratum grass

	DM	DMY	CP	CPY	NDF	ADF	ADL	PH	NTPP	NLPP	LLPP	LSR	TA
DM	1.00	-0.05	-0.07	-0.07	-0.17	0.24	0.06	0.00	-0.04	0.14	0.03	-0.05	-0.07
DMY		1.00	0.75**	0.95***	-0.84***	-0.33	-0.5*	0.857***	0.76**	0.65**	0.74**	0.73**	-0.88***
CP			1.00	0.91***	-0.69**	-0.16	-0.13	0.87***	0.81***	0.77**	0.89***	0.77**	-0.76**
CPY				1.00	0.83***	-0.30	-0.39	0.92***	0.85***	0.77**	0.87***	0.82***	-0.89***
NDF					1.00	0.29	0.49*	-0.80***	-0.60**	-0.68**	-0.73**	-0.61**	0.73**
ADF						1.00	0.66**	-0.27	-0.38	-0.28	-0.30	-0.47*	0.32
ADL							1.00	-0.22	-0.34	-0.24	-0.24	-0.42	0.51*
PH								1.00	0.82***	0.73**	0.91***	-0.75**	-0.80***
NTPP									1.00	0.79***	0.90***	0.93***	-0.82***
NLPP										1.00	0.78**	0.74**	-0.70**
LLPP											1.00	0.81***	-0.76**
LSR												1.00	-0.82***
TA													1.00

*Level of significance: *** = P<0.0001; ** = P < 0.01; * = P < 0.05; DM = dry matter; DMY = dry matter yield; CP = crude protein; CPY = crude protein yield; OM = organic matter; NDF = neutral detergent fiber; ADF = acid detergent fiber; ADL =*

acid detergent lignin; LSR = leaf to steam ratio; TA = total ash; NLPP = number of leaves per plant; LLPP = leaf length per plant; NTPP = number of tillers per plant; Ph = plant height.

4.8 Partial Budget Analysis

The profit obtained from *Panicum coloratum* production by integrated rates of vermicompost and inorganic fertilizer application was summarized in Table 10. The maximum farm net-benefits of 17,310/ha ETB was obtained from the rate of 2.5 ton per hectare vermicompost with 50 kg/ha inorganic fertilizer (T3) application on the *Panicum coloratum* grass, and followed by T5. A plot incorporated with T2, T3, T4 and T5 showed higher net-income over T1, but with application of T6 gave lower net-income than T1. From the previously mentioned treatments highest %MRR with value of 382.46 was obtained from T3. A plot amended with T2 and T3 showed higher %MRR among other treatments.

The current value implies that a plot treated by 50% each sources of fertilizer (T3) with 100 Ethiopian birr (ETB) invested per hectare it was possible to attain 382.46 ETB extra incomes when compared with sole application of inorganic fertilizers. The current result showed that both net-income and total variable cost increased with higher %MRR than minimum acceptable marginal rate of return at T2, T3, and T5. In line with the current finding, CIMMYT (1998) reported that if both net income and total variable costs increases, the marginal rate of return (MRR) should be looked at, the greater increase in net income and the higher marginal rate of return, the more economically an alternative technology is, the new technology should be acceptable only if its marginal rate of return is higher than (50-100) %. Moreover, Shah *et al*. (2009) reported that new technology accepted only if its marginal rate of return higher than (50-100) %.

Marginal rate of return of a plot applied with T4 and T6 were lower than minimum acceptable marginal rate of return, whereas marginal rate of return of T2, T3 and T5 greater than minimum acceptable marginal rate of return. The marginal net-benefit from T2 and T3 gave a marginal rate of return of 357.53 and 382.46% respectively, which was higher than minimum acceptable marginal rate of return. Since the marginal rate of return (MRR) of T3 was greater than T2, T 3 can be regarded as relatively the best treatment in terms of its economic return.

Table 10: Partial budget analysis showed in integrated rates of VC and NPSB fertilizers effect on DMY of *Panicum coloratum* grass production.

Treatment	Descriptions									
	AVDMY ton/ha	ADMY ton/ha (10% loss)	GB (2,500 ETB/kg)	VCPC (50 ETB/man /day	Cost of NPSB (13.5 ETB/kg)	VCAC 50 ETB /man /day	Cultivation cost(50ETB /man /day	Harvesting cost50/man /day	Total variable cost (ETB)	Net-benefit
T1	8.17	7.36	18,400	0	1350	0	2790	2,400	6,540	11,860
T2	10.04	9.03	22,575	500	1,012.50	200	2790	2950	7,452.5	15,122.5
T3	11.23	10.11	25,275	950	675	250	2790	3,300	7,965	17,310
T4	8.74	7.86	19,650	1500	337.5	350	2790	2,550	7,527.5	12,122.5
T5	12.44	11.2	28,000	2500	1350	550	2790	3,750	10,940	17,060
T6	9.04	8.13	20,325	2500	0	550	2790	2,650	8,490	11,835

Noted: AVDMY = average dry matter yield; ADMY = adjusted dry matter yield (percent of adjusted yield considered 10% loss due to management difference); GB = Gross benefit; VCPC = vermicompost preparation cost; VCAC = vermicompost application cost; NPSB = nitrogen, phosphorus, sulfur and boron; ETB = Ethiopian birr; T1= control treatment (VC 0ton/ha:NPSB100kg); T2 = 1.25 ton/haVC:75kg/ha NPSB; T3 = 2.5 ton/ha VC: 50 kg/ha NPSB; T4 = 3.75 ton/ha VC: 25 kg/ha NPSB; T5=5 ton/ha VC: 100kg/ha NPSB; T6 = 5ton/ha VC: 0kg/ha.

Table 10: Partial budget analysis showed in integrated rates of VC and NPSB fertilizers effect on DMY of *Panicum coloratum* grass production (continued)

Treatment	TVC	MC (▲TVC)	NB	MNB (▲NI)	MRR (%)	Dominance
T1	6,540	_	11,860	_	_	-
T2	7,452.5	912.5	15,122.5	3,262.5	357.53	ND
T3	7,965	1425	17,310	5,450	382.46	ND
T4	7,527.5	987.5	12,122.5	262.5	26.58	D
T5	10,940	4,400	17,060	5,200	118.18	ND
T6	8,490	1,950	11,835	-25	1.28	D

Noted: TVC = total variable cost; MC = marginal cost; ▲TVC = changes of total variable cost; NB = net benefit; MNB = marginal net benefit; ▲NI = changes of net benefit MRR (%) = marginal rate of return; ND = non-dominance (non-dominated treatments resulted in a rate of return above the minimum acceptable value (50–100%)).

5. CONCLUSION

The result of the current study pointed out that, at an equal proportion of both vermicompost and inorganic fertilizer application specifically in T3 (50:50%) and T5 (100:100%), there was improvement in agronomic parameters, above-ground biomass yield and non-fiber chemical composition of the grass. However, the ash and fiber content of the grass (NDF, ADF, and ADL) decreased at balanced rate of both vermicompost and inorganic fertilizer application and vice-versa. The soil chemical properties after harvesting the grass increased with an increased rate of vermicompost under the integrated rate of vermicompost and inorganic fertilizer application. Association between morphological and nutritional parameters of *Panicum coloratum* grass indicated that the fiber fractions (NDF, ADF and ADL) were significantly and negatively correlated with plant morphological fractions (PH, NLPP, LLPP, NTPP and LSR).

The current results also indicated that vermicompost can be a better replacement of inorganic fertilizer by 50% to improve agronomic performance, above-ground biomass yield and chemical compositions of *Panicum coloratum* grass as well as for economic feasibility. With 100 ETB costs incurred, a 382.46 ETB extra income was attained from T3 when compared with the sole application of inorganic fertilizer. In the current result, as both net income and total variable cost increases; the greater increase in net income and the higher marginal rate of return was obtained from treatment applied 50% vermicompost with 50% NPSB fertilizer per hectare (T3). Therefore, vermicompost can be used to improve soil structure, major nutrient of the soil after harvest, agronomic performance, and nutritional quality of *Panicum coloratum* grasses as well as be economically feasible especially at 50% replacement of vermicompost for inorganic fertilizers application.

6. RECOMMENDATION

From the present study, the following points are recommended;

- ❖ The application of integrated rate of vermicompost and inorganic fertilizer can be best recommended at equal proportion specifically in 50% VC with 50% NPSB for improvement of agronomic performance, biomass yield, and nutritional quality as well as economic feasibility for production of *Panicum coloratum* grass.
- ❖ The study was conducted only at one agro-ecology and one season, so that it will be worth repeating the experiment at different seasons and agro-ecology condition.
- ❖ The application of integrated rate of vermicompost with inorganic fertilizer should be verified under farmers' condition before being scaled out
- ❖ In addition, the following specific recommendations can be drawn based on the current findings for areas not covered under this study;

1) Comparison of types of raw materials to be used for vermicompost preparation for their maximum effectiveness and efficiency.
2) Testing the effect on rate of 2.5 ton/ha vermicompost with 50 kg/ha inorganic fertilizer for identification of high yield and quality on different type of forage.
3) It is also advisable to do on animal performance and laboratory trial using forage produced by vermicompost and inorganic fertilizer application

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APPENDIXES

Tables in Appendixes

Appendixes in Table 1: Summary of ANOVA for chemical analysis of soil sample after harvest of Panicum coloratum grass

Parameter	DF	SS	MS	F Value	Pr>F
pH	5	5.31	1.062	13.55	0.0001
OC	5	3.89	0.78	23.84	<.0001
TN	5	0.10	0.021	179.40	<.0001
Av.P	5	2403.72	480.74	417.95	<.0001
OM	5	8.38	1.68	44.19	<.0001
CEC	5	97.55	19.51	8.37	0.0013

Appendixes in Table 2: Summary of ANOVA for plant phonological and morphological parameters of Panicum coloratum grass affected by integrated application of vermicompost and inorganic fertilizer

Parameters	DF	SS	MS	F-Value	PR>F
FGD	5	42.85	8.57	9.53	0.0007
DIF	5	279.61	55.92	19.36	<.0001
D50%F	5	100.72	20.14	21.12	<.0001
PH	5	2548.67	509.73	21.14	<.0001
LLPP	5	296.50	59.30	44.48	<.0001
NLPP	5	13.10	2.61	5.38	0.0080
NTPP	5	77.61	15.52	21.49	<.0001
LSR	5	0.64	0.13	34.17	<.0001

Appendixes in Table 3: Summary of ANOVA for biomass yield ton per hector of Panicum coloratum grass affected by integrated application of vermicompost and inorganic fertilizers.

Parameter	First Harvest					Second harvest					Third harvest				
	DF	SS	MS	F Value	Pr>F	DF	SS	MS	F Value	Pr>F	DF	SS	MS	F Value	Pr>F
FBY	5	6040.59	1208.12	7.54	0.0021	5	5849.69	1169.94	7.74	0.0018	5	5132.92	1026.58	5.37	0.0080
DMY	5	31.60	6.32	10.46	0.0005	5	24.65	4.93	9.26	0.0008	5	39.51	7.90	14.41	0.0001
CPY	5	1.85	0.37	70.43	<.0001										

Appendixes in Table 4: Summary of ANOVA for chemical composition (as DM bases) of Panicum coloratum grass influenced by integrated amendment of vermicompost and inorganic fertilizer

Parameter	DF	SS	MS	F VALUE	Pr>F
DM	5	0.89	0.18	2.06	0.1410
CP	5	38.47	7.69	22.20	<.0001
ASH	5	11.92	2.38	10.87	0.0004
OM	5	11.92	2.38	10.87	0.0004
NDF	5	222.59	44.52	15.43	<.0001
ADF	5	197.63	39.53	7.98	0.0016
ADL	5	37.11	7.42	6.58	0.0036

Figures in Appendixes

Appendixes in Figures 1: Summary of vermicompost preparation and harvest photos

Appendixes in Figures 2: Summary of Panicum coloratum grass during on field, cutting and its regrowth in photos

Appendixes in Figures 3: Summary of chemical composition in nutritional laboratory of Jimma University, college of agricultural and veterinary medicine