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BAHIR DAR UNIVERSITY

COLLEGE OF AGRICULTURE AND ENVIROMENTAL SCIENCE

GRADUATE PROGRAM

RESPONSE OF SOYBEAN [*Glycine max* L.] SEED YIELD AND QUALITY TO VERMICOMPOST AND BLENDED NPS FERTILIZER RATES IN PAWE DISTRICT, NORTHWESTERN ETHIOPIA

M.Sc. Thesis

By

Girmaye ketema

July 2023

Bahir Dar, Ethiopia

RESPONSE OF SOYBEAN [*Glycine Max* L.] SEED YIELD AND QUALITY TO VERMICOMPOST AND BLENDED NPS FERTILIZER RATES IN PAWE, NORTHWESTERN ETHIOPIA

M.Sc. Thesis

By

GirmayeKetema

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE (M.Sc.) IN "AGRONOMY"

July 2023
Bahir Dar, Ethiopia

THESIS APPROVAL SHEET

THESIS APPROVAL SHEET

As member of the Board of Examiners of the Master of Sciences (M.Sc.) thesis open defense examination, we have read and evaluated this thesis prepared by Mr. Girmaye Ketema W/Tsadik entitled **Response of Soybean [*Glycine Max* L.] Seed Yield and Quality to Vermicompost and Blended NPS Fertilizer Rates in Pawe District, Northwestern Ethiopia**. We hereby certify that the thesis is accepted for fulfilling the requirements for the award of the degree of Master of Sciences (M.Sc.) in Agronomy.

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DECLARATION

This is to certify that this thesis entitled **"Response of Soybean** [*Glycine Max* (L). *Merrill*] **Seed Yield and Quality to Vermicompost and Blended NPS Fertilizer Rates at Pawe, Northwestern Ethiopia''** submitted in partial fulfillment of the requirements for the award of the degree of M.Sc., in Agronomy to College of Agriculture and Environmental Science, Bahir Dar University through the Department of plant Sciences, done by **Mr. Girmaye Ketema**, Id.No. CAES/ BDU1402338 is an authentic work carried out by him under my guidance. The matter embodied in this project work has not been submitted earlier for the award of any degree or diploma to the best of my knowledge and belief.

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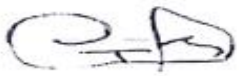
Girmaye Ktema		6/15/2023
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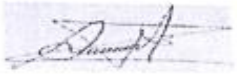
Dr. Yayeh Bitew		6/15/2023

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DEDICATION

This thesis is dedicated to my beloved families; for their wholehearted partnership in the success of my life.

LISTS of ABBREVIATIONS AND ACRONYMS

AATFANOVA	African Agriculture Technology Foundation Analysis
CSA	of Variance
CADU	Central Statistical Agency
ATA	Chilallo Agricultural Development Unit
CSA	Agricultural Transformation Agency
DAP	Central Statistics Agency
EIAR	Di-ammonium phosphate
EthioSIS	Ethiopian Institute of Agricultural Research
FAO	Ethiopian Soil Information System
FYM	Food and Agricultural Organization
GHG	Farm Yard Manure
IAR	Green House Gas
LSD	Institute of Agricultural Research
MRR	Least Significant Difference
NPS	Marginal Rate of Return
PARC	Nitrogen, Phosphorus and Sulfur
PH	Pawe Agricultural Research Center
PRY	Potential of Hydrogen
RCBD	Plant Relative Yield
SSA	Randomized Complete Block Design
VC	Sub- Saharan Africa
	Vermicompost

RESPONSE OF SOYBEAN [*Glycine max* L. *l*] SEED YIELD AND QUALITY TO VERMICOMPOST AND BLENDED NPS FERTILIZER RATES IN PAWE, NORTHWESTERN ETHIOPIA

By: GirmayeKetema

Advisor: Dr. YayehBitew

ABSTRACT

*Soybean is the most important leguminous crop in Ethiopia. However, its national productivity particularly in the Northwest Ethiopia is lower than that of worlds' productivity due to lack of appropriate agronomic managementpractices such as application of unbalanced chemical fertilizersand improper soil fertility management. Hence, a field experiment was carried out in 2022 cropping season in Pawe district, Northwest Ethiopia to determine appropriate Vermicomposti and Blended NPS Fertilizer Rates for optimum seed Yield and Quality of Soybean [Glycine max (*L*). Three rates of NPS fertilizer (0, 50, 100, kgNPS ha^{-1}) and five rates of vermicompost(0, 3, 6, 9, 12 t ha^{-1}) were arranged in factorial and laid out in randomized complete block design with three replications. Data on soybean agronomic attributes and soybean seed quality were collected and analyzed using SAS software. The result of this study revealed that most phenological, growth, yield components, yield, and quality traits of soybean were significantly (P<0.05) affected by blended fertilizer rates, vermicompost rates and their interaction effects. Application of 50kg NPS ha^{-1} combined with 6(3078.55 kg ha^{-1}) followed by 9 (3059.39 kg ha^{-1}) tons vermicompost ha^{-1} resulted in the highest seed yield. Similarly, the former soil amendment practise also gave the maximum net benefit (78,118.85 ETB ha^{-1}) with a 1707.25% acceptable marginal rate of return (MRR). In conclusion, plating soybean with the combined application of 50 kg NPS ha^{-1} and 6 tonnes vermicompost ha^{-1} gave significantly the highest seed yield, protein content, and profitability and is recommended for soybean production in the Northwesternagro-ecologies of Ethiopia. It is suggested that further comprehensive research on integrated soil fertility management strategies to improve the nitrogen fixing ability of various soybean varieties needs to be done over numerous sites and years.*

Keywords*; blended fertilizer, soybean, seed quality, vermicompost,*

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CHAPTER 1. INTRODUCTION

1.1 Background and Justification

Soybean [*Glycine max* L. l] is a member of the Fabaceae family that originated in Eastern Asia, probably in North and Central China (Adane Arega & Alemayeh Dabessa, 2018). Soybean is widely distributed in most parts of the world and has a lot of potential in Africa (Hartman *et al*., 2011). It was first introduced to Ethiopia in the 1950s because of its nutritional value, multiuse nature (human food, livestock feed, and manufacturing purposes), source of bio-energy, and wider adaptability. It is a promising pulse crop proposed for alleviation of acute protein shortages and as a source of oil, unsaturated fatty acids, minerals (Ca and P), and vitamins (A, B, C, and D) (Mulugeta Atnaf *et al*., 2013).

Currently it has become a crop grown in different agro-ecological areas of the country, as currently the area covered under soybean production is 55,643 ha with a total production of 127,978.9 t (CSA, 2020/2021) and national average productivity of 2.3 t ha^{-1} which is lower than that of the world average productivity (2.79 t ha^{-1}) (AsmachewAgegne *et al*., 2021). Soybean is used to prepare different kinds of soybean foods, animal feed, soy milk, and raw materials for processing factories like the Tasty Soya and Fafa Food Factory. Since it is a legume crop, soybean is used in climate mitigation and adaptation through N2 fixation, crop diversification, and reducing the amount of inorganic N fertilizer (ChalaDebela *et al*., 2021).

Despite the numerous benefits of soybean, the grain yield per unit area is low in Ethiopia.
The potential, attainable, and actual yields of the soybean are 3.8, 2.9, and 2.30 respectively (Derese Hunde *et al*., 2019), indicating that there is a huge yield gap between these production situations that further reflects that the current soil fertility, climate, farmers' skill, and their average use of technology have been the main constraint.
Ethiopia's soil fertility mapping project reported that deficiency of NPS in major Ethiopian soils was common (Ethio-SIS, 2014). Depletion of soil nutrients other than N and P could also be an additional reason for the observed decrease in productivity (Wassie Haile and Tekalign Mamo, 2013). Accordingly, soybean production status around the study areas is more familiar with farmer and investors the covered large amount of area, but the productivity

is not more than 1.5 t ha^{-1} which is below the national average productivity (2.3 t ha^{-1}) (Mirzaei *et al*., 2021). Thus, appropriate soil fertility management practices, such as the integrated use of inorganic and organic fertilizer, are necessary to increase the productivity and production of soybeans (Zerihun & Haile, 2017) According to Materechera (2012), vermicompost (VC) and wood ash were reported to increase the pH of acid soils and improve soil fertility by supplying essential plant nutrients. Applying combined organic and inorganic fertilizers is a viable solution to restore, and maintain soil fertility and increase crop yields (Ullah *et al*., 2022). Moreover, integrated nutrient management is considered a key cultural practice to avert the problem of crop production by enhancing soil fertility and has an advantage in climate change mitigation (Gruhn *et al*., 2000).

1.2 Statement of the Problem

Soybean is the most important cash crop in Ethiopia. Recently, enormous oil industries have been established in Ethiopia, which in turn requires a high amount of oil seed, mainly soybean. The attempts to increase the productivity of soybeans in Ethiopia have been mainly done through the application of inorganic fertilisers. This type of agriculture has increased yields and become more economically rewarding in a short time, but the improvement has not been without its costs. The continuous use of fertilisers and pesticides costs an enormous amount of energy, causes degradation, disrupts the environment, and causes human poisoning (Malezieux *et al.,* 2009). Thus, the use of few inorganic fertilisers for a long time has been attributed to the depletion of soil nutrients (Crews and Peoples, 2004; Ashenafi Nigussie *et al*., 2021), which in turn generally contributes to a large extent to the issue of sustainable crop production (Sainju *et al.,* 2011). Taking this into consideration, blended NPS fertilisers have been introduced and used to increase the production and productivity of crops, including soybeans. Thus, to reduce the amount of mineral fertiliser required, there is a need to adopt integrated nutrient management technologies that combine organic fertilisers with small amounts of mineral fertilisers and build up soil conditions to enhance soil microbial activity, soybean yields, and seed quality. The effectiveness of vermicompost and other organic nutrient sources in maintaining soil fertility, improving crop yields, and sustaining productivity, as well as their increased potential when applied along with mineral fertilisers,

are reported by Lim *et al*. (2015). However, unless it is integrated with inorganic fertilisers, the use of vermicompost alone may not fully satisfy crop nutrient demand, and it needs a large amount of vermicompost ha^{-1}, especially in the year of application (Song *et al*., 2015), which in turn causes difficulty for farmers. Vermicompost is also useful in improving the efficiency of fertiliser recovery, resulting in higher crop yield (Moe *et al*., 2017). Seed quality is a multiple criterion that encompasses several important seed attributes, genetic and chemical composition, physical condition, physiological germination and vigor, size, appearance and presence of seed borne pathogens, crop and varietals purity and moisture content (Tekrony et al., 1987). Hence, the effect happens by using integrated fertilizers on quality of soybean in study area was not examined (Chaluma Tujuba, 2020). However, the previous studies indicate that there is no specific recommendation whether national or regional level different authors recommend different levels. Therefore, the study was conducted to find out the suitable combination of organic and inorganic fertilizers in order to obtain better yield and quality of soybean

1.3. Objectives

1.3.1. General objective

- The overall objective of this study is to enhance the productivity and quality of soybean seed through organic and inorganic soil fertility management practices in Northwestern Ethiopia.

1.3.2. Specific objectives

- To investigate the effect of blended NPS fertilizer and vermicompost on the yield component, yield, and quality of soybean seed and
- To determine the optimum and profitable rate of blended NPS and vermicompost fertilizers for maximum soybean production.

CHAPTER 2. LITERATURE REVIEW

2.1 Botany and Morphological Description of Soybean

The cultivated soybean, Glycine max (L.) Merrill, belongs to the family Leguminosae, the subfamily Papilionoideae, the tribe Phaseoleae, the genus Glycine Willd., and the subgenus Soja (Moench). (Singh, 2017). It is an erect, bushy herbaceous annual that can reach a height of 1.5 metres. Three types of growth habits can be found among soybean cultivars: determinate, semi-determinate, and indeterminate (Kato *et al*., 2019). Determinate growth is characterised by the cessation of vegetative activity in the terminal bud when it becomes an inflorescence at both the axillary and terminal racemes. Indeterminate genotypes continue vegetative activity throughout the flowering period (Kumudini & Sing, 2010). Semi-determinate kinds have stems that are indeterminate and abruptly stop growing vegetatively after the flowering season. None of the soybean cultivars can withstand frost and cannot endure the harsh winter weather. The secondary leaves are trifoliate and alternate, and compound leaves with four or more leaflets are occasionally present. The primary leaves are unifoliate, opposite, and elliptical. The modulated root system consists of a taproot, from which emerges a lateral root system. The plants of most cultivars are covered with fine trichomes, but glorious types also exist (Lersten& Carlson, 2004). The papilionaceous flower consists of a tubular calyx of five sepals, a corolla of five petals (one banner, two wings, and two keels), one pistil, and nine fused stamens with a single separate posterior stamen (Gazzoni, 2016). One day prior to pollination, the stamens extend and create a ring at the base of the stigma. At this point, the raised anthers form a ring around the stigma. The pod's length ranges from two to seven centimetres, is straight or slightly curved, and is made up of two carpel halves that are connected by a dorsal and ventral suture. The seed's typically oval shape can vary amongst varieties, ranging from almost spherical to elongate and flattened (Lersten& Carlson, 2004).

2.2 Origin and Distribution of soybean

Origin and distribution of Soybean Soybean [*Glycine max* (L.) Merrill] was originally domesticated in Northern China in approximately 1100 B.C. and subsequently spread to other

nearby Asian countries (BASF USA, 2015) and later introduced into North America, Europe, then into South and Central America (Asmachew Agegn *et al*., 2021). Currently, about 50 countries worldwide grow soybean (Wilcox, 2004). Moreover, it is also cultivated in Brazil and in Sub Saharan Africa (Engelbrecht *et al*., 2020). Soybean cultivation reached Africa in the late 1800s although little is known of the countries to which it was first introduced (Khojely *et al*., 2018). Because that region had extensive contact with the Chinese, it is conceivable that soybean was cultivated there at an early date. For Ethiopia's underprivileged farmers who cannot afford animal products, soybeans can be a significant source of protein. In addition, it may be grown for oil, used as animal feed, made into chicken meal, improved soil fertility, and most crucially, utilized to generate cash for the nation (KibiruKena *et al*., 2022). Because that region had extensive contact with the Chinese, it is conceivable that soybean was cultivated there at an early date. For Ethiopia's underprivileged farmers who cannot afford animal products, soybeans can be a significant source of protein. In addition, it may be grown for oil, used as animal feed, made into chicken meal, improved soil fertility, and most crucially, utilized to generate cash for the nation (KibiruKena *et al*., 2022). It was first introduced to Ethiopia in 1950's by Chilallo Agricultural Development Unit (CADU) because of its nutritional value, multipurpose use and wider adaptability in different cropping system (Chaluma Tujuba, 2020). However, this attempt was unsuccessful primarily due to unacceptability by farmers, which was due to lack of knowledge of domestic consumption and market constraints. The following introduction was made by CADU in cooperation with the Ethiopian Nutrition Institute in the 1970s with the primary goal of replacing imported soy beans used in the production of meals for children and introducing soy beans into the community's local diet (FerehewiotDeressegn and TeleleTekalign, 2017). The responsibility for soybean research was shifted from CADU to IAR in 1966 with the founding of the Institute of Agricultural Research (IAR). Institute of Agricultural Research has entered in to collaboration with International Institute of Tropical Agriculture, Asian Vegetable Research and Development Center and International Soybean Program and undertook number of research activities in different location throughout the country. Nationally coordinated soya bean research was started in 1974 by IAR, and Hawassa Research Center has been coordinating Soybean research from the time up to 2011 (Bewket Getachew &NetsanetAbera 2021), and since then Pawe Agricultural Research Center (PARC) coordinates 7 the national

soya bean research activities (Asmachew Agegn *et al*., 2021). Consequently, in1980's varieties like Clark-63, Williams and Davis were released and put under demonstration for farmers at Hawassa and Shebidino with 60 kg ha^{-1} seed rate, 60 cm × 5 cm spacing and 2 to 3 times of hand weeding before full blooming stage of the crop with 100 kg ha^{-1} DAP and mid-July planting with the purpose of increasing supply of raw material for agroindustry's and also earning foreign exchange income for the country (Bewket Getachew &Netsanet Abera, 2021).

2.3 Environmental Requirements of soybean

Soybean grain yield as a complex character is associated with some yield components and influenced by environmental fluctuations (Jaleel *et al*., 2009). Soybean yield potential in various agro-ecological environments vary depending on the compatibility with the agro-ecosystem, biotic and abiotic stress magnitudes, and level of crop management (Krisnawati & Adie, 2018). Environmental variables such as soil type, growing season, planting pattern and elevation often become a determinant of suitability adaptation of soybean varieties in Ethiopia (Deresse Hunde *et al*., 2019). It also leads to the interaction between soybean and environment. Optimization of such diverse environments can be achieved by the provision of high yielding and stable adaptation soybean varieties. So far, the Ethiopian Institutes of Agriculture released 26 soybean improved varieties. Superior/improved variety is recognized as a cultivation technology component which is inexpensive, easy to adopt and compatible with other technological innovations as well as safe for the environment (Krisnawati & Adie, 2018). Multi-environment yield trials are widely used for selecting superior soybean advanced lines to be released as a new variety for target environments in Ethiopia soybean breeding programs (Deresse Hunde *et al*., 2019).

In Ethiopia, soybean is grown over wider agro-ecologies especially in low to mid altitude areas (1250 to 2200 meters above sea level) that have moderate annual rainfall (450-1500 mm) and the optimum temperature is 230 c -250 c for optimum growth, nodulation, and nitrogen fixation (Mesfin Hailemariam &Abush Tesfaye, 2017). The need for a long growing season and satisfactory soil moisture during flowering and pod filling are very important for higher yield of soybean. It grows best under good soil conditions. A fertile, medium textured,

sandy or clay loam and alluvial soils of good fertility with optimum soil PH of 6.0 to 6.5 soil usually is best (Duane & Ted, 2003). The temperature below the optimum point is adversely affects growth, development, dry matter production and grain yield. Furthermore; low root zone temperatures affect nodule development and N fixation. Thus, temperature is one of the major limiting factors in soya bean production in areas with relatively short growing seasons. The environment to which plants respond resulted from the interaction among atmospheric and soil factors as well as physiological and morphological characteristics of the plant (De Ronde *et al*., 2004). Moisture availability is particularly critical during two periods of soya bean development; these are the crop emergence and pod filling. Depending soil moisture, soil temperature and planting depth soybean seedlings emerge 4 to 14 days after seeds are planted. There was a significant relationship between seed yield and amount of rainfall during the period between flowering and pod formation. The plant activity accumulates nutrients from the soil during most of the pod and seed formation period. Moisture stress during pod filling stage reduces yield more than the stress during earlier stages of growth including the flowering stage (Brevedan & Egli, 2003).

2.4 Production Status and Trends of Soybean in Ethiopia

There are good climatic and soil conditions for soybean production in South and Western Ethiopia which is indispensable both for commercial purposes in addition for subsistence farming (Gebre-EgziabherFentahun, 2019). In addition to low profitability and production, a lack of processing facilities, a lack of capital to increase production, and the absence of a market information system (or a market data framework) for successful agricultural marketing (or farming promotion), there are other issues (problems) with producing soybeans (UrgessaTilahun, 2015). The total area coverage under the production and whole volume of production of soy bean has been increasing over years. Hagos Afework and Bekele Adam (2018) discovered that the growth in the area of land set aside for soy bean farming was the main cause of the considerable wellspring of increase in soy bean production overall. While the total volume of soy bean production during (2001/02 - 2016/19) has increased by more than 50 folds, this is significantly greater from the study of (Mekonnen Hailu and Kaleb Kelemu., 2014) total increment between 2001/02 and 2011/12 equals to 21 folds, the total increment between 2001/02 and 2016/17 is greater than 20 folds, this is double as compared

to the former one. The increased hectare of land for the production of soybean as well as increased total production during the last 15 years has been resulted from increasing demand for soy bean at local and international market (CSA 2001-2019).

Productivity level of many other major crops is very low. The current normal national productivity level of soy bean is additionally low. The average productivity level of soy bean during the last 15 year was 1.4tons ha^{-1}. This level is additionally low contrasted with the potential which could go up to 4 ton/ha if improved varieties are used. The last 15 years trend in the productivity level has grown from 0.92tons ha^{-1} in 2001/02 to 2.22 tons ha^{-1} in 2016/19 (Table 2.1). During this period average productivity level has been greater than doubled.

2.5 Importance and Utilization of soybean

Soybean (Glycine max L.) is an essential source of dietary protein, oil and minerals. Soybean meal is used mainly in developed countries and some higher income developing countries (Liu, K., 2012). Soybean meal is a major protein component in livestock feed. Livestock and poultry feeds containing soybean meal as their major protein ingredient are used worldwide. The relative importance of soybean meal in the international market has increased over the years as seen by comparing percentage of soybean meal production (Pettersson & Pontoppidan, 2013). Soybean oil accounts 20 to 25% of total 7 world fats and oil production and 30 to 35% of total edible vegetable oil production. Soybean is a grain legume that is very nutritious and contains on average 40% protein, 21% oil, 34% carbohydrates and 5% ash on a dry matter basis (Dugje *etal*., 2009). It can be used directly for food in the household, or processed for soy-milk, cooking oil and a range of other products, including infant weaning food. Also the poultry industry uses soybean for feed production. Soybean grain often has a good market demand. Soybean provides a wide range of opportunities for improving household food and nutrition security, as well as an important source of cash (Mekuria, 2022). The majority of the populations in Ethiopia do not have access to expensive animal protein sources such as egg, milk and meat, while child and maternal malnutrition are among the highest in the world(Wilson *et al*., 2021). In Ethiopia, soybean is a multipurpose crop, which can be used for a variety of purposes including preparation of different kinds of soybean foods, animal feed, soy milk, raw material for the food processing industry, and it counter

effects depletion of plant nutrients in the soil resulting from continuous mono-cropping of cereals, especially maize and sorghum, thereby contributing to increasing soil fertility (Mekonnen Hailu, and Kaleb Kelemu, 2014; Abebe Zerihun, and Deressa Haile, 2017). However, soybean contributes nearly nine percent to the country's total oilseed production and account for only four percent of area planted to oilseeds (Erana Kebede, 2020). The crop residues are also rich in protein and are good feed for livestock or form a good basis for compost manure (Dugje *et al*., 2009). The remarkable success of the soybean in temperate zones is well known, but there is also a good potential role for the crop in many cropping systems of the tropics and subtropics, where farms tend to be smaller and less mechanized (RehimaMussema*et al*., 2021). Farmers need to rotate crops to break disease and pest cycles and to maintain soil fertility, and the rotation crops need to be profitable. There are other options for rotation crops, but soybean can be a good choice especially when other legumes are subject to heavy insect and disease pressures and where there is a clear market link from the grower to the industry. In this respect, soybean is one of the few choices where major expansion in production area appears feasible due to further rising demand in the vegetable oil and feed sub-sectors (Thoenes & Trade, 2007). Soybean is important nitrogen fixing leguminous crop, known for its wide adaptability coupled with its higher productivity per unit area compared to other grain legumes. It is useful in crop production as its nodules fix atmospheric nitrogen and thus builds up the soil fertility by fixing large amount of atmospheric nitrogen through the root nodules and also through leaf fall on the 8 ground at maturity (Singh & Shivakumar, 2010). N2 fixation potential of soybean shoot and root could vary ranging from 0−450 kg N ha^{-1}(Mathenge *et al*., 2019). Studies on N2 fixation in soybean using different methodologies revealed that soybean shows a strong demand for N for optimal development and grain productivity and obtain up to 80% of its total nitrogen requirement from BNF (Salvagiotti *et al*., 2008). Biological nitrogen fixation by soybean contributes significant quantities of nitrogen to both natural and managed ecosystems and offers a relatively cheap alternative source of nitrogen to resource poor farmers (Salvagiotti*et al*., 2008; Getachew Zerihun*et al*., 2017). Also, WorknehBekere*et al*. (2012) reported that biological nitrogen fixation is becoming more attractive and economically viable and is an environmentally friendly agricultural input.

2.6 Soybean Production Potential and Constraints in Ethiopia

2.6.1 Soybean production potential in Ethiopia

The current Soybean production in small farmers or large scale is highly dependent on marketable value and suitability of the environmental conditions especially in the lowlands of North western and south western part of the country (Takele Atnafu*et al*., 2022). The suitability of potential environmental opportunity for Soybean crop production and the presence of the yield potential of Soybean in Ethiopia would give better image and possibility for yield gap improvement (KumilachewAchamyelh and Mesfin Hailemariam, 2020). The proximity of the country to international market and the high market demand for Ethiopian Soybean seed/especially organic soybean seed/can be considered as another opportunity. The oil qualities of varieties currently under production are relatively good and encouraging but needs to improve further that targeted to the customer traits of interest (Deresse Hunde, 2019). Though there is an effort by some research centers in Ethiopia in variety development and agronomic research practices, but yet it is not enough to bring impact in increasing production and productivity in line with increasing soybean seed system. Therefore one of the most important means of increasing soybean production and productivity in line with increasing soybean seed system is expanding, addressing and pushing soybean crop towards the competitive crops belts like maize and sesame(Reijntjes *et al*., 1992). Pawe Agricultural Research Center in particular with Jimma and other collaborative centers were working research on soybean in all disciplines includes: Variety development research (Breeding and Genetics research), Agronomy research, Crop protection research (pest and disease control, Soil fertility regulation research, food and nutritional quality laboratory research and Socio-economic research (Deresse Hunde, 2019). Soybean varietal development through conventional breeding methods that involves germplasm introduction, selection, crossing and hybridization followed by advancing generation plays a great role on soybean technology generation. Crossing and hybridization of soybean in Ethiopia were started since 2011/12 particularly at jimma and Pawe to increase genetic diversity in line with acceptable, stable and new varietal development) (Adane Arega, 2016).

2.6.2 Soybean Production Constraints in Ethiopia

The production and productivity of soybean in Ethiopia is limited mostly due to unbalanced fertilizer uses (ToleraAbera *et al*., 2009) and limited use of improved soybean varieties (Gebre-Egziabher Fentahun, 2019). As a result, smallholder farmers' yield is far below from the potential production of the crop. The production increment can be highly associated with the use of seeds of improved crop varieties and application of fertilizer (Gebre-Egziabher Fentahun, 2019). Balanced fertilizer is the most important tools to overcome soil fertility problems and increase food production. However, 30 % to 50 % crop yield declination is observed due to no application of fertilizer (Stewart *et al*., 2005). Disease (yellow rust), weed management issues, low grain prices, low productivity, a lack of information, and a lack of information and credit were the main production obstacles cited by respondents. A current obstacle to increasing soy bean yield and productivity in the research area is the soy bean yellow rust and weed control issue (Kumilachew Achamyelh, and Mesfin Hailemariam, 2020). Regarding marketing (traders and lead-firms) were low supply, poor infrastructure (poor market linkage and road), and low capital are reported as major constraints by respondents. Poor infrastructure, shortage of credit and low supply were the series of problems in soya bean marketing in the study area (Morales, 2009). Due to the weak of vertical linkage, there is an information gap between lead-firms and producers on grain quality amount supply in a year. Even though there is a supply increase in the past five years; it's not full fill demand interest (with both quality and quantity of lead firms) (Kumilachew Achamyelh, and Mesfin Hailemariam, 2020).

2.7 Effect of Blended NPS Fertilizer Rates on Yield and Quality of Soybean

Balanced fertilizer application enhances the yield and quality attributed characters of legume crops (Asmachew Agegne., 2021). According to Teriku Legesse *et al*. (2020), When compared to no application of balanced fertilizer, blended NPS fertilizer increases plant height, number of pods per plant, seed weight per pod, grain yield, straw yield, and biological yield of soybean by 44.9 percent, 45.18 percent, 20.29 percent, 15.54 percent, 120.77 percent, 45.12 percent, and 51.34 percent, respectively. In addition, Teriku Legesse *et al*. (2020)also found that application of blended NPS fertilizer increases 100 seed weight of soybean by 1.5 % than application of NP fertilizer. Likewise, Birhanu Gebeyehu (2021) showed that the application of mixed NPS fertilizer to the legume crop (faba bean) enhanced the number of

pods per plant, number of seeds per pod, hundred seed weight, total biomass production, grain yield, and straw yield. Legume crop output is much higher when balanced fertilizer applications of N, P, K, S, Zn, and B are made than when no fertilizer is applied(Choudhary *et al*., 2013; Srinivasarao, 2021). Application of N fertilizer at a rate of 30 kg ha^{-1} had a positive impact on the soybean's growth characteristics. At this rate, plant height increased from 40.3 cm to 45.7 cm. Similarly, application of N fertilizer at a rate of 180 kg ha^{-1} resulted in higher grain yield (2990 kg ha^{-1}) and seed weight (10.54 g) than the control.(Kuntyastuti *et al*., 2020). Similarly, Deibert *et al*. (1979) observed that biomass of soybean was significantly increased from 2.4 t ha^{-1} to 3.2 t ha^{-1} by application of 134 kg ha^{-1} N fertilizer at planting. A Mississippi study, conducted by Van Vugt *et al*. (2005), concluded that applying a high rate of N (>291 kg N ha^{-1}) to replace fixed N increased soybean yields above the nil application of N fertilizer by 327 and 442 kg ha^{-1} in irrigated and non-irrigated areas, respectively. Khanam *et al*. (2003) also reported that P significantly influence yield and yield attributes of soybean as, highest number of seeds per pod are recorded when 100 kg ha^{-1} P2O5 was applied and minimum number was recorded when no P was applied. Similarly, Akter *et al*. (2013) showed that the supply of 50, 50, 30, 30, 50, and 30 kPa increases the number of primary branches $plant^{-1}$ by 45.9% (2.46 to 3.59), the number of leaves $plant^{-1}$ by 10.48% (10.30 to 11.38), the number of pods $plant^{-1}$ by 90.3% (14.57 to 27.73), the yield of grain by 33.46 percent (1518 to 2026 kg ha^{-1}), the yield of stored product by 20.24 percent (2470 to 2970), and the biological yield of soybean. Dereje Getahun *et al*. (2018) Furthermore, it has been shown that growing soybean plants accumulate more dry matter throughout the entire plant, as well as having larger leaves overall. Importantly, varying quantities of P were seen for oil and protein content(Malik *et al*., 2006). According to Devi *et al*. (2012) research, As a result of the application of sulfur fertilizer, several soybean yield-attributing characteristics, such as the number of branches per plant, pods per plant, 100-13 seed weight, grain yield, stover yield, harvest index, and protein and oil content of soybean grain, have increased dramatically. Similarly, Das *et al*. (2022) also showed that Sulfur application considerably raises the height of the plant, the quantity of primary branches, the yield of grain, stover, and biomass of soybean by 8.5 percent, 33 percent, 31 percent, 16 percent, and 20 percent, respectively. The soybean seed yield was significantly increased with the application of

Sulphur @ 20 kg ha^{-1} (2534 kg ha^{-1}) compared to Sulphur levels; 30 kg ha^{-1} (2494 kg ha^{-1}), 40 kg ha^{-1} (2376 kg ha^{-1}) and 10 kg ha^{-1} (2226 kg ha^{-1}) (KAUR *et al*., 2016).

2.8. Vermicompost and its effects on soil and soybean productivity and quality of the seed

Vermicompost is created when numerous microorganisms and earthworms work together to degrade organic materials in anaerobic biodegradation. Vermicompost is a significant source of plant nutrients that can replace artificial fertilizers, lowering crop production costs (Lazcano *et al*., 2013). Vermicompost significantly positively affected to the number of branches, number of pods and seed weight (Sondawale *et al*., 2023). The application of zinc and vermicompost had a substantial impact on the plant's uptake of macro- and micronutrients as well as growth metrics (Purna *et al*., 2020). Vermicompost applications, either alone or in conjunction with other organic fertilizers, have been shown to be beneficial at promoting the development and yield of a variety of plants, including soybean and other crops (Moghadam *etal*., 2014). Application of vermicompost fertilizer and mycorrhiza decreased the toxic effects of cadmium chloride. By application of vermicompost fertilizer plant height, chlorophyll content and carotenoid leaf was increased and application of mycorrhiza increased leaf soluble protein significantly (Yadavi *et al*., 2014). The quantity and quality of field crops, vegetables, flowering plants, and fruit crops have improved thanks to the application of vermicompost, which also reduces the occurrence of disease and pests(SAHA, 2021). The water holding capacity and electrical conductivity of the soil were increased in the plots supplied with 5.0 t vermicompost per ha compared to control plots (BISWAS, 2016). The organic carbon content of the soil increased by 0.27 percent due to application of vermicompost compared to application of chemical fertilizer alone (HOSSAIN, 2019). Application of vermicompost @ 5 t ha^{-1} in scented rice Basmati-1 resulted in significantly higher yield (4889 kg ha^{-1}) as compared to no vermicompost application (Murali & Setty, 2004). Increased availability of nutrients in vermicompost compared to non-ingested soil resulted in significantly better growth and yield of rice has been reported by several workers (Jothi *et al*., 2021). Apart from the improvement in fertilizer use efficiency, vermicompost ensured a steady supply of secondary nutrients like Mg as well as micronutrients throughout the growth period, which improved the chlorophyll content of leaves and reduced the chaff

percentage. Unlike other organic manures, vermicompost 10 addition has got the added advantage of quick nutrient absorption by plants, to result in better dry matter accumulation (BISWAS, 2016). Conjunctive use of vermicompost @ 2 tha^{-1} along with 50 per cent Nha^{-1} enabled hybrid rice to produce grain yield on par that obtained by application of recommended dose of fertilizer along. Vermicomposting is the bioconversion of organic waste materials into nutritious compost by earthworm activity and is an important component of organic farming package (Maharjan & Regmi, 2020). Application of vermicompost improved the chemical and physical structures of the soil. Application of vermicompost increased the infiltration and reduced runoff and thus increased soil water availability for plant growth (HOSSAIN, 2019). The soil organic carbon content increased with the treatment receiving potato vermicompost over the control. Availability of nitrogen increased in earthworm cast application as compared to non-ingested soil (Lourduraj & Yadav, 2005).

Vermicompost application had a significant impact on all attributes examined at the 1% probability level. Comparing the means of different vermicompost levels revealed that all examined features increased when vermicompost rates rose to 10 t ha^{-1}(SAHA, 2021). The highest seed yield with 2868 $kgha^{-1}$, 100 seed weight with 16.25 g, plant height with 73.93 cm, number of pods per plant with 26.43 pods and number of seed per plant with 60.29 seeds was obtained from use of 10 tha^{-1} vermicompost (V3) (Azarpoor *et al*., 2012). On the other hand, the lowest amounts of seed yield, 100 seed weight, plant height, number of pods per plant and number of seeds per plant respectively with 1661 kg/ha, 13.98 g, 62.07 cm, 18.42 pods and 42.96 seeds were recorded from V1 treatment (without vermicompost application). Vermicompost application has been linked by many researchers to improved crop growth, yield, and yield components. This is because it provides the ideal nutrient conditions (Akhzari *et al*., 2016).

2.8 Interaction Effect of Vermicompost and Blended NPS Fertilizers on Soybean Productivity and Quality

Integrated soil fertility management combines physical and biological soil and water conservation strategies with organic and inorganic soil fertility management techniques. To address nutrient imbalance and organic matter deterioration, it integrates methods that are

site-specific to agronomic and socioeconomic situations, with an emphasis on the prudent use of mineral fertilizers, maximizing organic fertilizers, and minimizing environmental impacts (Sommer *et al*., 2013). By employing integrated soil fertility management and greater utilization of the organic resources available on farms to increase soil organic matter, waste lands are transformed into high fields on the same lands for many years, reducing the need to clear additional lands (Hintsa *et al*., 2016).

The majority of research findings showed that there was a significant increase in the number of primary branches, pods per plant, seed output, and harvest index when vermicompost and NPS rates interacted (Chala Debela *et al*., 2020; AemiroBirhanu, 2020; Fayera Asefa, and Alemayehu Wagari, 2021). Chala Debela *et al*. (2020) indicated that treatments treated with 100 kg NPS ha^{-1} + 2 t VC ha^{-1} recorded the largest number of pods per plant (87.6), maximum seed yield (3762kg ha^{-1}), and maximum harvest index (41 percent). Application of 100 kg NPS per hectare plus 2 t of VC per hectare resulted in the highest grain yield and quality, as well as the greatest economic benefit. Likewise, Zerihun Abebeand Hailu Feyisa (2017) reported that in acidic soil of Bako, Western Ethiopia, the yield of 19 soybean Boshe varieties improved by 100–200 percent using combined application of organic and inorganic fertilizers as compared to the control. Devi *at al*. (2013) found that compared to the other treatments, the 75 percent RDF mixture with 1 ton ha^{-1} of vermicompost and phosphate soluble bacteria (PSB) provided a grain yield of soybean that was much greater (1.92 tons ha^{-1}). However, using a combination of organic and inorganic fertilizers can help to recover, maintain, and boost crop production.(Ullah *et al*., 2022). Also, Anetor and Akinrinde (2006), In Nigeria, researchers discovered that the amount of soybean seeds, the weight of the pods, and the quantity of pods were all significantly affected by lime and organic fertilizer. In India, it has also been observed that using both organic and inorganic fertilizers together increased soybean output by 12.9%(Murage, 2019). Aziz *et al*. (2013) reported that as the suggested inorganic levels were raised, grain and straw yields increased dramatically. Characters that indicate yield, such as seed weight and nodule count, significantly increased with increasing doses of advised inorganic fertilizers. The highest 100-seed weight over other levels was obtained with the application of the 75 percent recommended inorganic fertilizer amount (Singh *et al*., 2004). Oil and lysine content was found superior with application of 75%

recommended inorganic fertilizers over other levels, Protien content increased with increasing levels of recommended inorganic fertilizers(Aziz *et al*., 2018).

Shivakumar *et al*. (2008) undertook a two-year field study to examine the impact of INM (integrated nutrient management) on soybean seed yield and nutrient absorption available in rainfed conditions in Karnataka, India. According to the findings, 50 percent N + 10 t FYM was equally effective as 50 percent N + 50 percent N through PM + FYM + BS + PM in terms of nutrient availability (248, 50, and 245 kg of NPK ha^{-1}, respectively) and nutrient absorption (122.0, 37, and 110 kg, respectively). 100 percent N + 10 t FYM (1835 kg ha^{-1}) and 50 percent N + 50 percent N thru PM + FYM + BS + CRC produced the highest seed yields, respectively (1793 kg ha^{-1}). Absolute control produced the lowest seed yield (823 kg ha^{-1}) (Kumar *et al*., 2018).

Sourav Saha. (2021) stated that all metrics of soybean showed statistically significant change at various degrees of integrated nutrition management. The tallest plant was found in Biochar (10 t ha^{-1}) +50 percent RDF, measuring 37.3, 50.67, 52.53, and 52.93 cm at 30, 50, and 70 days after sowing and harvest, respectively. The largest seed yield, biological yield, number of pods per plant, number of seeds per pod, and thousand seed weight (g) (Asefa, Fayera, and Alemayehu Wagari, 2021). The T6 (biochar 10 t ha^{-1}) treatment had the highest harvest index. The T13 treatment (Biochar 10 t ha^{-1} + 50% RDF) had the highest germination rate (94.33%). The T13 treatment (Biochar 10 t ha^{-1} + 50% RDF) recorded the highest germination index, coefficient of velocity, energy of emergence, shoot length, root length, vigour index, and viability (Sourav Saha, 2021).

CHAPTER 3.MATERIALS AND METHODS

3.1. Description of the Study Area

The field experiment was conducted at the Pawe Agricultural Research Centre in Pawe District during the main crop growing season in 2022. The experimental site is located at 575 km from Addis Ababa and has an elevation of 1120 metres above sea level at latitude of 11°18′ N and longitude of 36°24′ E. Pawe district is situated in a hot, humid agro-ecological zone that is well known for soybean cultivation by the farmers.

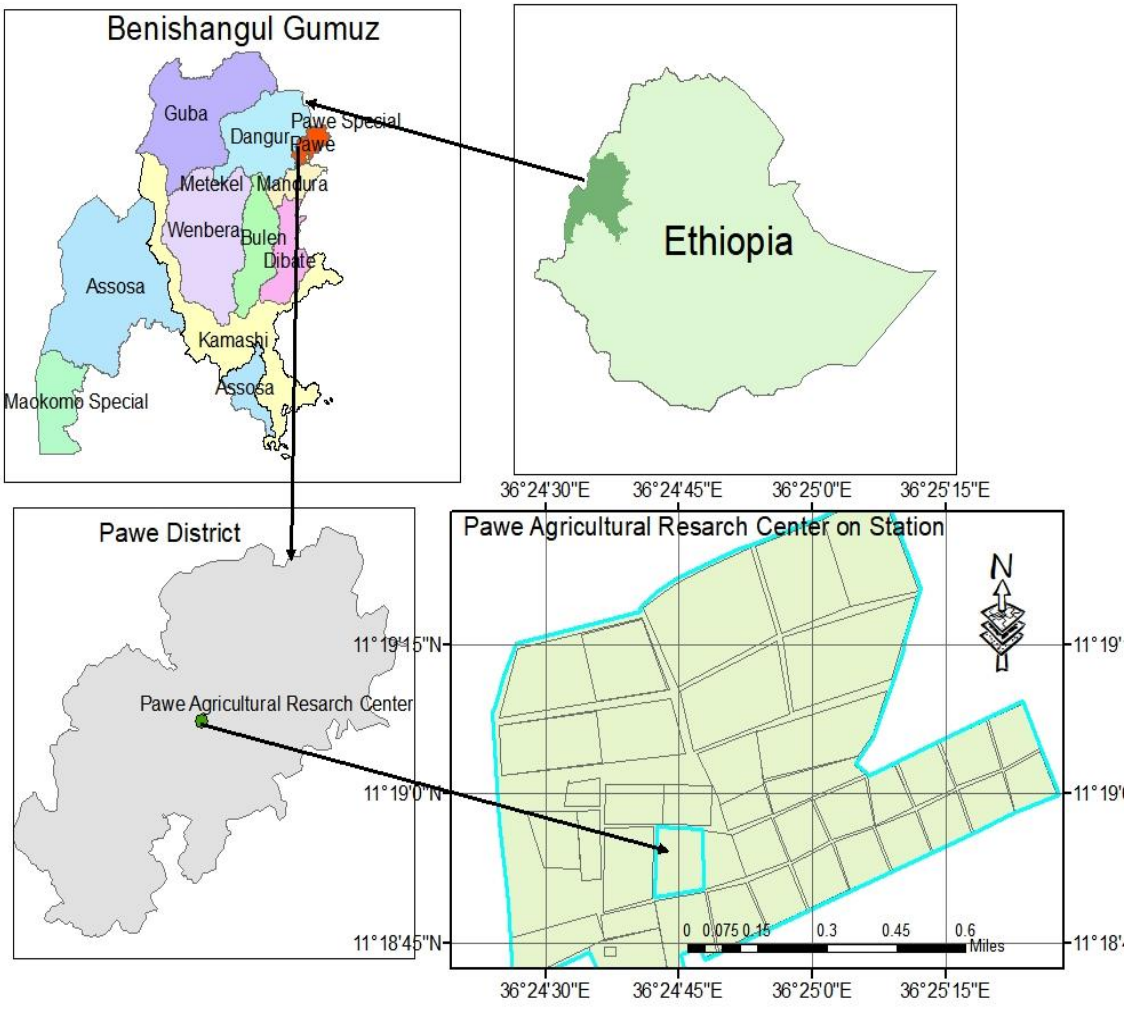

Figure 3.1Map of the study area

The experimental area is characterized by long-season rainfall, which falls primarily from early May to early November with a mean annual rainfall of 980–1587 mm per year, and the average annual minimum and maximum temperatures were 16°C and 30°C, respectively, during the experimental year (Figure 3.2).

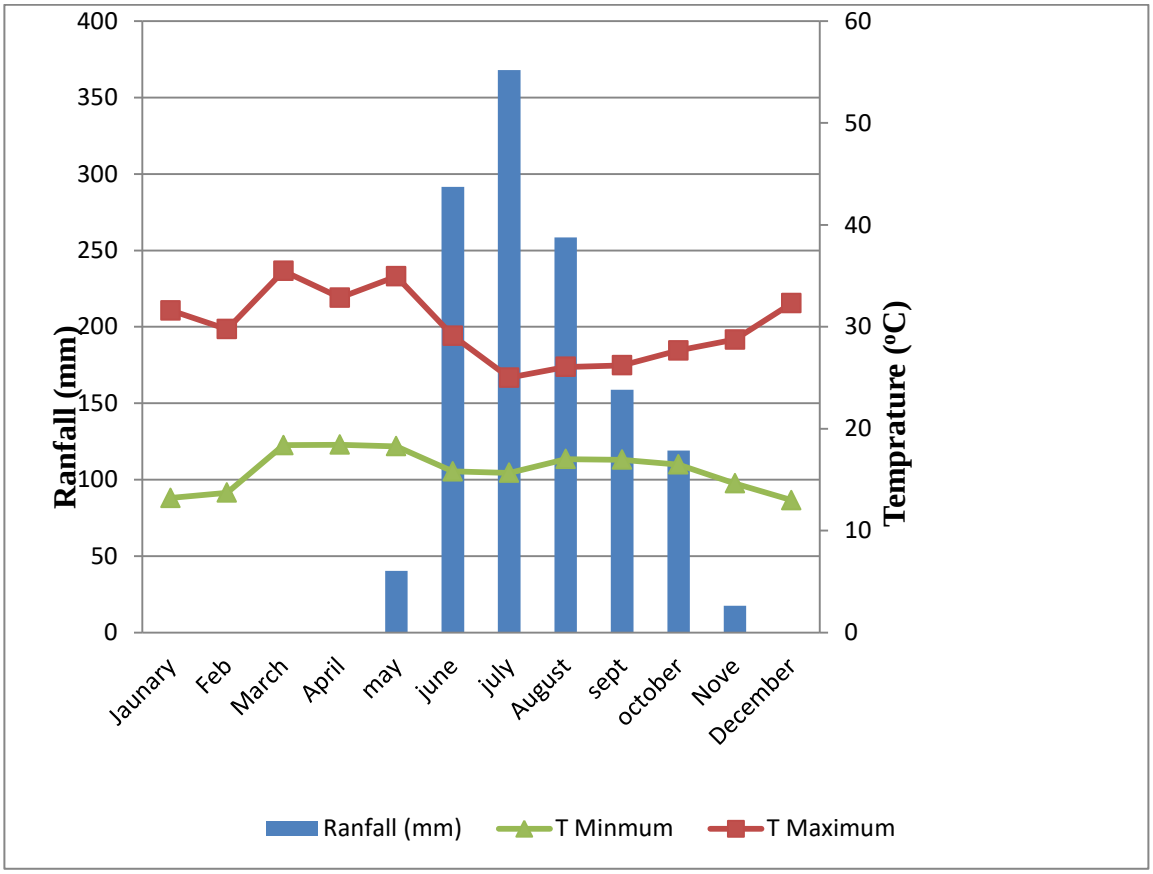

Figure 3.2Monthly mean rainfall, maximum and minimum temperature of the experimental areaduring 2021/2022 cropping season.

3.2. Experimental Materials

Soybean Variety, *Andinet*was used in the experiment as a test crop. The selection criteria of this variety are higher yield potential both in research (19.6-25.7) and farmers (17-23) fields, medium set, plant height 69.1, protein content (%) 35.4, oil content (%) 23.5, recent release, resistance to lodging, and major soybean diseases (PARC, 2019). Vermicompostand NPS (19-38-7) fertilizer were taken from the Pawe agricultural research centre.

3.3. Experimental Treatments, Design and Field Layout

The treatments consisted of three blended NPS fertilizer rates (0, 50, and 100 kgNPS ha^{-1}) and five vermicompost rates (0, 3, 6, 9, and 12 tha-1). The NPS rates were derived based on 100 kg ha^{-1} di-ammonium phosphate (DAP) national blanket recommendations. The experiment was laid out in a randomised complete block design (RCBD) in factorial arrangements with three replications.

The distances between adjacent plots and blocks were 0.5 m and 1m, respectively. The total size of each plot was 3 m × 3 m ($9m^2$), with 300 plants in 5 rows with a 60 cm spacing and a 5cm distance between plants. The external rows of one row on both sides of each plot and 10 cm on both ends of each row were considered border effects and were not used as working samples to avoid border effects. As a result, the net plot is 2.9 m × 1.8m (5.22 m^2), with three rows of 2.9m length.

3.4. Experimental Procedure

The experimental field was ploughed using a tractor, disc, and harrow with human labour to make the soil fine. The seeds were planted by hand at a specified spacing (60 cm × 5 cm) in June at the recommended seed rate of 60kg ha^{-1} by putting one seed per hill. Blended NPS fertiliser was used as a source of different nutrients, and full doses, which varied depending on treatments, were applied as side banding at sowing time. Within a few months, 2021, at Pawe Agricultural Research Center, utilizing concrete tank material as a pit, the vermicompost used for the trial was prepared using the conventional vermicompost preparation processes. Materials including cow dung, straw (made from soybean, finger millet, and groundnuts), and others were first gathered, cut into little pieces with a sickle, and soaked for a week in water. At the bottom of the bin was this straw material that had been well moistened, then there was a thin layer of forest top soil, and last, cow dung was added. After that, about 2000 of the famous vermiworms (Eisenia fetida) from across the country were added to the top of the pit and covered with thoroughly saturated straw. Water was sprayed into each layer to keep the prepared material's moisture content between 70 and 80 percent. Finally, the vermicompost was manually detached from the vermiworms and placed

in a shaded area to air dry. The vermicompost maturity was determined from 80 to 90 days visually by observing the creation of the granular structure of the compost at the surface of the tank. 23 The vermicompost was pulverized and sieved to pass through a two mm sieve after being air-dried. The vermicompost's chemical characteristics, including total N, organic carbon, pH, and total P, were then examined using the protocols given in (Peters, 2003). Vermicompost was used depending on treatments, were applied one week before sowing and incorporated into the soil at 10 cm depth. Finally, all necessary cultural and agronomic practises were carried out uniformly for all plots as per the recommendation for the crop at all stages of growth and development, and the crop was harvested when it reached maturity.

3.5 soil sampling and analysis

To characterize the general soil property of the experimental site, soil samples at 0-20 cm soil depth were collected from five randomly selected spots before planting. The five soil samples from the experimental site were composited, air dried and sieved through a 2 mm sieve and finally submitted to Pawe Agricultural research center (PARC) soil laboratory. Soil PH was determined from the filtered suspension of 1:2.5 soils water ratio to potassium chloride (Kcl) solution using a glass electrode attached to the digital PH meter (Maclean, 1965). The textural class of the soil was determined by the hydrometer method (Juo, 1979). The organic carbon and total soil nitrogen were determined by following the methods of Walkely and Black (1934) and Kjeldahal method (Bremner and Mulvaney, 1982), respectively. Available P was determined by extraction with 0.5M Sodium bicarbonate (NaHCo3) according to the method of Olsen *et al*. (1954). Cation exchange capacity was determined by summation (Hazelton and Murphy, 2016). The results of the soil analysis are discussed in Table 3.1.

Table 3.1Major soil physical and chemical characteristics of the experimental field before planting

Parameters	Values Soil	Rating	Reference
pH (H_2O)	5.30	Moderately acidic	Tekalign Mamo (1991)
OC (%)	1.74	Moderate	Alemayehu Terefe (2000)

OM (%)	3.28	Moderate	Alemayehu Terefe (2000)
CEC (meq/100g soil)	27	High	Landon *et al*. (2014)
TN (%)	0.14	medium	EthioSIS (2013)
AvP (ppm)	9.24	Low	Alemayehu Terefe (2000)
Texture			
Clay	44		Hazelton and Murphy (2007)
Silt	9		
Sand	47		

pH=Power of hydrogen, OC=Organic carbon, OM=Organic matter, TN=Total nitrogen, AvP=Available phosphorus, CEC= Cation exchange capacity,

Table 3.2Selected chemical properties of vermicompost

Parameters	Ph	OC (%)	OM (%)	TN (%)	CEC Cmol	TP (%)	C:N ratio
Value	8.45	10.69	18.44	1.66	65.59	0.61	6.46

TN, OC and, P Means total Nitrogen, organic carbon and phosphorus respectively

3.5.1 Soil Physico-Chemical Properties before Soybean Planting

The results of the analysis of selected physicochemical properties indicate that the particle size distribution of the soil is dominated by clay (44%) followed by sand (47%), and silt (9%) (Table 3.1). Accordingly, the textural class of soil of experimental site is sandy clay. Rieke and Joke (2005) reported that soybean produced a high yield in loamy textured soil, but it can also grow well in clay soils. The soil pH of experimental site is 5.30, which is moderatly acidic according to Tekalign Tadese (1991). Soybean has been found to grow well in pH values of 5.5 – 7 and any pH below and above these values will affect its growth and thus such soil needs amendment to neutralize the extreme soil reactions (Ferguson *et al*., 2006). The organic carbon content of the soil is 1.74% which is medium according to the rating of

Alemayehu Terefe (2000). The medium organic carbon content of the soil might be attributed to the intensive cultivation and continuous removal of crop residues. Organic carbon in soils influences physical, chemical and biological properties of the soils such as soil structure, water retention, nutrient contents and retention and micro-biological life and activities in the soils. Hence, amending the soils with organic fertilizers is important for enhancing crop yields as well as soil health. The available soil phosphorus (9.24 mg kg^{-1}) of the experimental site was low according to the rating of Alemayehu Terefe (2000). The low available phosphorus could be ascribed to the high phosphorus sorption and due to high P fixing capacity of the soil at pawe (Wakene *et al*., 2003). Total nitrogen (0.14%) was medium according to the rating of EthioSIS (2013). Cation exchange capacity (CEC) is an important parameter of soil, because it gives an indication of the type of clay mineral present in the soil and its capacity to retain nutrients against leaching. According to Landon (1991), top soils having CEC greater than 40 cmol (+) kg^{-1}. The experimental site soil has medium CEC (27 cmol (+) kg^{-1}), indicating its very high capacity to retain the cations. Medium CEC of the soil might be due to moderate organic matter content and high soil acidity. Johnson (2002) reported low CEC for strongly acidic soil.

3.6. Data Collection and Measurements

3.6.1. Crop phenology and growth parameters

Days to 50% emergence (days): It was recorded by counting the number of days starting from the time of sowing up to when 50% of the plants emerged from each plot by visual observation.

Days to 50% flowering (days): It was recorded by counting the number of days starting from the time of sowing up to the time when 50% of the plants in the plot flowered.

Lodging susceptibility [%]: This is a permanent displacement of plants from their upright position and is scored at seed maturity (scale of plants lodged). Then lodging score (ranging from 0-7) and the mean data was recorded (EAIR, 2020).

0 = None (all plants standing)

3 = Low

5 = Medium

7 = High

Days to 90% physiological maturity (days): This refers to the duration from sowing up to the time of attaining 90% maturity, and it was recorded as the number of days from sowing to the time when about 90% of the plants in a plot have mature pods in their upper- and lower-parts changing colour to yellow. Hence, the physiological maturity was determined by the yellowness and dryness of the leaves and the whole plant.

Plant height (cm): This refers to the plant height (cm) from the ground level to the tip of the main stem at harvesting; it was measured by using a tape on five plants randomly selected from the three middle rows.

Leaf area index (LAI): it was estimated that the leaf area index (LAI) of soybeans will be taken at $1m^2$ quadrat using a digital camera (Canon) from 1m above ground. Measurements were carried out shortly before sunset at the full vegetative stage of the soybean. All the photographs were imported to the computer and saved as uncompressed, high-resolution files. All these files were directly imported into the LAI calculator to analyse the LAI (Yayeh Bitew *et al.*, 2020).

Numbers of branches per plant: This refers to the number of primary branches on the main stem per plant that will be harvested at maturity. It was obtained by counting the branches from ten randomly selected plants from the three middle rows, and the means were recorded as the number of branches per plant.

3.6.2. Yield parameters

Number of pods per plant: Tt was determined by counting the average number of pods of five randomly selected plants in each plot (the total number of pods of five randomly selected plants was divided by five).

Number of seeds per pod: this refers to the total number of seeds per pod. It was obtained by counting seeds per pod from ten randomly sampled plants in three middle rows.

Above ground dry biomass yield (t ha^{-1}): this refers to the dry weight of above-ground biomass. It was obtained by rejecting two border rows (60cm each border) and two plants from each end of rows (10 cm), harvesting three middle rows, and fully sun drying until constant weight was obtained.

Grain yield (t ha^{-1}): was obtained by separating the total dry biomass yield by threshing and weighting, and then converted to kilogrammes per hectare. The moisture content of grain yield was adjusted to 10% by sun drying for two weeks to attain maximum dry weight near the completion of straw drying with minimum moisture content.

Harvest index(ratio)is calculated on a plot basis as the ratio of grain yield to total aboveground biomass yield (EAIR, 2020).

Hundred (100) seed weights (g): this refers to the weight of a hundred seeds. It was determined by weighting the weight of 100 seeds using an electronic sensitive balance, and samples were taken from each plot.

3.6.3. Soybean seed Quality Analysis

Standard Germination: Germination testing was designed to estimate the maximum number of seeds that will produce a normal seedling.

Vigor Index: After the final count of the standard germination test, ten normal seedlings were taken randomly, and then the shoot and root lengths were measured starting from the point of seed attachment to the tip of the root and shoot.

Speed of Germination: Replicas of 100 seeds were normally used, spaced sufficiently far apart on the germination box to minimise the interference of adjacent seedling development**.**

Moisture Tests: The electronic moisture metre used follows ISTA standards.

$$\textbf{SPG} = \frac{\text{Normal seedlings} + \ldots\ldots + \text{Normal seedlings}}{\text{No of days of 1st count} \ldots\ldots \text{No. of days to final count}}$$

Crude protein content: the crude protein content was determined by total nitrogen determination, according to the micro Kjeldahl method, technique 920.87 (AOAC, 1990), using a 6.25 conversion factor and expressed in dry matter percent.

Seed health:
To determine whether a seed is healthy or diseased, a scale (0–9) recording method was used.

3.7. Data Analysis

3.7.1 Statistical data analysis

All agronomic data from the experimental field was collected and entered into Microsoft Office Excel. The same software was used for data editing and management. Data were subjected to analysis of variance (ANOVA) using statistical procedures as described by Gomez and Gomez (1984) with the help of SAS 9.4 software and(SASJMP). Before analysis, the data were checked for normal distribution following the scatter plot technique. The data were analysed with NPS fertilizer and vermicompost rates as fixed effects and replication as random effects. When the analysis of variance showed significant differences among treatments at any level of probability, mean separation was conducted using LSD. Using the same software, a simple linear regression analysis was conducted to determine the association between (i) grain yield and other agronomic and quality attributes and (ii) agronomic and quality attributes with NPS fertilizer and vermicompost rates. A simple correlation analysis was also carried out to investigate the strength of the associations among grain yield and yield and quality traits of bread wheat. The value of r (correlation coefficient) lies within the range of -1 and +1; a value close to +1 or -1 represents a strong linear relationship; a value of r close to zero means the linear relationship is very weak; and an intermediate value of r indicates the portion of variation in one variable that is accounted for by the linear function of the other variable.

3.7.2. Partial budget analysis

To determine economically profitable treatment (s), partial budget analysis was performed following the procedure of the International Maize and Wheat Improvement Centre (CIMMYT) (CIMMYT, 1988). NPS fertilizers, labour requirement for fertilization, vermicompost preparation and labour requirement for vermicompost application costs were

considered as the input and variable costs. Other production costs such as land renting, labour for land preparation, weeding, harvesting, trashing and cleaning were considered as fixed costs across treatments. Grain and straw yields were considered as the output yields and the cost is output cost. All costs were calculated as average value of the months of June 2022 to February 2023.The local costs of NPS fertilizer was 50 Birr kg^{-1}. Labor cost for vermicompost 2 Birr kg^{-1}. The price of soybean seed and straw yield were30 Birr kg^{-1} and 4 Birr kg^{-1}respectively. Grain yield was adjusted downward to 10% so as to reduce the yield gabs between experimental plots and farmers. Finally, total variable cost (TVC), gross benefit (GB), net benefit (NB) and marginal rate of return (MRR) were calculated as follows:

Total variable cost (TVC): Total costs that vary for each treatment is the sum of the individual costs that vary.

Gross benefit (GB): The gross field benefit for each treatment is calculated by multiplying the field price by the adjusted yield.

Net benefit (NB): This is calculated by subtracting the total costs that vary from the gross field benefits.

Marginal rate of return (MRR): Which is the marginal net benefit (i.e. the change in net benefits) divided by the marginal cost (i.e. the change in costs), expressed as a percentage. After treatments were arranged in ascending order by TVC value, treatments with high NB and lower TVC than the preceding treatment were selected for further analysis. Thus, treatments with a lower NB value and a greater TVC than the preceding were excluded (dominated). Selected treatments were subjected to MRR analysis, which was calculated by the following formula:

$$\text{MRR}\ (\%) = \frac{\text{NBT2} - \text{NBT1}}{\text{TVCT2} - \text{TVCT1}} \text{x}100$$

Where T2 and T1 are consecutive treatments (T) arranged in ascending order based on their TVC after excluding treatments with low NB and high TVC.

CHAPTER 4. RESULTS AND DISCUSSION

4.1. Phenological and Growth Variables

In the reason of my parameters are very numerous Days to emergency and days to flowering are not including in the discussion part.

4.1.1. Days to maturity (DM)

The number of days required for 90% maturity was highly significantly *(P<0.01)* influenced by the main effects of blended NPS fertilizer and vermicompost application (VC) and by their interaction (Appendix Table 1). The maximum period required to attain 90% maturity (123 days) was recorded from the combined application of 100 kg ha^{-1} blended NPS fertilizer and 6 t ha^{-1} vermicompost, which had a statistically similar effect to the application of 50 kg ha^{-1} blended NPS fertilizer and 12 t ha^{-1} vermicompost. While the shortest duration (107 days) was recorded from the control and combined application of 100 kg ha^{-1} blended NPS fertilizer and 12 t ha^{-1} vermicompost (Table 4.1). Longer maturation times could be due to favoured vegetative growth due to increased nitrogen supply from NPS and vermicompost fertilizer applications. Moreover, the delaying in physiological maturity with increasing application rates of vermicompost enhances microbial activity and hence nitrogen levels causing greater root expansion, which in turn leads to greater uptake of nutrients, water, and the rate of photosynthesis in crops. This result is in line with the result of Bewuket Getachew (2019), who reported that the maximum period required to attain days to 75% maturity (97.67 days) was recorded from the combined application of 199 kg ha^{-1} blended NPSZnB fertilizer and 30 t ha^{-1} cattle manure. In contrast to this result, Chala Debela *et al*. (2021) reported that the main effects of NPS rate, vermicompost (VC) and Rhizobium inoculation (Rh) were significant*(p<0.01)* on days to physiological maturity, while the interaction effects were not significant. When we added too much amount of N-source fertilizer, it leads to lodging. When plants are lodged, relatively fewer of the upper leaves and more of the lower leaves are

exposed to sunlight so the entire energy-producing mechanism is disturbed it also decreases maturity time (SEMU & Hume, 1979).

4.1.2. Plant height (PH)

Plant height was highly significantly *($p < 0.01$)* influenced by the main effects (blended NPS fertilizer and vermicompost rates) and their interaction effects (Appendix Table 1). The highest plant height (83.73 cm) was recorded from plants that grow with a combined application of 100 kg ha^{-1} blended NPS fertilizer and 12 t ha^{-1} vermicompost. The shortest plant height (54.7 cm) was observed in the control treatment (Table 4.1). The significant increase in plant height observed by plants treated with the combined use of the highest blended NPS fertilizer and vermicompost could be due to the fact that nitrogen is considered one of the major limiting nutrients in plant growth, and an adequate supply of it promotes the formation of chlorophyll, which in turn results in higher photosynthetic activity, vigorous vegetative growth, and taller plants. Phosphorus is required in large quantities in shoot and root tips, where metabolism is high and cell division is rapid. Similarly, sulphur promotes the formation of chlorophyll, higher photosynthetic activity, vigorous vegetative growth, and taller plants (Alemu Fessha, 2019). In addition to these, according to Tahir *et al*. (2009), there was a significant increase in plant height in relation to increases in nitrogen application rates on soybean. Moreover, the increase in plant height with the increased NPS application rate indicates maximum vegetative growth of the plants under higher N and S availability, and P also plays a pivotal role in early root proliferation that might increase the nutrient uptake of the plant, thus resulting in increased vegetative growth and increased cell elongation and their multiplication. Combined increases in vermicompost and blended NPS fertilizer led to an increase in plant height, which is supported by the significant ($P< 0.05$) positive linear relationship between them (Table 4.4). In conformity with this result, the maximum (63.37 cm) plant height was observed with an application of 200 kg NPS ha^{-1}, while the shortest (48.23 cm) plant height was obtained (AsmachewAgegn*et al*., 2022). This observation also confirms the conclusions of SAHA (2021), reported that inorganic nutrients are readily available for plant uptake after application, while organic forms are only slowly available. In this way, the plant is continuously supplied with nutrients until it is matured.

4.1.3. Leaf area index (LAI)

The leaf area index was highly significantly ($p< 0.01$) influenced by the main effects (blended NPS fertilizer and vermicompost (VC) applications) and their interactions (Appendix Table 1). The highest leaf area index (9.02) was recorded from the combined application of 100 kg ha^{-1} blended NPS fertilizer and 12 t ha^{-1} vermicompost. On the other hand, the lowest value for the leaf area index (3.67) was obtained from the control treatment (Table 4.1). The increased leaf area index in the former soil amendment could be attributed to the development of more above-ground biomass with the expanded leaves produced in response to nitrogen (Bewket Getachew, 2019).Combined increases in vermicompost and blended NPS fertilizer led to an increase in LAI, which is supported by the significant ($P< 0.05$) positive linear relationship between them (Table 4.4). It quantifies the amount of leaf area in an ecosystem and is a critical variable in processes such as photosynthesis, respiration, and precipitation interception (Alton, 2016; S. Boussetta *et al*., 2013; Jarlan *et al*., 2008). Brintha and Seran (2009) stated that productivity rates increase with LAI because of increased total light interception, but larger LAI values often cause no more increases and then decrease on a ground basis, probably due to respiratory CO2 loss from heavily shaded leaves and stems. Vermicompost may have improved soil physical properties such as bulk density and porosity (Getenesh Belay, 2019) and moisture-holding capacity, promoting early root growth. Enhanced root growth could have improved the ability of plants to access nutrients. Then increased amounts of nutrients within a plant enhance leaf area expansion and leaf number development. A similar result was reported by Bewuket Getachew. (2019), the highest total leaf area index (7.55) was recorded from the combined application of 199 kg^{-1} blended NPSZnB fertilizer and 30 t ha^{-1} cattle manure.

4.1.4. Number of branches per plant

The analysis of variance showed that the main effects of NPS fertilizer and vermicompost application and their interactions significantly ($p< 0.01$) affected the number of primary branches. The maximum number of primary branches per plant (7.77) was produced by plants treated with the combined application of 50 kg NPS ha^{-1} and 9 tons vermicompost ha^{-1}, while

the minimum number of primary branches per plant (4.35) was recorded from the control (Table 4.1). The maximum primary branches (9.2) at a medium rate of vermicompost and NPS rate might be due to greater availability of macro and micronutrients, a form of organic and inorganic sources, which assisted in the acceleration of various metabolic processes of NP and S, which help in better absorption of nutrients combined with the proper distribution. The significant (*P 0.05*) positive linear connection between vermicompost and mixed NPS fertilizer indicates that increasing both of these fertilizers together improves the number of branches per plant (Table 4.4). This study's results agree with those of Singh *et al*. (2011), who reported that combined treatment of vermicompost at a rate of 3.75 t ha^{-1} with a 25% rate of NPK fertilizers led to an increased number of primary branches of French bean (Phaseolus vulgaris). Similarly, Hossain *et al*. (2018) reported that combined application of vermicompost at 2.5 t ha^{-1} + RDF (25:50:50 kg NPK ha^{-1}) gave a higher number of branches (6.92) in groundnut. Also, Chala Debela*et al*. (2021) reported that the maximum number of primary branches per plant (9.2) was produced by plants treated with the combined application of 100kg NPS ha^{-1} and 1 tonne vermicompost ha^{-1} inoculated with Rhizobium.

Table 4.1Interaction effects of vermicompost and NPS fertilizer rates on growth and yield component of soybean the 2022 main cropping season, in Pawe district

Source of variations		Log	DM	PH	LAI	NBP
NPS	VC					
0	0	0d	107f	54.70i	3.67g	4.35i
	3	0d	114d	58.15h	4.13fg	5.17h
	6	0d	114.33d	72.53ef	5.53def	5.76fg
	9	0d	115c	74.4df	6.13cde	6.5de
	12	0d	121b	74.28df	7.03bcd	7.27bc
50	0	0d	114.33d	71.26fg	5.27ef	5.57gh
	3	0d	121b	71.93ef	7.07bcd	6.23ef
	6	0d	121b	71.86ef	7.73ab	7.63ab
	9	0d	121b	74.32df	8.13ab	7.77a
	12	3c	123a	79.21bc	8.2ab	7.18bc
100	0	0d	121b	68.83g	7.17bc	6fg
	3	0d	121b	73.26ef	7.57abc	7.53ab
	6	0d	123a	76.4cd	8.27ab	7.56ab
	9	3.7b	112e	81.03ab	8.5ab	6.97cd

12	5a	107f	83.73a	9.02a	5.96fg
LSD (5%)	0.50**	0.35**	3.00**	1.60**	0.49**
±SE	0.17	0.12	1.06	0.33	0.17
NPS	1.13**	3.71**	4.89**	0.88**	0.70**
VC	1.27**	5.13**	4.48**	1.35**	0.81**
CV (%)	38.33	0.18	2.48	13.90	4.50

Log, DM, PH, LAI, NBP, NPS and VC means lodging, days of maturity leaf area index, numbers of branch per plant, nitrogen phosphorus sulfur and vermicompost respectively. Means in the column followed by the same letter(s) are not significantly different at 5% level of significance. LSD (*0.05*) = Least significant difference at 5% level and CV (%) = coefficient of variation in percent.

4.2. Yield and Yield Component Variables

4.2.1. Number of pods per plant

The productive potential of soybeans is ultimately determined by the number of pods per plant, which is a main yield component (Devi *et al.*, 2013). The number of pods per plant was highly significantly (*P<0.01*) influenced by blended NPS fertilizer application, vermicompost (VC) application, and their interaction (Appendix Table 2). Generally, the integrated use of organic and inorganic fertilizers influences the number of pods per plant (Mamia *et al*., 2018). The maximum number of pods per plant (140.15) was recorded from the combination of fertilizers (50 kg NPS ha^{-1} with 9 tons vermicompost ha^{-1}), while the minimum number of pods per plant (34.51) was recorded from the control (Table 4.2). Combined increases in vermicompost and blended NPS fertilizer lead to an increase in Number of pods per plant which is supported by the significant (*P< 0.05*) positive linear relationship between them. This indicates that the synergistic effect of the mineral fertilizers and mineralization of organic manures throughout the growing period did not put the plant's nutrient stress at any stage, resulting in an enhancement of the number of pods per plant (ChalaDebela *et al*., 2021). Moreover, the supply of adequate nutrients through the combined application of vermicompost and NPS might have facilitated the production of primary branches, secondary branches, and plant height, which might in turn have contributed to the production of a higher number of pods per plant. And also, the increase in the number of pods at these levels might be due to various enzymatic activities that control flowering and pod formation. These results corroborate the study of Kumar *et al*. (2014), who reported the highest number of pods per

plant (54.57) was from the combination of 20N+45P2O5 kg ha^{-1} + 5.0 tonne ha^{-1} VC + Rhizobium + PSB in chickpea. Likewise, ChalaDebela *et al*. (2021) reported that the maximum number of pods per plant was produced at the combination of the highest rates of the two fertilizers (100kg NPS ha^{-1} and 2 tons vermicompost ha^{-1}) in soybean.

4.2.2. Hundred Seeds weight

Blended NPS fertilizer, vermicompost and their interaction had a highly significant ($p<0.01$) effect on hundred Seed Weight (HSW). The heaviest weight (13.43 g) of 100 seeds was obtained after the combined application of 50 kg ha^{-1} of the blended NPS fertilizer and 9 tons ha^{-1} of vermicompost, while the lowest weight (9.77 g) of 100 seeds was recorded from the control. The heaviest weight (20 g) of hundred seeds was obtained after the combined use of 75 kg ha^{-1}NPS with 2.5 tonha^{-1}vermicompost.

This variation in seed weight may be related to the availability and balanced amount of nutrients in the soil, in fact, the efficient use of nutrients (NPS and vermicompost) during the critical plant growth period was improved by optimal dosing of fertilizer mixture NPS and vermicompost. Optimal levels of nitrogenous nutrients in the soil increase the weight of the grain in the crop and also decrease the sterility of the grain (Fageria, 2014). This study agreed with the results of Winarso *et al*. (2020) who found that with the combined application of NPK fertilizer with manure, the greater weight of hundred soybean seeds was achieved than without the application of NPK fertilizer. Combined increased in vermicompost and blended NPS fertilizer leads to increase in Hundred Seeds weight which is supported by the significant ($P< 0.05$) positive linear relationship between them.

4.2.3. Aboveground dry biomass yield

Aboveground dry biomass was highly significantly ($p< 0.01$) influenced by the main effects of blended NPS fertilizer and vermicompost rates and by their interaction effects (Appendix Table 2). The maximum aboveground dry biomass (6.70qt ha^{-1}) was obtained from the application of 50 kg NPS ha^{-1} combined with9 t vermicompostha^{-1}, followed by 12 tons of vermicompost ha^{-1} while the lowest aboveground biomass (1.92 t ha^{-1}) was obtained from the control (Table 4.2). This is further demonstrated by the significantly ($P<0.05$) positive linear

relationship between the integrated application of fertilizers and the dry biomass yield (Figure 4.1). The increase in aboveground dry biomass obtained might be due to optimum nutrient availability, which increases plant growth and development. Another possible reason for the increase in aboveground biomass due to NPS and VC might be that nitrogen, sulphur, and phosphorus are essential in most metabolic processes like energy generation, nucleic acid synthesis, photosynthesis, respiration, glycolysis, membrane synthesis and integrity, enzymatic activation or inactivation, redox reactions, signalling, and carbohydrate metabolism, leading to the enhancement of dry biomass yield that happens above the ground (Chala Debela *et al*., 2021). Moreover, the increase in aboveground biomass yield of soybean at a high rate of vermicompost and maximum rate of NPS may be due to the fact that P and S nutrients found in applied fertilizers were playing a role in the metabolism, chlorophyll formation, and photosynthesis activities of the plant, which in turn increased biological yield (Fageria, 2014). In agreement with this result, Begum *et al*. (2015) reported that, significantly higher stover yield (2.04 t ha^{-1}) was produced by the integration of 75% RDF with vermicompost at the rate of 1 t ha^{-1} and PSB and the lowest (0.97 t ha^{-1}) from control.

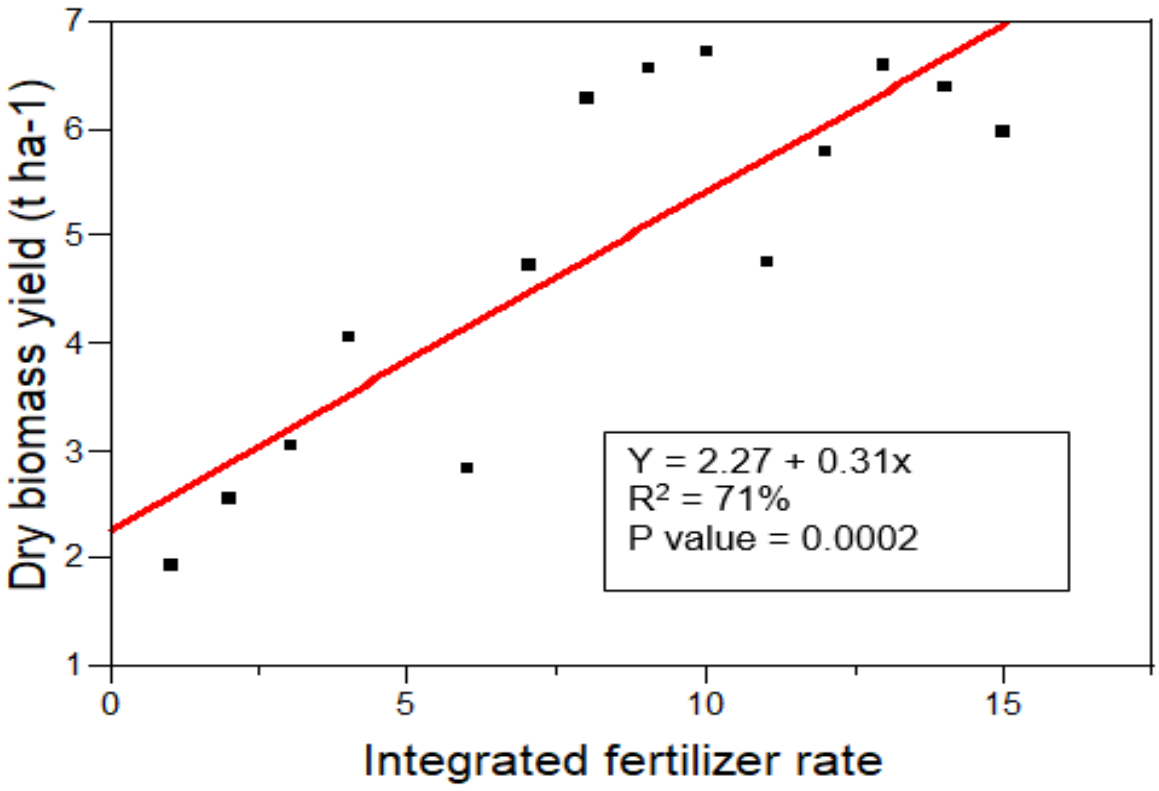

Figure 4.1Simple linear regression between integrated fertilizer rate (X) and dry biomass yield of soybean (Y).

4.2.4. Seed yield

The analysis of variance showed that the main effects of blended NPS, vermicompost (VC), and their interaction highly significantly ($p<0.01$) affected soybean seed yield (SY) (Table 4.2). Combined increases in vermicompost and blended NPS fertilizer lead to an increase in seed yield, which is supported by the significant ($P< 0.05$) positive linear relationship between them. Application of 50 kg NPS ha^{-1} combined with 6 tons vermicompost ha^{-1} resulted in the highest seed yield (3.08 t ha^{-1}), which is statistically not different from the application of 50 kg NPS ha^{-1} combined with 9 tons vermicompost ha^{-1} (3.06 t ha^{-1}). On the other hand, the lowest seed yield (0.85 t ha^{-1}) was recorded from the control treatment (Table 4.2). The highest seed yield in the former soil amendment practices might be attributable to the availability of macro- and micro-nutrients, the occurrence of different beneficial microorganisms, and the presence of growth-promoting substances in vermicompost (Chala Debela *et al*., 2021). Moreover, maximum seed yield might also be due to the increased agronomic attributes of soybean. This is clearly confirmed by the significantly positive linear relationship between grain yield and all agronomic attributes of soybean (Table 4.5 and Figure 4.2a). In conformity with this result, Joshi et al. (2015) reported that the combined use of vermicompost, chemical fertilizers, and bio-fertilizers led to higher yields on different legume cropping systems. Likewise, Fayera Asefa and Alemayehu Wagari (2021) reported that the combination of 75 kg NPS ha^{-1}, 2.5 tons of vermicompost, and farmyard manure produced a significantly higher grain yield of soybean (2536.50 kg ha^{-1}) than the other treatments. On the other hand, increased seed yield at a higher rate of vermicompost and NPS combined might be due to increased availability of major nutrients such as N, P, and S to the plant, which enhanced early root growth and cell multiplication, leading to more absorption of other nutrients from deeper layers of soil, ultimately resulting in increased grain yield. Polynomial regression analysis showed that further increased in combined fertilizer resulted in reduction of seed yield (Figure 4.2). Chala Debela *et al*. (2021) reported that the application of nutrients through 75% recommended fertilizer (20 N: 40 P2O5: 20 K2O kg ha^{-1}) + 2.5 t ha^{-1} vermicompost + Rhizobium) gave a significant improvement in seed yield (1.234 t/ha) in green gram. Likewise, the application of NPS combined with vermicompost supplied S

nutrients to soybean plants, which might have increased the availability of nutrients to soybean plants due to an improved nutritional environment, which in turn favourably influenced the energy transformation activation of enzymes, chlorophyll synthesis, and increased carbohydrate metabolism (Zerihun Getachew *et al*., 2017). Many researchers reported that the application of vermicompost, because it supplies optimum nourishment conditions, improves growth, yield, and yield components in crops (Mestawut Adane *et al*., 2020; Azarpoor *et al*., 2012; Moraditochaee *et al*., 2011).

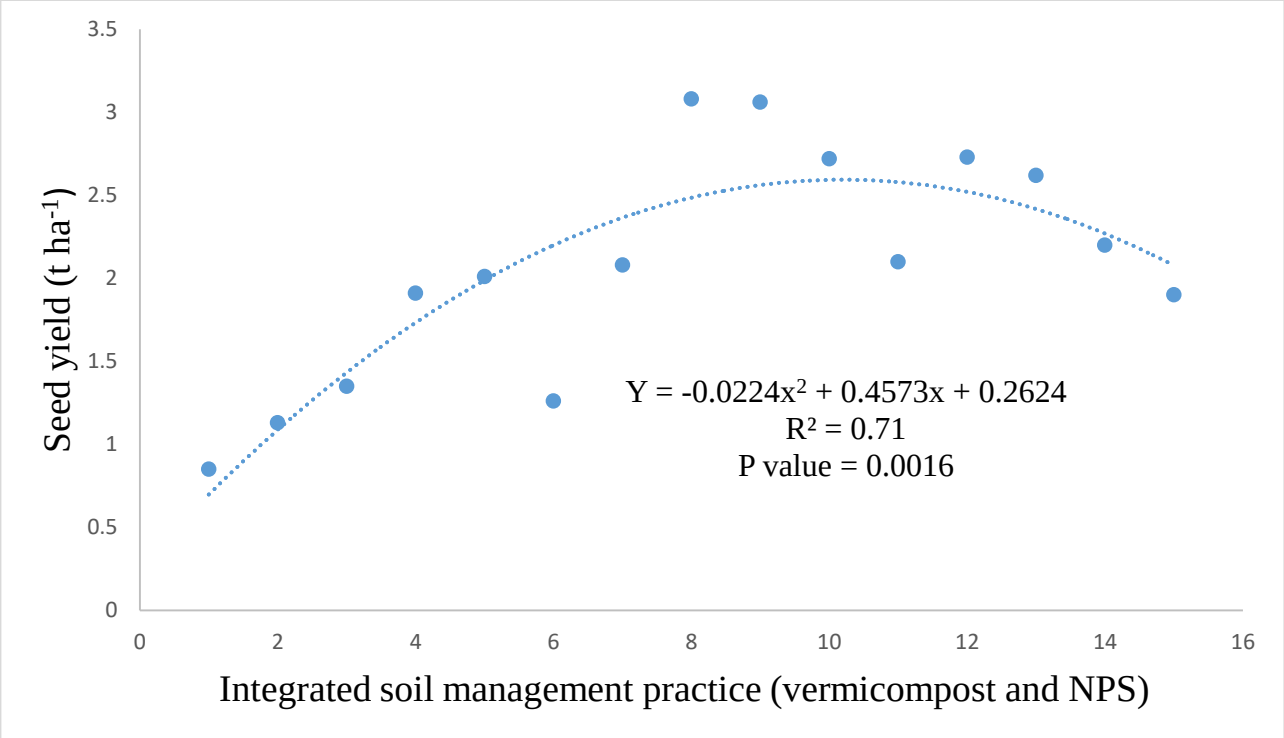

Figure 4.2: Polynomial regression showing the response of (a) grain yield to integrated soil management practice (vermicompost and NPS).

Each grain yield values are the means of the three replications and for integrated siol management practice (NPS and Vermicompost) 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, means (0, 0), (0, 3), (0, 6), (0, 9), (0, 12), (50, 0), (50, 3), (50, 6), (50, 9), (50, 12), (100, 0), (100, 3), (100, 6) (100, 9), 100, 12) respectively.

Yield comparison

The average productivity of soybean in the district is very low (1.5 t ha-1) and which is far below from the national average productivity of 2.3 t ha-1 (CSA, 2019/20). This low productivity occurred due to limited utilization of improved soybean production technologies (PARC, 2010).

The combined application of 100 NPS ha-1 + 2 tons ha-1 vermicompost and Seed inoculation were found to be superior and can be used for improvement of soybean productivity (Chala debela *et al*., 2020). However, the previous studies indicate that there is no specific recommendation whether national or regional level, different authors recommended different rate of integrated fertilizers.

4.2.5. Harvest index (%)

The harvest index is very useful in measuring nutrient partitioning in crop plants, which provides an indication of how efficiently the plant utilizes acquired nutrients for grain production. The analysis of variance revealed that the main effects of blended NPS fertilizer, vermicompost (VC) and their interaction significantly ($p< 0.01$) influenced the harvest index of soybean (Appendix Table 2).

Application of 50kg NPS $ha^{-1}$and 6 tons vermicompost ha^{-1} resulted in the highest harvest index (49.18%), which is statistically not different from the application of 100kg NPS ha^{-1} and 3 tons vermicompost ha^{-1}(47.79%). On the other hand, the lowest harvest index value (31.99%) was recorded from the application of 100kg NPS ha^{-1} and 12 tons vermicompost ha^{-1} (Figure 2). This might be due to the produce an optimum application of mainly N and S nutrients from the blended fertilizer and vermicompost that enhanced the partitioning of assimilates from different parts of plants to economical yield (grain yield), which leads to having high crop harvest index. The present result is in line with the research of Khaim*et al*. (2013), who reported a significant influence on harvest index. The highest harvest index was observed in the RDCF100% (37.09) treatment, and the lowest value was observed in the control (34.24). Mona *et al*. (2014) showed that the highest harvest index was observed from the application of 5-tone vermicompost, and the non-application of vermicompost had the lowest harvest index. Likewise, Getachew Bekele *et al*. (2019) reported the highest seed harvest index (35.9%) was obtained from a combined application of 46 kg N and 46 kg P2O5,

with 2.5 t VC ha^{-1}, which was followed by plots that received a combination of 23 kg N and 46 kg P2O5, with 2.5 t VC ha^{-1} at Babile, Eastern Ethiopia.

Table 4. 2. The interaction effects of vermicompost and NPS rates on yield and yield components of soybean the 2022 main cropping season ,in Pawe district

Source of variations		NPP	NSP	DBY	SY	HI	HSW
NPS	VC						
0	0	34.51i	2.50a	1.92g	0.85i	44.74abc	9.77g
	3	54.35f	2.50a	2.54f	1.13h	46.08abc	10.93efg
	6	67.11g	2.52a	3.04f	1.35g	44.67abc	11.42def
	9	68.28g	2.52a	4.03e	1.91ef	47.49ab	11.90b-e
	12	94.91f	2.52a	4.54de	2.01def	44.21abc	12.53a-d
50	0	53.88h	2.49a	2.82f	1.26gh	45.02abc	10.93efg
	3	74.04g	2.51a	4.72d	2.08cde	44.1abc	12.29a-d
	6	133.23ab	2.51a	6.27abc	3.08a	49.18a	13.07ab
	9	140.15a	2.50a	6.54ab	3.06a	46.81ab	13.43a
	12	140.15a	2.48a	6.71a	2.72b	40.58bcd	12.75abc
100	0	74.32g	2.50a	4.73d	2.10cd	44.38abc	12.67abc
	3	122.22cd	2.51a	5.78c	2.73b	47.79a	13.23a
	6	118.22d	2.52a	6.58a	2.62b	39.71cd	12.48a-d
	9	104.89e	2.52a	6.36abc	2.199c	34.50de	11.73c-f
	12	89.82f	2.50a	5.94bc	1.90f	31.99e	10.56f
LSD (5%)		8.38**	0.05ns	0.61**	0.18**	5.20**	1.23**
±SE		2.87	0.01	0.22	0.06	2.34	0.36
NPS		20.09**	0.02ns	877.51**	403.19*	3.92**	0.81**
VC		25.84**	0.02ns	1337.9**	595.13**	5.30**	1.08**
CV (%)		5.55	1.26	7.52	5.36	6.94	6.18

SE±,NPP, NSP, HSW,DBY, HI andGY mean Standarderror; number of pod plant; number of seed per pod; hundred seed weight; dry biomass yield; grain yield; harvest index respectively.Means in the column followed by the same letter(s) are not significantly different at 5% level of significance.

4.3. Seed Quality Variables

4.3.1. Vigor index I

Vigor index I was highly significantly *(p< 0.01)* influenced by blended NPS fertilizer and vermicompost rates and their interactions (Appendix Table 3). The highest vigor index I (3891.3) was registered on the application of 50 kg NPS ha^{-1} and 9 tons vermicompost ha^{-1} which is statistically not different from the application of 50 kg NPS ha^{-1} and 6 tons vermicompost ha^{-1} (3813.5). The least vigor index (1710.7) was recorded from the control (Table 3). The assumption for the importance of this index is that vigorous seed produces strong and healthy/uniform seedlings having better field establishment and exhibiting relatively greater longevity (Chaluma Tujuba, 2020). Sumathi *et al*. (2013) reported that the vigor index of any seed is the sum of those properties of the seed that determine the potential level of activity and help it to withstand a wide range of field conditions. Seed vigor indicates seed properties, which determine the potential for rapid, uniform emergence and development into normal seedlings under a wide range of field conditions (TeKrony&Egli, 1991). The main effect of NP fertilizers, vermicompost, and their interaction showed a highly significant (*P<0.01*) influence on seed vigor index I and II; the highest seedling vigor index I (1022.2) was obtained from the interaction of NP fertilizer 75 % recommended fertilizer) with VC 5.0 t ha^{-1} (KirosAsgele*et al*., 2018). Similarly, SAHA (2021) reported that the vigor index showed highly significant differences at different levels of integrated nutrient management. The highest vigor index of 148.20 was recorded in 35 T13 (Biochar 10 t ha^{-1}+ 50% recommended dose of fertilizer) treatments, compared to the germination index of 143.80 recorded in T14 (Biochar 10 t ha^{-1} + 75% recommended dose of fertilizer) treatments.

4.3.2. Speed of germination

The highest speed of germination (4.81) was registered on the application of 50kg NPS ha^{-1} and 6 tons vermicompost ha^{-1}. On the other hand, the lowest speed of germination (3.77) was recorded from control, followed by the application of 100kg NPS ha^{-1} and 12 tons vermicompost ha^{-1} (Table 4.3). The speed of germination indicates the rate at which the seeds are germinating rapidly and seedlings can emerge and escape adverse field conditions(Bitwoded Derebe *et al.*, 2022). Seeds that have a high germination speed were found vigorous in the field and could withstand harsh conditions. A similar result was reported by SAHA (2021), where the longest mean germination time of 5.78 days was observed from Vermicompost 5 t ha^{-1} + 75% of the recommended dose of fertilizer. The

shortest mean germination time of 4.88 days was found in the Cow dung 5 t ha^{-1} +75% recommended dose fertilizer. The main effect of NP fertilizers and vermicompost, with their interaction, had a highly significant (*P<0.01*) influence on the speed of germination. The fastest speed of germination (33.63%) was recorded from plots that received an application of VC at 5.0 t ha^{-1} without NP fertilizers, followed by 2.5 t ha^{-1} VC with no NP fertilizers and no VC and no NP fertilized plots (control), and they differed significantly among each other (Kiros Asgele *et al.*, 2018).

4.3.3. Protein content

Seed protein content is directly influenced by fertilizer and is an important parameter that governs the quality of soybeans (Khaim *et al*., 2013). The main effects of vermicompost, blended NPS fertilizer rates, and their interaction significantly ($p < 0.01$) affected the protein content of soybean seed (Table 4.3). Application of 12 t ha^{-1} and 50 kg ha^{-1} blended NPS fertilizer rates recorded the highest (41.95%) protein concentration, while the control gave the lowest protein content (38.27%). Simple linear regression also showed that protein content has a direct relationship with seed yield (Figure 4.2b). The optimum application of fertilizer with balanced plant nutrients increases the protein content of soybean seed, but an increment in fertilizer rates diminishes the protein concentrations of the grain. These plant nutrients increase the protein content of soybeans through the synthesis of certain amino acids (cysteine and methionine) (Asmachew Agegnehu *et al*., 2021). This result coincides with the findings of Bonde and Gawande (2017), who showed that application of 100% NP and 75% NP + 4 t FYM + 25kg S ha^{-1} gave significantly superior results to other treatments in respect of protein content in soybean seeds, while the minimum protein content was noted under control, which may be attributed to the lower seed yield of soybean. This may be due to the accumulation of more nitrogen with these treatments, ultimately showing a higher protein percent (Singh, 2011).

Table 4. 3 The interaction effects of vermicompost and NPS fertilizer rates on seed quality variables of soybean at pawe district the 2022 main cropping season, in Pawe district

Source of variations		**StG**	**VI1**	**SpG**	**MC**	**Pcon**
NPS	VC					

0	0	99.67ab	1710.70h	3.77h	7.4a	38.27j
	3	99.33b	2008.00gh	3.97gh	7.37ab	39.47fg
	6	100a	2226.70fg	4.2d-g	7.37ab	39.98d
	9	99.67ab	2618.00ef	4.19d-g	7.37ab	40.48c
	12	100a	2839.30de	4.39b-e	7.4a	41.18b
50	0	100a	2278.70fg	4.05fgh	7.37ab	39.54efg
	3	99.67ab	3226.30cd	4.48bcd	7.4a	39.38gh
	6	100a	3813.50a	4.81a	7.4a	41.05b
	9	100a	3891.30a	4.66ab	7.37ab	41.09b
	12	100a	3718.00ab	4.53abc	7.4a	41.95a
100	0	100a	3215.30cd	4.36cde	7.4a	40.10cd
	3	99.67ab	3341.00bc	4.43bcd	7.33b	39.83def
	6	99.67ab	3318.00bc	4.29c-f	7.4a	39.92de
	9	99.67ab	2850.00de	4.11efg	7.4a	39.00hi
	12	100a	2506.70ef	3.79h	7.4a	38.86i
LSD (5%)		0.66ns	434.71**	0.30**	0.06ns	0.39**
±SE		0.23	153.96	0.10	0.02	0.14
NPS		0.29ns	394.54**	0.21**	0.02ns	0.69**
VC		0.36ns	653*	0.30**	0.03ns	0.88**
CV (%)		0.40	8.98	4.20	0.49	0.59

SE±, StG, VI1, SpG, MC and Pcon are Standard error, standard germination, vigor index I,speed of germination, moisture content and protein content, respectively.Means in the column followed by the same letter(s) are not significantly different at 5% level of significance.

Table 4.4Simple linear regression between integrated fertilizerrate (X) and agronomic attributes ofsoybean (Y).

Growth and yield component	Regression parameters				R^2 (%)
	Intercept		Regression coefficient		
	Value (α)	Pvalue	Value (ß)	Pvalue	
LAI	4.31	<.0001	0.32	<.0001	79.82
Log	-1.03	0.1906	0.23	0.0161	36.99
PH	62.19	<.0001	1.28	0.0013	56.40
NPP	53.09	0.0034	4.78	0.0118	39.74
NBP	5.46	<.0001	0.13	0.0292	31.58
HI	48.79	<.0001	-0.67	0.0135	38.56
VI1	2228.55	<.0001	84.44	0.0297	31.44
SYld	1.28	0.001	0.1	0.0116	39.87

LAI, Log, PH, NPP, NBP, HI, VI1 and SYld leaf area index, lodging, plant height, number of pod per plant, number of branch per plant, harvesting index, and seed yield arerespectively

In the simple liner regression analysis, yield components were taken as a response variable (Y) and integratedfertilizer rates (X) were taken as an explanatory variable. R^2 is Coefficient of determination.

Table 4.5Simple linear regression between seed yield (Y) and other Agronomic attributes (X) as affected by vermicompost and blended NPS fertilizer application rates.

Agronomic attributes	Regression parameters				R^2 (%)
	Intercept		Regression coefficient		
	Value (α)	Pvalue	Value (ß)	Pvalue	
MD	-8.58	0.0105	0.09	0.0026	51.43
LAI	-0.36	0.4725	0.35	0.0002	67.00
PH	-1.77	0.2603	0.05	0.0236	33.58
NoBPP	-2.04		0.63	<0.0001	87.23
HSW	-4.78	0.0003	0.57	<.0001	78.52
ABY	0.19	0.4437	0.39	<.0001	84.57
VI1	0.84	0.0016	0.001	<.0001	93.84
SpG	-6.09	0.0018	1.91	0.0002	68.02
Pcon	-15.58	0.0217	0.44	0.0112	40.15

In the simple liner regression analysis, seed yield was taken as a response variable (Y) and other agronomic attributes (X) were taken as explanatory variables. R^2 is Coefficient of determination.

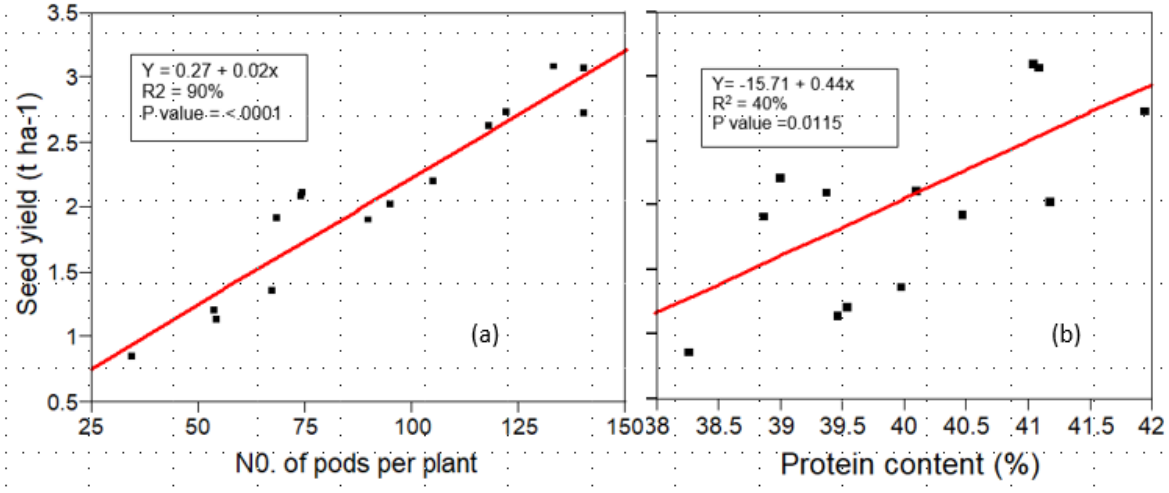

Figure 4.3 Simple linear regression between seed yield with (a) Number of pods per plat ad (b) Protein content as affected by vermicompost and blended NPS fertilizer application rates.

4.4. Correlation Analysis of Growth and Yield Variables

A correlation analysis between soybean crop growth and yield-related parameters is indicated in Table 4.4. Except for lodging and seed per pod, the seed yield was highly significant and strongly correlated in a positive sense with plant height (r = 0.91**), leaf area index (r = 0.75**), pod per plant (r = 0.94**), branch per pod (r = 0.90**), protein content (62**), and dry biomass yield (r = 0.90**) as affected by the combined use of NPS fertilizer and vermicompost rates (Tale 4.6).

Generally, except for lodging and seed per pod the seed yield was significantly and positively correlated to plant height (r = 0.91**), leaf area index (r = 0.75**), pod per plant (r = 0.94**), branch per pod (r = 0.90**), and dry biomass yield (r = 0.90**). Here, a positive increase in such characters will enhance the increase in seed yield. Lodging (r = -0.70**), plant height (r = -0.47**), and dry biomass yield (0.36**) were significantly and negatively correlated. In addition, pod per plant was also negatively correlated with harvesting index, but seed per plant (r = 0.01ns) and grain yield (r = 0.05ns) were positively correlated with harvesting index. The hundred seed weight was the main character, which highly positively influenced the seed yield (r = 0.77**), protein content (65**), branch per plant (r = 0.75**), and pod per plant (r = 0.69**). In addition to this, biomass yield was highly significant and related in a positive sense to leaf area index (0.83**), lodging (0.42**), plant height (0.74**), pod per plant (0.90**), and branch per pod (0.83**).

Table 4. 6.Relationships of among various growth, yield component and yield variables of soybean

	LAI	Log	PH	PPP	SPP	BPP	DBY	SYld	HI	HSW	Pcon
LAI	1										
Log	0.49**	1									
PH	0.79**	0.60**	1								
PPP	0.71**	0.21ns	0.60**	1							
SPP	0.25ns	-0.03ns	0.15ns	0.05ns	1						
BPP	0.70**	0.05ns	0.61**	0.90**	0.12ns	1					
DBY	0.83**	0.42**	0.74**	0.90**	0.08ns	0.83**	1				
Yld	0.75**	0.10ns	0.57**	0.94**	0.10ns	0.90**	0.90**	1			
HI	-0.26ns	-0.70**	-0.47**	-0.06ns	0.01ns	0.03ns	-0.36*	0.05ns	1		
HSW	0.53**	-0.20ns	0.34*	0.69**	0.14ns	0.75**	0.62**	0.77**	0.24ns	1	
Pcon	0.32*	-0.15ns	0.32*	0.61**	0.03ns	0.62**	0.43**	0.62**	0.30*	0.65**	1

LAI=Leaf area index, DM= Days of maturity, Log= Lodging, PH=Plant height, PPP = Pod per plant, SPP= Seed per plant, BPP= Branch per plant, ADBY= Above ground dry biomass yield, SYld= seed yield, HI= Harvesting index, HSW= Hundred seed weight, StG= Standard germination, VI1= Vigor index one, SG= Speed of germination, MC= Moisture content, * = Correlation is significant at the 0.05 level, and ** = Correlation is significant at the 0.01 level.

4.5 Partial Budget Analysis

The results of the partial budget analyses revealed that the maximum net benefit (78,118.85 ETB ha^{-1}) with an acceptable marginal rate of return (MRR) (1707.25%) was recorded in the treatment that received 50 kg ha^{-1} blended NPS fertilizer combined with 6 t VC ha^{-1} (Table 4.5). This treatment generated 61,016.42 ETB ha^{-1}more compared to the control treatment. On the other hand, the next maximum net benefit (72,056.73 ETB ha^{-1}) with an acceptable MRR (1144.13%) was recorded in the treatment that received 50 kg ha^{-1} blended NPS fertilizer combined with 9 t VC ha^{-1} (Table 5). Hence, the money generated from the application of 50 kg ha^{-1}blended NPS fertilizer combined with 6 t of VC $ha^{-1}$was 6,062.12 ETB ha^{-1} more than the money generated from the application of 50 kg ha^{-1} blended NPS fertilizer combined with 9 t VC ha^{-1}. Therefore, depending on a total variable cost, net benefit analysis, dominance analysis, and marginal rate of return, the best economically profitable combination of NPS rate and VC was 50 kg NPS ha^{-1} with 6 t VC $ha^{-1.}$ This result is in agreement with that of Chala Debela.*et al.* (2021), who reported that the combined application of 100 kg NPS ha^{-1} + 2 t VC $ha^{-1}$and seed inoculated with the Rhizobium strain (TAL-379) produced the highest net benefit of 23537.2 ETB $ha^{-1}$with a marginal rate return of 339.4%.

Table 4. 7Results of the partial budget analysis for combined use of blended NPS fertilizer and vermicompost in soybean

Treatments		Gross benefit (ETB ha^{-1})	TVC (ETB $ha^{-1)}$	NB (ETB ha^{-1})	MRR (%)
NPS Fertilizer (kg ha^{-1})	Vermicompost (t ha^{-1})				
FR	VC				
0	0	30702.43	13600	17102.43	0.00
50	0	45410.39	16900	28510.39	345.70
100	0	75504.94	19400	56104.94	1103.78
0	3	40754.62	20200	20554.62	D
50	3	75194.71	23500	51694.71	943.64
100	3	96843.47	26000	70843.47	765.95
0	6	48579.74	26800	21779.74	D
50	6	108218.85	30100	78118.85	1707.25

100	6	97072.95	32600	64472.95	D
0	9	67700.6	33400	34300.6	D
50	9	108756.73	36700	72056.73	1144.13
100	9	84667.43	39200	45467.43	D
0	12	72341.73	40000	32341.73	D
50	12	100192.5	43300	56892.5	743.96
100	12	74996.21	45800	29196.21	D

Where, NPSZ cost = 50birr kg^{-1}, Vermicompost cost = 2 birr kg^{-1} fertilizer application cost = 800 birr ha^{-1}, vermicompost application cost = 200 birr ton^{-1}, market price of soybean grain 30 birr kg^{-1}, market price of soybean Stover = 4 birr kg^{-1}, TVC = Total variable cost, NB = Net benefit MRR=Marginal Rate of Return (%), ETB = Ethiopian Birr, D = Dominated.

CHAPTER 5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

The result of the present study revealed that the combination effect of blended fertilizer with vermicompost rates significantly affected most of the growth, yield, and quality-related traits of soybean. The combination of 50 kg NPS ha^{-1} with 6 tonnes ha^{-1} vermicompost application gave the highest grain yield, which resulted from the maximum speed of germination (4.8), number of pods per plant (140.15), number of branches per plant (7.77), and hundred seed weight, while the lowest agronomic attributes were obtained from the control treatment. Moreover, combined use of 50 kg NPS ha^{-1} and 6 tonne ha^{-1} vermicompost rate gave the highest net benefit and MRR. In In conclusion, plating soybean with integrated applications of 50 kg NPS ha^{-1} and 6 tonne ha^{-1} vermicompost boosts the productivity and profitability of soybean in a hot, humid agro-ecological zone of north-western Ethiopia.

5.2. Recommendations

Plating soybean with integrated applications of 50 kg NPS ha^{-1} and 6 tonne ha^{-1} vermicompost boosts the productivity and profitability of soybean and can be recommended in a hot, humid agro-ecological zone of north-western Ethiopia and similar agro-ecological areas. However, further comprehensive research on integrated soil fertility management strategies to improve the nitrogen fixing ability of various soybean varieties needs to be done over numerous sites and years.

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LIST OF APPENDICES

Appendix Table.1Treatment combination and description

No	Treatment	Treatment Descriptions	Remark
	T1	0 kg NPS ha^{-1}without vermicompost ha^{-1}	With 3 Replication
	T2	0 kg NPS $ha^{-1}$with 3t vermicompost ha^{-1}	
	T3	0 kg NPS $ha^{-1}$with 6tvermicompost ha^{-1}	
	T4	0 kg NPS $ha^{-1}$with 9t vermicompost ha^{-1}	
	T5	0 kg NPS ha^{-1} with 12t vermicompost ha^{-1}	
	T6	50 kg NPS ha-1 without vermicompost ha^{-1}	
	T7	50 kg NPS ha^{-1} with 3t vermicompost ha^{-1}	
	T8	50 kg NPS ha^{-1} with 6tvermicompost ha^{-1}	
	T9	50 kg NPS $ha^{-1}$with 9t vermicompost ha^{-1}	
	T10	50 kg NPS ha^{-1} with 12t vermicompost ha^{-1}	
	T11	100 kg NPS ha^{-1} without vermicompost ha^{-1}	
	T12	100 kg NPS ha^{-1} with 3t vermicompost ha^{-1}	
	T13	100 kg NPS $ha^{-1}$with 6t vermicompost ha^{-1}	
	T14	100 kg NPS ha^{-1} with 9t vermicompost ha^{-1}	
	T15	100 kg NPS ha^{-1} with 12t vermicompost ha^{-1}	

BL I

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
T2	T11	T7	T15	T1	T5	T13	T10	T6	T12	T9	T3	T8	T14	T4

BL II

P30	P29	P28	P27	P26	P25	P24	P23	P22	P21	P20	P19	P18	P17	P16
T1	T14	T5	T13	T10	T6	T9	T12	T3	T2	T7	T15	T11	T4	T8

BL III

P31	P32	P33	P34	P35	P36	P37	P38	P39	P40	P41	P42	P43	P44	P45

T15	**T4**	**T9**	**T10**	**T6**	**T12**	**T1**	**T3**	**T7**	**T8**	**T11**	**T5**	**T2**	**T13**	**T14**

Note: **P = plot**; **T = treatment**

Appendix Figure 1 Field lay out and randomization

Appendix Table 2. Mean square values of phenology and growth variables as affected by combined applicationof NPS fertilizer and Vermicompost rates.

Source of variation	DF	Log	DM	PH	LAI	BPP
Replication	2	0.08ns	0.02ns	0.90ns	9.24**	0.03ns
Inorganic fertilizer	2	11.62**	126.82**	382.59**	31.17**	5.33**
Vermicompost	4	12.55**	40.70**	316.21**	10.62**	4.76**
INFR*VC	14	8.22**	90.04**	173.13*	7.85**	3.16**
Error	30	0.08	0.04	3.23	0.91	0.08

Where; DF = degrees of freedom; FD=Days to 50% flowering, DM= Days to 90% maturity; PH = plant height; LAI= Leaf area index; BPP = Branch per plant; ns, * and ** implies non-significant, significant and highly significance differences, respectively.

Appendix Table 3.Mean square values of yield and yield component variables as affected by combined application of NPS fertilizer and Vermicompost rates.

Source of variation	DF	NPPP	NSPP	DBY	GY	HI	HSW
Replication	2	33.80ns	0.0067**	1.63ns	1.53ns	29.01ns	2.91**
Inorganic fertilizer	2	8060.34**	0.0008ns	3033.94**	433.47**	157.89**	14.61**
Vermicompost	4	4475.72**	0.0007ns	1063.58**	145.87**	67.33**	6.08**
INFR*VC	14	3219.96**	0.0004ns	809.28**	144.80**	70.15**	3.44**
Error	30	25.27	0.0009	13.22	1.22	17.30	0.55

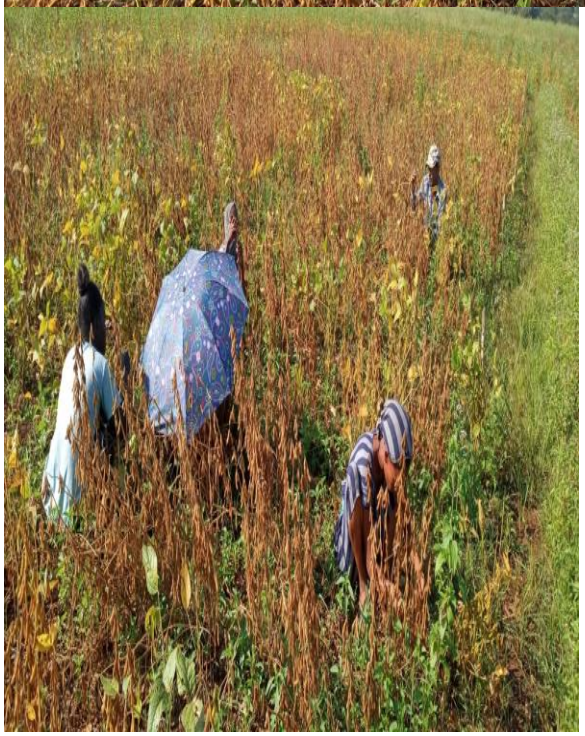
Where; DF = degrees of freedom; NPPP= Number of pod per plant, NSPP= Number of seed per pod; DBM = Dry biomass; GY= Grain yield; HI = Harvesting index;HSW = hundred seed weight; ns, * and ** implies non-significant, significant and highly significance differences, respectively.

Appendix Table 4. Mean square values of seed quality variables as affected by combined application of NPS fertilizer and Vermicompost rates:

Source of variation	DF	StG	VI1	SpG	MC	Pcon
Replication	2	0.02ns	23866.55ns	0.05ns	0.00ns	0.01ns
Inorganic fertilizer	2	0.15ns	4806236.47**	0.66**	0.00ns	4.14**
Vermicompost	4	0.25ns	812790.96**	0.17**	0.00ns	2.83**
INFR*VC	14	0.13ns	1360970**	0.27**	0.00ns	2.99**
Error	30	4.66	67960.45	0.03	0.00	0.05

Appendix Figure 2.Picture taken during field preparation and seedling stage at paweagriculture research center (Photo taken by the author, 2023)

Appendix Figure 3Picture taken during vegetative stage at pawe agriculture research center (Photo taken by the author, 2023)



Appendix Figure 4Picture taken during maturity stage at paweagriculture research center (Photo taken by the author, 2023)

Appendix Figure 5Picture taken during drying and seed weighting at pawe agriculture research center (Photo taken by the author, 2023)

Appendix Figure 6Picture taken during laboratory work at pawe agriculture research center (Photo taken by the author, 2023)

BIOGRAPHY

The author, Girmay Ketema, was born on 13 September 1986 in Mehal-meda town, North-shewa Zone, Amhara Regional State, Ethiopia. He followed his primary education from 1992 to 1997 at k.2Village 12 Elementary School, his junior education from 1998 to 1999 at k.2 village 14junior School and his high school education from 2000 to 2003 at pawe Senior Secondary School. He joined Assosa TEVET College in 2004, and graduated with diploma in plant science in 2006. Upon graduation, he was employed in pawe district agricultural office from 2007 to 2009 and from 2010 to 2015 in Ethiopian Institute of Agricultural Research, Pawe Agricultural Research Center serve as technical assistance and technology multiplication coordinator respectively. In 2017, he joined Bahir Dar University, college of agriculture and environmental science completed his study with Bachelor of Science in plant science in 18 July 2019he back again Pawe Agricultural Research Center and serve as assistant II researcher. In 2022, he joined Bahir Dar University, college of agriculture and environmental science, school of post graduate programs to pursue his M.Sc. degree in agronomy.