EVALUATION OF LIMA BEAN (*Phaseolus Lunatus* L.) ACCESSIONS FOR AGRONOMIC PERFORMANCE AND MINERAL COMPOSITION AT TEPPI, SOUTHWEST ETHIOPIA

M.Sc. THESIS

BY

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Evaluation of Lima Bean (*Phaseolus Lunatus* L.) Accessions for Agronomic Performance and Nutritional Composition at Teppi, Southwest Ethiopia

By

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DEDICATION

This thesis manuscript is dedicated to my sister Yewonihareg Chane. Serkalem Chane. My beloved wife Seble Fekede, my son Sofenias Asrade and daughter Amen Asrade for their patience, support, prayer, and outgoing assistance.

STATEMENT OF THE AUTHOR

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BIOGRAPHICAL SKETCH

The author was born on Aug 22, 1983, to his father Chane Belachew, and his mother Worke Erena at Teppi, Sheka Zone of South West Ethiopia people Regional State. He attended his education at Teppi elementary and Senior Secondary School. In 2005, he joined Wolaita Soddo Agricultural Technical Vocational Education and Training College and graduated with a Diploma in plant science on Aug 2, 2008. After graduation, he was employed by the Ethiopian Institute of Agricultural Research Teppi agricultural research center in Technical assistance in soil and water process and served for 7 years. Then he joined Mizan Teppi University and graduated with a BSc degree in Plant Science on July 18, 2019. After graduation, he was assigned to work as a junior researcher in the technology multiplication and seed research process where he served in different positions including farm manager up to Oct.2021. In November 2021, He then joined the School of Graduate Studies program of Jimma University at the College of Agriculture and Veterinary Medicine to pursue a study leading to the degree of Master of Science in Agronomy.

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LIST OF ACRONYMS

Acc.	Accession
ALS	Angular Leaf Spot
ANOVA	Analysis of Variance
ANT	Anthracnose
AOAC	Association of Official Analytical Chemists
CBB	Common Bacterial Blight
CV	Coefficient of variance
EFN	Extra Floral Nectar
FAO	Food and Agriculture Organization
HCN	Hydrogen Cyanide
IBPGR	International Board for Plant Genetic Resources
ICP_OES	Inductively Coupled Plasma Optical Emission Spectroscopy
LAI	Leaf Area Index
MI	Meso-American One
MARC	Melkasa Agricultural Research Center
MASL	Meters above sea level
MNUGL	Miscellaneous Neglected Underutilized Grain Legumes
NPS	Nitrogen, Phosphorus and Sulphur
PG	Phaeoisariopsis griseola
PGIPS	Polygalacturonase-Inhibiting Protein Sequence
RCBD	Randomized Complete Block Design
RF	Rainfall
SW	Seed Weight
TARC	Teppi Agricultural Research Center
VOC	Volatile Organic Compounds

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ABSTRACT

Lima bean is one of the nutritionally important grain legumes cultivated in the humid areas of southwest Ethiopia. However, the crop is neglected in research and development and information is lacking on the extent and nature of agronomic performance and mineral composition of the locally available lima bean accessions. This study was conducted with the objectives of assessing the performance of locally collected accessions based on agro-morphological and mineral composition under Teppi ecological conditions. The study was conducted during the 2022/2023 cropping season. A total of nine (9) lima bean accessions, two of which were standard checks (Kibat and Wako), were investigated in a randomized complete block design (RCBD) with three replications. Data on grain yield and its components as well as grain mineral composition were recorded and subjected to analysis of variance (ANOVA). ANOVA showed that accessions had significant differences for most of the agronomic and disease incidence traits. Significant differences among accessions for stand count at emergence was observed-where accession-006 had the highest (140 plants per plot) and Wako had the lowest (36.6 plants per plot). Days to 50% flowering were the minimum for Kibat and Wako (41.33 days), while accession-004, accession-009 and accession-008 were late in flowering. Days to 90% maturity was early for Kibat and Wako (94 days) while the longest days to maturity was recorded for accession-004 (213 days) and accession-008 (213 days). Number of pods per plant was statistically significant and the highest pod number was recorded from accession-002 (19.3) and the least pod number was from accession-004 (4.6). The highest number of branches per plant was recorded on accession-002 (4.73) while the lowest was recorded on accession-008 (2.5). The highest 100 seed weight was recorded on accession-004 (143.7g) followed by Wako(C-2) (128.5 g) and accession-009 (123.45 g) while the least 100 seed weight was recorded on accession-002 (41.46 g). The highest total yield (t/ha) was recorded on accession-002 (1650 kg ha^{-1}) while the least total yield was obtained from Kibat (443.8 kg ha^{-1}). The highest mean incidence of Anthracnose was observed on Kibat and Wako (70.3%) and bean angular leaf spot on Kibat and Wako (55.6) while the local accessions showed resistance to both angular leaf spot (0-7%) and anthracnose (11-12%). Analysis of mineral composition revealed significant differences among the tested materials. Kibat and Wako were significantly different from the rest of the accessions concerning Calcium (161.7, 165.4 mg/100g) and Phosphorus (551.2, 559.43mg/100g). The performance of the accessions on the crude protein contents was statistically significant ($P<0.05$). The highest crude protein content was recorded on accession-008 (20.92%), accession-010 (19.7%) and accession-002 (19.41) while the lowest crude protein contents was recorded on Wako (14.5). In general, accesssion-002 was the most productive accession whereas, Wako and accession-008 were the best for mineral contents; accession-010, accession-002, and accession-008 were the best for crude protein content; and all the local accessions were ideal for disease resistance. Therefore results from this study will be helpful and can be used in the future lima bean variety development programs. However, ffurther analysis of the anti-nutritional factors in this crop is very important in the future. On top that, collection of lima bean samples from a wider geographic range of Ethiopia is very important to widen the genetic base of the crop in the future.

Keywords: Morphological traits, *Phaseolus lunatus*, mineral composition, yield

1. INTRODUCTION

The lima bean is a bisexual plant in which autogamy is promoted by the proximity within the bud and the synchronized maturity of the stigma and pollen grains in its flowers. (Martínez-Castillo et al., 2007) Lima beans (*Phaseolus Lunatus* L.) are annual herbaceous plants, determinate bush types, and indeterminate climber types the ovate, lanceolate or lineate, and acuminate leaflets are present in the trifoliate leaves. Flowers open early in the day when their buds open. After two to three days, the corolla sheds, but the flower does not close.(BAUDOIN, 1993). Self-pollination is encouraged by the stigma and pollen grains maturing at the same time and by their proximity within the bud. (Baudoin, 1990).
Optimal growth temperatures typically lie between 16°C and 27°C; frost cannot be sustained; an average annual rainfall of 900–1500 mm is typical, although once established, the crop can withstand as low as 500–600 mm; certain types can grow as high as 2000–2500 m.(Baudoin, 1989). High temperatures (typically around 30 °C) have several negative impacts on plants, including as shortened life cycles, pollen abortion, and bean shrinkage, decreased seed reserves, anther indehiscence, and decreased growth of the pollen tube. (ParedesLópez, Reguera, and Octavio 2023)

Lima bean seeds, is extensively grown and sold with more than 21,000 hectares under production, the USA is the greatest producer in the world. Madagascar, whose cultivated area ranges from 3,000 to 19,000, is the world's second-largest commercial producer.(Prota, 2014)Under traditional farming systems, dry seed yield is low, about 200-600 Kg ha^{-1} whereas under intensive agronomic management in the United States, dry seed yield may be as high as 1080-1350 kg/ ha. (Eco crop, 2011) reported that the yield of fresh seeds might range from 2.0 to 8.0 t ha^{-1}. In the tropical regions, the average dry seed production is 1.0 to 1.5 t ha^{-1}. Yields of dry seed may reach 2 to 2.5 t ha^{-1} for the bush types and 3 to 4 t ha^{-1} for climbing types (Baudoin, 2006). However, the type of cultivar and cultivation practices might, significantly, affect the yield of Lima bean (FAO, 2002). It is an orphan crop in Ethiopia, nevertheless, and there is no improved variety and agronomic practices. In southwestern Ethiopia Teppi, farmers use lima beans for food like nefro and wote.

In Africa including Ethiopia Lima beans as a minor and neglected legume crop, it has been aggregated with other legumes in (FAOSTATA) resulting in a lack of records of global production (Baudoin, 2006). African has produced 120,000 to 200,000 ha of Lima bean in the sub-humid and humid areas of Sierra Leone, Liberia, Cote d‟Ivoire, Ghana, and Nigeria (Nwokolo, 1996). The lima bean is grown, mostly, in gardens or backyards, usually, intercropped with other crops (Broughton *et al*., 2003). The state of Delaware planted more acreage, annually, for processing purposes than any other state in the USA (Kee *et al*., 2004) production in Africa is rather low. In the past two decades, the total annual production was 50000-100000 tonnes in countries, such as Ghana, Cote d’Ivoire, Nigeria, and DR Congo altogether (Baudoin, 2006). In Ethiopia, there are no documents or published works that provide information on the production of lime beans. In Ethiopia, Lima beans are used for making stew solely and/or mixed with other vegetables as well and the boiled lima bean and/or mixed with cereals like maize can be consumed. It is a high-value crop that the price of 1 kg of fresh lima beans is more than Birr 300, in several supermarkets. According to (FAO, 2015) pulses including lima beans are packed with proteins – double that found in wheat and three times that of rice and they are also rich in micronutrients, amino acids and b-vitamins and Pulses are an effective diet for treating anemia in women and children because of their high iron and zinc content they are also low in fat, high in minerals, and rich in soluble fiber also great for controlling cholesterol and digestive health.

Ethiopia is the main bean-producing country in Sub-Saharan Africa. The average bean production in the country is still falling below the standard worldwide, though. This is mostly due to the cultivars currently in use having low-yielding capacities because has a narrow genetic base, and lack of genetic information. Though there is no definite time regarding when the Lima bean was introduced to Ethiopia, (Engels *et al.,* 1991) stated that it was introduced, fairly, recently, and distributed widely in the southwestern parts. However, (Westphal, 1974) collected specimens from areas including Shoa, Wellega, Illubabor, Kefa, Gamo Gofa, Sidamo, and Hararge. In Ethiopia, since 1972 there have been only two varieties (Calico Pole and California baby lima bean) that were recommended for production (Gashawbeza, 2019) and recently two varieties(Wako and Kibat) were recommended for production by Melkassa Agricultural Research Center (Personal communication).

The gap identified in the Evaluation of Lima Bean Accessions for agronomic performance and nutritional compositions revolves around the limited research on genetic studies related to productivity and food nutrient content of Lima beans in Ethiopia. Thus, aimed to select landraces of lima beans accessions based on desirable agronomic traits contents of essential nutrients enabling their use in breeding programs and later recommendations for best varietal development. Despite the widespread cultivation of Lima beans in certain regions of the country, there is a lack of comprehensive genetic studies focusing on traits that could enhance productivity and nutritional value. The thesis suggests that conducting research in this area would be beneficial for future breeding programs and the development of new products. The lima bean accession "LB8510" is rich in crude protein, while the accession "LB85CH2" is rich in iron. As a result, both can be used for breeding, the development of new products, and the creation of alternative, nutrient-rich sources that can help reduce the prevalence of malnutrition in Ethiopia (Gemede, *et.al* 2022).While the mineral composition of Lima beans has been determined and variations among accessions have been detected, this highlights the need for more in-depth research to explore the genetic potential and nutritional aspects of Lima beans in Ethiopia. Since lima bean research and development in Ethiopia is still in its very early stages, it is crucial to identify as well as to examine their significance and morphological difference, given the crop's nutritional benefits and other important uses. This makes it possible to choose varieties based on crop performance and to use them in programs to intensify cropping systems in the future. It also helps to identify how to use and conserve lima bean landraces. Therefore, the general and specific objectives of the study were carried out to evaluate locally collected Lima Bean accessions in the humid tropics of Teppi's Southwest Ethiopia conducted as follows:

General Objective

- To evaluate the performance of locally collected Lima Bean accessions in terms of agronomic traits, yield, and mineral composition under the ecological conditions of Teppi in Southwest Ethiopia.

Specific Objectives

- To determine the mineral composition of the Lima Bean accessions grown in the humid tropics of Teppi, Southwest Ethiopia.

2. LITERATURE REVIEW

2.1. Economic Importance of Lima Bean

2.1.1. Food for human consumption

Ethiopians have traditionally categorized significant values in their own ways based on the benefits they offer, such as food, fuel, revenue creation, and therapeutic value. Informants were invited to share their thoughts on how the production of Lima beans improved their standard of living by providing food and fodder, as well as the socioeconomic and agro ecological significance of the landrace.(Nasir *et al*., 2020)

Given the increasing global population and the limited availability of land, water, and food resources, it is critical to accurately define the quantity and quality of protein needed to meet human nutritional needs and to appropriately characterize the protein found in food ingredients, whole foods, sole-source foods, and mixed diets. To sustain the health and well-being of human populations, there must be a match between the food supply and human protein needs (Sandoval-Peraza *et al*., 2020). According to (Stagnari *et al.*, 2017) Legumes including lima beans provide civilization with numerous valuable advantages, but their potential to mitigate climate change has received little attention as an important component of soil carbon sequestration, legumes can reduce greenhouse gas emissions, including carbon dioxide (CO2) and nitrous oxide (N2O), and they can also lower total fossil energy inputs in agricultural systems that rely on mineral N fertilization.

Regardless of how and where they are produced, customers in rural areas and cities benefit from more nutritious beans. As mentioned previously, beans are particularly high in protein and iron. When iron deficiency and anemia rates in women (of whom 27% are iron deficient) are compared to bean consumption patterns in Latin America, it is evident that iron-rich beans may have a particularly significant impact on health in this area. The situation is significantly worse in Sub-Saharan Africa, where 40% of women experience iron insufficiency(Broughton *et al.*, 2003).

For instance, according to (Oliveira *et al.*, 2004), the lima bean is an alternative food source for human food in the Northeast of Brazil. It can be dried and shelled, ground, or as a whole green bean and can be canned or frozen. It can also be baked, boiled, and fried in oil. The young pods and leaves are consumed, as vegetables in countries, such as Ghana and Malawi (Broughton *et al*., 2003). Seeds can be processed into porridge, puddings, and cakes by the Yoruba people, in Nigeria. The seeds and leaves can also be taken as beverages. In most parts of Asia, the young plants or leaves are consumed (Daisy, 1979 ;Van der Maesen ; Somaatmadja, 1989). It is also used in soups and stews and a variety of dishes, such as succotash (Floridata, 2012). Generally**,** lima beans have excellent nutrition and health benefits.

2.1.2 Use as fodder for livestock

Lima bean straw **(**dried vines left after harvest) provides fodder for cattle and sheep. Dairy cows can be fed on young vines which are highly nutritive (Ishler and Adams, 2010). Vines cut at the stage where leaves are still green promote high intake. The vines can easily be converted into silage (Ishler and Adams, 2010) and fed to growing and milking cows Ajayi (2011) indicated that silage made from young vines before flowering, incorporated with fresh Napier grass (*Pennisetum purpureum*) and pineapple increased dietary protein content, nutrient digestibility, nitrogen absorption and retention, and reduction in weight loss of goats, during the dry season. In addition, silage made from vines of lima bean, as compared to other crops, such as Cajon pea or African yam bean, produced optimal growth rate and weight gain in goats (Ajayi *et al.,* 2012). In comparison to the brown variety, the white Lima bean variety yielded a 10.2% higher dry matter yield for fodder (Ibrahim and Zaria, 2022).

2.2 Botanical Description of Lima Bean Accessions

A lengthy axillary raceme with numerous nodes and flowers is the inflorescence. On the outside, calyx bracts are glandular and typically extend half the length of the calyx. The standard typically has a pubescent exterior and is colored in shades of white, pink, violet, or pink to purple. The wings are violet or white, the keel greenish or occasionally tinged (pink or purple) with colorful flowers. The stems could reach lengths of 4.5-8 m. The trifoliate, alternating leaves have ovate leaflets that measure 3–19.5 cm in length and 1–11 cm in width. There are twenty-four white or violet bisexual flowers on 15 cm long inflorescences. The fruits are 5-12 cm long, dehiscent pods with 2 to 4 seeds (Ecoport, 2011; Ecocrop, 2011; Baudoin, 2006). Seeds are very variable in size, shape and colour. Cultivar groups have been distinguished according to seed differences (Baudoin, 2006).The stigma is introrse, slightly sub-terminal, and axially positioned; the apical part of the style is pubescent on the inner face. Oblong, usually curved pods hold two to four seeds that eventually dehisce.

P. lunatus is acclimated to the lowland tropical savannah climate, based on the natural range of its wild relatives. It has spread to a variety of ecologies during domestication, including hot temperate zones and wet, dry, or semiarid tropical regions. (BAUDOIN, 1993)

2.3 Types of Lima Bean Accessions

In wild Lima beans, the presence of two gene pools has been widely documented in the literature (Caicedo *et al.*, 1999; Fofana *et al.*, 1999; Gutiérrez-Salgado *et al.*, 1995 and Maquet *et al.*, 1997). These two groups of lima beans are fully inter-fertile and conspecific. They are, however, phenotypically distinctive, and crosses between them sometimes produce lethality among the F2 segregates, which suggests a degree of genetic divergence (Erickson, 1982). However, based on new evidence, three gene pools have been recently proposed (Andueza-Noh *et al.*, 2013; Serrano-Serrano *et al.*, 2012; Serrano-Serrano *et al.*, 2010) *i.e.*, the Andean gene pool (A) and two Mesoamerican gene pools (MI and MII). Furthermore, (Oliveira-Silva *et al.*,2017) showed that the Big Lima cultic group represents the "A" gene pool, whereas the Sieva and Potato cultic groups represent the "MI" and "MII" gene pools. These three cultic groups exist within the var. *lunatus*, the domesticated population as reported by (Baudet, 1977).

2.4 Importance of genetic diversity

2.4.1 Agronomic performance of lima bean

The maximum gene diversity (0.1864) and Shannon information index (0.2753) were found in West Wellega accessions. Accessions from Jimma displayed the lowest gene diversity (0.1614) and Shannon information index (0.2328). The greatest gene diversity (0.21) and Shannon information index (0.29) were displayed by primer DPISR2, while the lowest gene diversity (0.09) and Shannon information index (0.10) were displayed by primer 812. (Nasir *et al*., 2020) With the greatest 100-seed weight means throughout the four environments—69.2 g in Teresina, PI; 67.3 g in Domingos, MA; 58.4 g in Bom Jesus, PI; and 70.4 g in Tianguá, CE—the variety Boca de Moça stood out. Table 9 displays the genotypic values for the number of pods per plant. The values vary from 7.0984 (Fava Branca III CE) to 7.6417 (Mulatinha). The varieties with the highest averages were Fava Branca II MA, Fava Branca I MA, and Mulatinha. The cultivars Fava Raio de Sol, Branquinha, and Fava Branca I MA showed the greatest genotypic values, with the number of seeds per pod ranging from 3.0319 (Fava Branca III CE) to 3.4864 (Fava Branca I MA). Among the four habitats, the variety Boca de Moça had the largest mean weight of 100 seeds (69.2 g in Teresina – PI, 67 the genotypic values for 100-seed weight varied from 36.9234 g (Branquinha) to 64.9327 g (Boca de Moça), with the varieties that exhibited the greatest values being Rajada, Fava Raio de Sol, and Boca de Moça. Branquinha produced the highest grain yields, 10.9240 to 11.8738 g (Mulatinha), whereas Rajada, Boca de Moça, and Mulatinha were the most productive types.(De Assuncao Neto *et al.*, 2022) The range of days required for 50% blooming was 81.67 to 88.50, with NSWPP9 and NSWP46 flowering the earliest and later, respectively. With a value of 3.84 seeds per pod, cultivar NSWP83 had the most seeds compared to NSWP9, which had the lowest number. However, there was no discernible difference in this feature across any other cultivars. There was a significant difference in the 100 seed weight values between the cultivars, with cultivar NSWP53 registering the highest value at 69.31 g, more than three times the value noted for NSWP9 (21.79 g). Seed output showed the most diversity, ranging from 289.14 kg ha-1 in NSWP51 to 1358.74 kg ha-1 in NSWP53. Every cultivar was distinctly different from all the others. (Akande, *et al*., 2007). With the exception of the number of seeds per pod, univariate analyses of variance revealed a significant difference between genotypes ($p < 0.05$ and 0.01%) for most variables, showing genetic variability among the landraces under study and offering the opportunity to choose those with desired qualities.

The later landraces, flowering at 94, 100, 100, and 101 days after germination, were the earliest in the flowering, occurring on average 73 days after germination. The amount of time before flowering and the number of days till pod maturation are critical characteristics, particularly in the drier parts of the semi-arid zone where rainfall is infrequent and scarce. Small farmers will thus be able to schedule their plantings at the most advantageous moment. There were notable variations between the kinds.(De Assunção Neto *et al.*, 2022).

The interaction between the isolates and the lima bean accessions showed a significant effect ($p<0.01$), with the severity of the lima bean anthracnose indicating that the 10 accessions caused varying degrees of susceptibility to the pathogen isolates. Because it exhibited the highest level of aggression among the assessed accessions, the CT35 isolate was chosen. The UFPB13 accession achieved the lowest area under the anthracnose progress curve, reaching 3% of severity. The accession UFPB04 showed the highest vulnerability, with 100% of severity. Due to its large seeds, consumer appeal, and unpredictable development pattern, the UFPB13 accession is one of the most farmed; therefore this outcome is quite significant. (Gomes *et al.*, 2022)

Montero-Rojas *et al.*, 2013 also reported a wide range of seed colors and seed color patterns in the Caribbean lima bean landraces: black seeds without pattern color, buff seed color with pattern colors including either black, dark brown, and dark red, and light brown seed with a dark brown pattern, pink seeds with dark red patterns, purple seeds without patterns, white seeds with no and with black pattern colors. Moreover, (Oliveira-Silva *et al.*, 2017) reported high genetic variability as the seed length and width were the main contributors to genetic divergence among the accessions. (Purwanti; Fauzi, 2019) also reported variation in seed shape; among the studied accessions most of them were kidney-shaped (70%) whereas, some were oval-shaped.

Flower color and pod color are also important traits that can be considered to show variability in lima beans. As in the descriptor (IBPGR, 1982), the color of mature pods can be either brown or brown with either red or purple spotting or mottling, red, purple, or black (pigmented all over). Carmo *et al.*(2013) reported that they observed only brown color of pods in all accessions. However, Purwanti; Fauzi; (2019) reported the monomorphic color of pods, green for all accessions they studied. Nevertheless, varying colors of flowers including purple, violet, white, and yellow were reported (Purwanti ; Fauzi, 2019 Montero-Rojas *et al.*, 2013).

Prominent variability in yield and yield-related traits has been noticed in lima beans. According to (Mello,2011) in (Brito *et al.*,2020), the descriptors including the number of days to flowering, pod length, width and number of locules per pod, and seed thickness, length, width, and weight are the traits of major economic importance concerning the production and commercial value of the crop. (Silva *et al.*, 2015) reported that lima beans show significant variability in the number of pods per plant, pod length and width, and number of beans per pod. Likewise, seed length and width were found to be more variable (Oliveira-Silva *et al.*, 2017). Moreover, days to flowering and days to pod maturity showed significant variation in lima beans (Brito *et al.*, 2020).

2.4.2 Reactions to Major Diseases

Lima beans have self-defense producing herbivore-induced volatile organic compounds (VOCs) and extra floral nectar (EFN) under natural growing conditions (Heil 2004 and Yi *et al.,* 2009), some pests cause serious damage to yield and quality of the crop. Root-knot nematodes tend to affect the underground portions of the plant and aphids suck fluids from the plant creating a honey dew substance behind, which results in pale yellowish color on leaves (Long *et al.*, 2014). Other pests of importance include cut worms and beetles. Several arthropods can be observed on *P. lunatus*, such as beetles, leaf miners, green leafhoppers, whiteflies, and trips (Lopes *et al.*, 2010).

The main diseases that directly cause the low yield of Lima bean is Anthracnose, caused by *Colletotrichum truncatum* (Schw.) Andrus & Moore, is the main disease of P. lunatus, and it is characterized by necrotic spots on leaves, petioles, and pods (Carvalho et al. 2015). (Sousa *et al.*, 2017) Angular leaf spot (ALS) is a disease of bean (*Phaseolus vulgaris* L.) caused by the fungus *Phaeoisariopsis griseola* (Pg). It occurs in tropical and subtropical countries and has significant economic consequences. In recent years, the incidence of the disease has increased in many areas where the common bean is cultivated, becoming a serious problem causing losses of up to 30%.(Stenglein *et al.,* 2003) Among the most destructive diseases of common beans is the common bacterial blight (CBB) caused by *Xanthomonas axonopodis pv. phaseoli* (Xap) is a serious yield constraint in Iran (Lak et al. 2002; Amani et al. 2004; Osdaghi et al. 2009; Zamani et al. 2011; Akhavan et al. 2013), and elsewhere (Audy et al. 1994; Schwartz et al. 2005, Osdaghi & Zademohamad, 2015) Therefore, the control measures include, the use of cultural practices, resistant varieties, and rotation of crops, in the severe case chemical action is relevant (EARO,2004).

Resistance and or tolerance of lima beans against insect pests have been reported by several scholars. (França *et al.* (2018) evaluated lima bean genotypes for red spider mite (*Tetranychus neocaledonicus*) resistance and observed how different levels of antibiosis and antixenosis affect the genotypes made against the mite. In screening for resistance to pests in Cuba, potato leafhopper (*Empoasca kraemeri*) was the most commonly observed followed by tiny snails (*Praticolella griseola*) causing skeletonization and different levels of resistance were realized among the six varieties of lima bean (Cansino and Sosa, 2017). (Nottingham and Kuhar, 2019) also reported that varieties of lima beans react to the Mexican bean beetle differently. Moreover, screening for lygus bug resistance through Polygalacturonase-inhibiting protein sequence (PGIPs) identified the resistant and susceptible varieties even though *in planta* evidence was required to correlate genetic differences in PGIPs to lygus resistance in lima bean (Dashner, 2018).

Generally, lima beans also react to pathogens differently. In Brazil, screening for bean charcoal rot (*Macrophomina phaseolina*) and resistance stability as well as screening against different isolates of the pathogen helped identify the accession 'UFPI 908' as a promising source of resistance to *M. phaseolina* (García *et al.*, 2019). And also, in greenhouse and laboratory conditions lima bean accessions showed a varying level of resistance to root-knot nematodes (*Meloidogyne javanica*) (Lucena *et al.*, 2018). Several works have also been done on the evaluation of lima beans for resistance and or tolerance to diseases including downy mildew which is caused by *Phytophthora phaseoli* Thaxt (Santamaria, 2007 and Santamaria *et al.*, 2018), lima bean pod rot caused by *Phytophthora capsici* (Evans *et al.*, 2012), leaf anthracnose (*Colletotrichum truncatum*) (Carmo *et al.*, 2015 and Cavalcante *et al.*, 2012), and bean golden mosaic virus disease (Suah *et al.*, 1988).

2.5 Mineral Characteristics of Lima Beans

2.5.1 Proximate analysis

Lima bean seeds, whether raw, cooked, soaked, roasted, or dehulled, contain macronutrients such as protein, ash, fat, crude fiber, total carbs, calories, and soluble and insoluble dietary fibers(El-Gohery, 2021). The deep cream variety (DCV) has the highest protein content (25.43%) when compared to other varieties. The mottled black contained the least quantity of protein (19.33%). The fact that there was little fat in any of the variants was not surprising. This is because beans store energy in the form of carbs instead of fat. There were variations in the ash content. It ranged from 3.83 to 4.13%. The accession MBRV had the highest ash value, and BKV came in second with 4.13 and 4.12%, respectively (Okeke, 2014). The dry weight basis crude protein contents of lima bean accessions ranged from 23.98 to 24.76%. The accession "LB8510" had the highest crude protein content (24.76%), followed by "LB45PL" (24.33%) and "LB85CH" (24.06%), in that order. The accession "LB45CH" had the lowest crude protein content ($p<0.05$) of all the accessions. Protein is essential for maintaining the health and well-being of human populations. (Acta *et al.*, 2020) where the moisture, protein, lipid, ash, and starch contents of the Lima bean flour were 10.2, 23.92, 1.15, 4.30, and 44.55%, respectively and Lima bean flour exhibited 13.34 % total dietary fiber(Palupi et al 2021). The four most essential amino acids were phenylalanine, leucine, valine, and lysine; lysine was abundant in lima beans and glutamic acid and aspartic acid were the two most abundant non-essential amino acids. (Brawijaya *et al.*, 2022).

2.5.2 Mineral contents

Minerals like potassium, calcium (Ca), phosphorus (P), magnesium (Mg), sodium (Na), iron (Fe), copper(Cu), and zinc (Zn) were present in lima beans. (Brawijaya *et al.*, 2022) reported that an important amount of minerals may be found in dry lima bean seed, as indicated by the ash content of 3.30% and dry lima bean seed included the following elements: magnesium (184 mg/100 g), phosphorus (75 mg/100 g), potassium (38 mg/100 g), calcium (11 mg/100 g), and iron (10 mg/100 g) and (Jayalaxmi *et al.*, 2016) reported similar values for the mineral composition of lima beans Potassium (1295.13 mg) was the most common mineral in raw beans, followed by calcium (326.46 mg), phosphorus (153.36 mg), magnesium (123.1), sodium (27.0 mg), iron (5.40 mg), copper (4.3 mg), zinc (2.64 mg), and manganese (2.63) in the least amount.

2.5.3 Medicinal values of lima bean

Various parts of the crop have medicinal properties. Juice from the leaves is used in nasal instillation against headache and as ear-drops against otitis in Senegal and DR Congo (Baudoin, 2006). In traditional Asian medicine, both seeds and leaves are valued for their astringent qualities, and consequently, used as a diet for fever (Roecklein, 1987). In other parts of Africa, seeds are processed into powder and applied into small cuts on tumors to promote suppuration (Baudoin, 2006).

2.5.4 Anti-nutritional factors

Natural or artificial plant components known as anti-nutrients hinder the body's capacity to absorb and digest vital nutrients like protein, vitamins, and minerals. (Lima and Phaseolus, 2018) The HCN value (43.55 mg) was highest in the black variety. The high and similar HCN results for each variety showed that lima beans contain a significant amount of this food toxin, which can be harmful if taken raw or prepared incorrectly. This observation was consistent with observations in the literature that stated that when compared to other legumes, lima beans have the highest level of HCN (10-312 mg/100g, 420 mg/kg) depending on the type. (Manay, 2001). Lima bean flour had a phytic acid content of 10.36 mg/g and its flour was at a low concentration of HCN (8.83 mg/kg) (Palupi et al 2021) The condensed tannin contents of the accessions studied by Palupi et alvaried from 29.44 to 116.46 mg/100g and the total phenol contents were ranged from 15.06 mg /g GAE to 31.59 mg/g GAE in “LB45PL” and “LB45CH“, respectively. The phytate contents of lima bean accession in this study ranged from 90.65 mg/100g (LB85CH2) to 111.41 mg/100g (LB8510) (Acta *et al.*, 2020).

Leaves and seeds of lima bean contain toxic substances, cyanogenic glucosides such as linamarin and lotaustralin (Cressey and Reeve, 2019), which have the potential to cause rapid respiration, drop in blood pressure, headache, vomiting, and convulsions (Heuzé *et al*., 2015). Baudoin (2006) estimated that domesticated species contain lower amounts of cyanogenic glucosides (100-120 ppm), as compared to wild species (2000-2400 ppm). Cyanogenic potential varies concerning maturity, stage of development, genotype, and cultivation conditions. Young leaves and seeds have higher HCN (hydrogen cyanide) potential, as compared to older leaves (Ballhorn *et al.*, 2005). It is important, therefore, to soak seeds overnight and cook lima beans properly to ensure most of the HCN is removed.

Raw beans of lima beans contain anti-nutritional factors, mainly protease inhibitors, and lectins, which act negatively on the digestive tracts (Ologhobo *et al.*, 1993) and affect growth and metabolism in broilers (Achi *et al.*, 2007). The foliage also contains factors, such as phytic acid, saponins, and tannins (Ajayi *et al.*, 2009). These factors can be eradicated using heat or moist treatment (Adeparusi, 2001). Rama *et al.* (2018) also concluded that proper processing and treatment should be done to remove inhibitors of protein digestibility and quality. Generally, lima bean production constraints can be diseases and pests, several factors like the amount of hydrogen cyanide contained in edible parts, and other anti-nutritional factors which are production constraints of this crop.

2.6 Methodologies for evaluations of Lima bean accession

According to (Da Silva *et al.*, 2015) the following characteristics were considered in the agro morphological assessment and characterization of the accessions: number of days to maturity (NDM), which is the number of days from emergence to a stage when 90% of plants have mature pods; number of pods per plant (NPP), which is the total number of fruit per plant; and number of beans per pod (NBP), which is calculated from 10 randomly chosen mature pods. The identified gap in the study "Evaluation of Lima Bean Accessions in Southwest Ethiopia" revolves around the limited research on genetic studies related to productivity and food nutrient content of Lima beans in Ethiopia. Despite the widespread cultivation of Lima beans in certain regions of the country, there is a lack of comprehensive genetic studies focusing on traits that could enhance productivity and nutritional value.

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The field experiments were carried out at Teppi (TARC) in South West Ethiopia regional state (Figure I). TARC is located with a latitude of 7º 3' N and a longitude of 35º 0' E with an altitude of 1200 m a.s.l and receives a mean annual rainfall of 1688 mm (TARC Metrological data station 2022). It is found in Southwest Ethiopia which is 611 km away from Addis Ababa The soil type of the experimental site is classified as Nitisols, which is dominated by a loam texture with a pH range of 5.6 to 6.0 (Abayneh and Ashenafi, 2005).

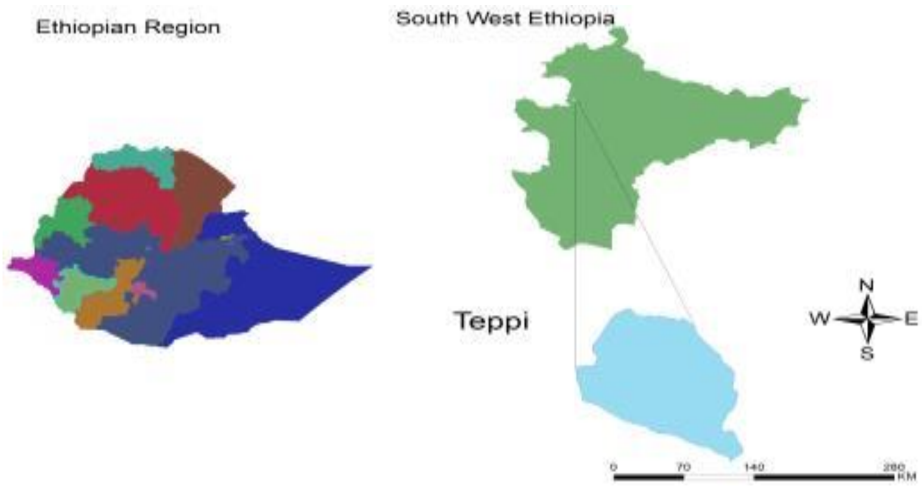

Figure I Map of the experiment area

A total of nine (9) accessions of lima beans were included in this study Seven local Lima bean landraces were collected from Qelem wellega (Table 1) and two standard checks from Melkassa agricultural research center make up the experimental treatments. These accessions were chosen because the only accessions in Ethiopia and they have originated from locations with comparable climatic conditions at the time of their collection and are known by various names in various parts of Ethiopia, including Aba choma, Aba bona, Adenguare, and Aba ferada. It was set up using a Randomized Complete Block Design (RCBD) and repeated three times.

3.2. Plant Materials

Table 1 Accession used for the evaluation trials in 2022/23

Treatment no.	Accession	Sources	color	Remarks
1	Acc-004	Qelem Wellega	White &dark red stripe	Accession
2	Acc-010	Qelem Wellega	Red	Accession
3	Acc-006	Qelem Wellega	Light red	Accession
4	Kibat(C-1)	Melaksa Agricultural Research Center	White	Check
5	Wako(C-2)	Melaksa Agricultural Research Center	White	Check
6	Acc-009	Qelem Wellega	White red Dotted	Accession
7	Acc-008	Qelem Wellega	Red white red dotted	Accession
8	Acc-002	Qelem Wellega	Light yellow	Accession
9	Acc-005	Qelem Wellega	Red with White Stripe	Accession

3.3. Experimental Procedures And Crop Management

The experimental site selection was chosen before May 02, 2022, taking into considers factors such as floodplain status, shade, and other factors that make the area suitable for growing lima beans. A suitable total area of 336 m^2 was selected, the area measured, and sufficient room was set out for the experimental investigation. Then, any unwanted vegetation was removed from the measured area, and the fields were cleaned and avoid unwanted debris the cleaned land was plowed by using oxen until the soil smooth and to make leveled the total plot by using human labor. The cleaned and leveled land was measured and layout by using a tape meter for block and plot preparation by using Pythagoras theorem (3*4*5). Then to prepared three blocks, each with nine plots, were created out of the entire experimental field. Each experimental plot was 1.6 meters in length and 4 meters in breadth. Plots were separated from blocks by a 1.5 m and from plot 0.5m walkway.

Each plot had four rows and intra rows 10cm and inters rows 40cm (10cm*40cm) and seeds were planted at a depth of 5 cm, and they were covered with soil. At the time of sowing, 80g of NPS was applied to each plot and applied as a blanket application (122 kg ha^{-1}). At last, the entire agronomic procedure was executed.

Stalking was necessary to prepare support and wood was polled a month after planting. One wood support served two plants. Weeding was done every 15 days. Data on growth, and yield-related parameters was recorded from five randomly selected and tagged plants that were grown in the middle rows. The yield of randomly selected plants was calculated from the net plot area ($3.2m^2$) of each experimental plot and converted into hectare bases.

3.4. Data Collection

3.4.1 Phonological parameters

- **Days to 50% flowering**: it was recorded when 50% of the plants in each plot reached flowering.
- **Days to 90% physiological maturity**: Days to 90% physiological maturity were recorded when in 90% of the plants the pods formed yellow. However, harvesting was done when all plants in the entire plots were fully matured.

3.4.2 Growth Parameters

- **Number of branches per plant**: It was counted from the lower base branch to the tip after flowering on five plants.
- **Stand Count at Emergence:** It was counted early emerging stand counts to give a precise view of the germination rate and seeding assessment.

3.4.3 Yield and Yield Components

- **Number of Pods per Plant:** The total number of pods from a randomly selected plot was counted from 20 pods.
- **The number of seeds per pod:** The number of seeds per pod was counted from the selected sample plant, which harvested 20 pods, and the seed was counted.
- **Grain yield (kg ha^{-1}):** After correcting the grain moisture content to 12.5%, the weight of the grains from the net plot area was measured and converted to kg ha^{-1} just use the techniques listed here.

$$\frac{(\text{Harvest yield}) \times (1 - \text{Harvest moisture})}{(1 - \text{Standard moisture})}$$

- **100 seed weight. (g):** The weight of 100 seeds, randomly taken from the harvested bulk seeds per net plot, was measured at 12.5% moisture content (standard moisture content for lima beans after sun drying) using a sensitive balance.

3.4.4 Disease score

Disease incidence is score at vegetative and reproductive stages and the percentage of plants exhibiting disease symptoms relative to the total number of plants examined in a sampling quadrate (five in this case) during the evaluation. The presently available 1–9 scale of global procedures for individual diseases, as well as the field guideline for disease detection and scoring methodology in mandatory crops, was scored like Anthracnose and Angular Leaf Spot (ALS). (Zoro Bi, Maquet and Baudoin, 2005)

The assessments were made using a standard scoring scale for both diseases as suggested by CIAT (1987); where, 1 = 1%, 2 = 2–5%, 3 = 6–10%, 4 = 11–15%, 5 = 16–30%, 6 = 31–50%, 7 = 51–75%, 8 = 75–85% and 9 = >85% lesion area on the infected lima beans leaves/pods. These reactions are coded where 3 Low susceptibility 5 Medium susceptibility 7 High susceptibility(IBPGR, 1982), and the disease incidence percentage calculated represented as follows:

$$\text{Disease incidence}(\%) = \frac{\text{Number of plants showing disease symptoms per quadrate}}{\text{Total number of plants assessed per quadrate}} \text{ X } 100$$

3.4.5 Determinations of crud protein and mineral composition analysis

3.4.5.1 Kejeildhal distillation methods for total nitrogen.

The sample was taken from every plot separately to determine the mineral content. The mineral composition analyses were carried out at the soil and plant analysis laboratory of Horticoop-Ethiopia in Debrezeyit. Samples of Lima beans were cleared of any undesirable material. The moisture percentage of the lima bean sample was measured. The seed samples of lima beans were weighed at 50g, and then the weighted sample was ground using a grinding machine and the flour was sieved, tagged, and packed. Using the micro Kjeldahl method, the protein content (%) of lima bean seed was ascertained. The procedure, which entails the steps of digestion, distillation, and titration, is a universally accepted approach for analyzing crude protein in food samples. The nitrogen content (%) was converted to protein content using a factor of 6.25. A catalyst was used to break down around 0.5 g of powdered lima bean flour, 1 g of mixture (Na_2SO4) combined with anhydrous CuSO4 in a 10:1 ratio, and 5 mL of concentrated H_2SO4. The sample was heated to 350 degrees Celsius until it was fully digested and looked clear. After that, it was cooled to room temperature. The Kjeldahl flask, which was attached to the distillation apparatus and had its outlet tube submerged in a 25 ml solution containing 4% boric acid, was filled with 50 ml of distilled water and 50 mL (40% NaOH) to carry out the distillation process. The distillate, 150 ml, was collected and titrated using the 0.1N HCl standard. The burette reading was used to determine the volume of HCl consumed, and the following equation was then used to get the percentage of protein in N.

$$N\ (\%) = \frac{\text{VHCl in Lx NHCl } (0.1) \text{x } 14}{\text{sample weight in g on dry matter basis(db)}} x100$$

% Protein = CF x %N

The proximate composition of the lima bean samples was determined using the standard method of AOAC (2005). Percent Nitrogen was converted to crude protein by multiplying with a factor of 6.25

4.4.5.2 Wet digestion methods by ICP determination for mineral compositions

The method of mass spectrometry was used for mineral analysis. ICP-OES was used to measure concentrations after closed-system microwave wet etching was used to make the minerals soluble. The Calcium, Potassium, Magnesium, Phosphorus, sodium, iron, Manganese, zinc, and copper contents were ascertained using the AOAC (2002) guidelines(Feldsine, Abeyta and Andrews, 2002). A typical process involved adding 0.5 milliliters of serum sample to 10 milliliters of a concentrated acid mixture that contained hydrogen peroxide ($HNO3/H_2O_2$) and nitric acid mixed at a 4:1 volume ratio. The mixture was then stored in a beaker and heated to 80 degrees Celsius until the digested sample's volume reached 1.0 milliliters. The contents were diluted with up to 10 milliliters of deionized water once they had cooled to room temperature. Following digestion, an ICP-MS macro and micro mineral element analysis was performed.

3.4.6 Statistical analysis

SAS (statistical analysis software) version 9.3 proc GLM technique was used to perform analyses of variance (ANOVA) for the observed parameters (SAS, 2012). Treatment differences were compared using the Least Significant Difference (LSD) procedure at a 5% level of probability. Pearson correlation analysis was carried out for growth, yield, yield components, and mineral contents of lima beans accessions, and correlation coefficients (*r*) were established to determine the magnitude and degree of their relation. Before the data was subjected to ANOVA, homogeneity and normality tests were done for the growth parameters, yield, yield components, disease score, and mineral compositions. The statistical model for treatment analysis of variance was outlined by (Gomez and Gomez, 1984).

$$Yxij = \mu + \alpha i + \beta j + \varepsilon\ ij$$

Where, Yijk, is the total variation of the response variable, μ the grand mean, α i = treatment effect /accessions effect, βj block effect, and ϵijk the residual effect.

4. RESULTS AND DISCUSSION

4.1. Mean Comparison of the lima bean Accessions for Phenology and yield Traits

4.1.1. Stand count at Emergency

Lima bean stand count significantly differed ($p<0.001$) influenced by accession populations (Table 2 and Appendix I). The result indicated that the highest number of plant populations was recorded from acc-006 (140 plants per plot) followed by acc-002 and acc-005) (135 plants per plot) and the lowest numbers of populations were recorded from local check-1 and check-2 (36.67 plants per plot). Lima bean accessions have different stand counts within treatments because the seed germination ability was different within lima bean accessions the reasons the check-1 and check-2 have low Viability, Hard Seed Coat, and Important germination inhibitors are abscisic acid, phenolic acid, etc. Other factors are the Impermeability of the seed coat to water and oxygen, Genotype, and Lack of growth hormones. Stand count varied significantly between accessions because genetic makeup of accessions could be the cause of this difference.

4.1.2. Days to 50% flowering

Analysis of variance showed that the lima bean accessions significantly differed ($p<.0001$) for days to flowering (Table 2 and Appendix II). The result indicated that the earliest number of days to reach 50% flowering was observed from the variety Kibat (C-1) and Wako(C-2) (41.33 days) at the Teppi experimental site (Table 2). The longest days to attain 50% flowering were recorded from accession008 (73 days) followed by accession 005. Days to flowering, varied significantly between accessions. The genetic makeup of accessions could be the cause of this difference the outcome indicates that while certain accessions flower earlier.

4.1.3. Days to 90% maturity

Analysis of variance showed that accessions significantly differed for days to maturity ($p<.0001$) (Table 2 and Appendix III). The result indicated that the shortest for number of days to reach 90% maturing was observed from the variety Kibat (C-1) (97 days) and Wako(C-2) (94 days) at the Teppi experimental site. The longest days to attain 90% maturity were recorded from accession 008 and accession 004 (213.3 days) days to maturity, varied significantly between accessions because the genetic makeup of accessions could be the cause of this difference.

Table 2 Mean performance of nine lima bean accessions for stand count at emergency Days of 50% flowering and Days to maturity evaluated at Teppi, in 2022/2023

Accessions	SCE	D.F	D.M
acc-004	84.33^{dc}	72.000^{a}	213.333^{a}
acc-010	105.33^{bc}	63.667^{c}	189.667^{c}
acc-006	140.33^{a}	65.000^{cb}	185.667^{c}
Kibat(C-1)	54.00^{de}	41.333^{d}	97.000^{d}
Wako(C-2)	36.67^{e}	41.333^{d}	94.667^{d}
acc-009	38.67^{e}	72.000^{a}	211.000^{ab}
acc-008	83.00^{dc}	73.000^{a}	213.333^{a}
acc-002	135.67^{ba}	66.333^{cb}	187.000^{c}
acc-005	127.00^{ba}	67.667^{b}	192.667^{bc}
SEM(±)	19.6391	1.61446	11.83372
LSD(0.05)	33.9***	2.7945***	20.483***
CV (%)	21.96	2.6	6.72

Means in the same column followed by the same letters are not significantly different at 5% level of significance DF= days to flowering, DM=days to maturity, SCE= stand count at emergency, SEM = Standard Error, LSD= least significant difference CV=coefficient of variations, ***=very highly significant.

The result showed that lima bean accessions varied in terms of flowering and maturity days, potentially providing breeders with the opportunity to choose accessions for early or late maturity based on the lima bean breeding objectives. Thus accessions with early blooming and maturing could be suitable for locations under moisture stress, whilst accessions with late flowering and maturing might be suggested for areas with ideal moisture levels. Early maturity is an important trait for increasing and stabilizing lima bean productivity early phenology (time of flowering and maturity) enhances lima bean adaptation in environments that have early ending rains and rains coming late.

4.2. Yield and yield components

4.2.1. Number of pods per plant

The number of pods per plant (NPP), had significant (P<.0.05) variations among accessions, during the 2022 /023 cropping seasons (Table 3 and Appendix IV**)**. The highest number of pods per plant was counted on acc-002(19.333pods per plant) and the lowest pod number was recorded from acc-004 (4.66pods per plant) in the 2022/2023 cropping season. The reason for the different number of pod counts was that genetic potentials of accessions to produce branch and pod the accessions that produce more amount of productive branches that might produce more pods, which in turn reduced the number of pods per plant. The same result was recorded by(Olawuyi, Adeyeye, and Ajayi, (2023)The 2006-005A, PS-16, 2006-007, and 2006-015 accessions were significantly different, while accessions 2005-015 and TPI-198 are highly significant for some pod per plant. (Da Silva *et al.*, 2015)The lima bean accessions differed from each other for most of the evaluated traits, and genetic variability. NPP average was 8.70 and ranged from four (UFPI-582) to 16 (UFPI220) pods per plant. Similar work was reported by (Rana *et al.*, 2015)the average number of pods/plant was 16.3 while the range was 4.2–49.6 for IC556535 and EC500299, respectively.

4.2.2. Number of seeds per pod

Analysis of variance revealed that the number of seeds/pod was a significant ($p<.0001$) difference affected by the accession (Table 3 and Appendix V). As a result, the maximum number of seeds/pod (3 seeds/pod) was counted from the “check-2”. This showed that the significant variations in seed number per pod between the lima bean accessions because more related to the difference inherent characteristics of the accessions. The same result was recorded by (Olawuyi, Adeyeye, and Ajayi, 2023) Values for the number of seeds per pod, TPI2429, TPI-178,118-2, 198-3, TPI-189, 2005-015 and 2006-003B accessions are highly significant but different at $p<0.05$. The results show high accession difference of variations for, number of seed per pods, which indicates high genetic variation in these traits among the lima bean accessions evaluated.

4.2.3. Number of branches per plant

Analysis of variance revealed that the number of branches per plant was a significant different ($p<.0001$) (Table 3 and Appendix VI) the number of branches observed to vary among accessions ranged from 4.3 to 2.5 branch per plant. The highest number of branches (4.73branch per plants) for acc-002 and the lowest (2.5 number of branches per plant) was recorded from acc-008 similar results on variation of materials for number of branch per plant were reported by (Obafemi and Plantation, (2007). The results show high accession difference of variations for number branch per plant, which indicates high genetic variation in these traits among the lima bean accessions evaluated.

4.2.5. 100 seed weight

Significantly different variation (p<.0001) was observed for the hundred seed weight (Table 3 and Appendix VII) Acc-004 showed the highest (143.7g) hundred seed weight in this study was observed for the hundred seed weight for followed by C-1 (128.5g), and acc-009 (123.45g). On the other hand the least hundred seed weight was recorded on acc-002 (41.46g). This might be attributed to the genetic makeup of varieties and Seed weight is a key character that can be used to clarify the origin and diversity of lima beans, according to (Almeida *et al.*, (2021) considering that seeds classified as cultivated biological status and having 100SW greater than or equal to 56 g belong to the Andean domestication center, while lighter seeds are related to the Mesoamerican center. The findings demonstrate a large accession difference of variations for the number of branches per plant, indicating a high level of genetic variation in these attributes among the evaluated lima bean accessions.

4.2.6. Total Seed Yield

The grain yield of lima beans accessions was found significant different (P<0.0095) (Table 3 and Appendix VIII.). The maximum total yield was recorded from accession-002(1650 kg ha^{-1}) and the least total yield was obtained from the C-1(Kibat) (443.8 kg ha^{-1}). (Lyman, 2022) The reason might be different accessions have different yield potential due to genetic make-up. (Lyman, 2022).

The mean grain yield of the 9 lima bean accession ranged from 443.8kg ha^{-1} (local check-1) to 1650kg ha^{-1} (acc-002) Table 3. Compared to the standard checks (Check-1and Check-2), five accessions (acc-002, acc010, acc-006 and acc-009, acc-004) gave higher yield than the checks and showed a significant difference from the standard checks for grain yield with a grain yield advantage of 18%, 13.9%, and 7%, 5.98%, and 2% respectively.

Pod per plant, seed per pod, branch per plant, and days to maturity 100 seed weight were all significantly and positively correlated with yields and similar result was reported by(Obafemi and Plantation, (2007) and (Ribeiro *et al.*, (2018)

Table 3 Mean performances of nine lima bean accessions for yield and yield component traits evaluated at Teppi in 2022/2023

Accessions	NPP	NSP	NBP	HSW(g)	Yd. (Kg h^{-1})
acc-004	4.667^{d}	2.2667^{dc}	2.8000^{cd}	143.37^{a}	961.0^{bcd}
acc-010	16.333^{ba}	3.0000^{ba}	3.0000^{cbd}	68.86^{b}	1289.6^{ba}
acc-006	13.000^{bac}	2.8000^{b}	3.3667^{b}	68.49^{b}	1062.5^{bc}
Kibat(C-1)	12.667^{bac}	2.3333^{c}	3.0667^{cb}	115.86^{a}	443.8^{d}
Wako(C-2)	15.667^{ba}	3.0333^{a}	3.0000^{cbd}	128.59^{a}	705.7^{cd}
acc-009	8.000^{dc}	2.0000^{dc}	2.9333^{cbd}	123.45^{a}	804.2^{bcd}
acc-008	6.000^{dc}	1.8667^{d}	2.5333^{d}	125.43^{a}	645.8^{cd}
acc-002	19.333^{a}	1.9333^{dc}	4.7333^{a}	41.46^{b}	1650.0^{a}
acc-005	10.333^{bdc}	2.2667^{dc}	2.8000^{cd}	45.38^{b}	991.7^{bc}
SEM(±)	4.206476	0.231741	0.288835	18.66766	316.3297
LSD$_{(0.05)}$	7.281***	0.659***	0.4999***	32.312***	547.5**
CV (%)	35.715	15.67	9.20	19.51	33.28

Means in the same column followed by the same letters are not significantly different at 5% level of significance. NB= number of branches per plant SCE= stand count at emergency NP= number of pods per plant NS= number of seeds per pods Yd. = yield HSW= Hundred seed weight SEM = Standard Error LSD= least significant difference CV=coefficient of variations, **=high significant, ***= very highly significant

4.3. Mean Comparison of Accessions for Expression in Relation to Disease

The percent of incidence of diseases Angular leaf spot (ALS caused by *Pseudocercospora griseola* and Anthracnose caused by *Colletotrichum truncatum)* was found significantly different (p<.0001) (Table 4 and Appendix IX) among accessions. The mean incidence of ALS was found ranged from lowest on acc-002 and acc-005 (with no symptom observed) to highest (on local check-2 and local check-1(55.5%-70.3 %,). The mean incidence of Anthracnose disease was ranged from lowest on acc-009 and on acc-008 (13%-14%) to highest (on local check-2 and local C-1 (55.5% and 70.3%, respectively). Disease assessment and scoring are good criteria for the future resistance variety development (Gomes *et al.*, 2022) therefore from the present study accessions acc-002,acc-05,acc-004acc-009,acc-010, and acc-008 were found with significant levels of resistance to anthracnose and ALS can be used as resistance sources for future lima bean breeding programs. Disease incidence scoring is also need to be considered for selections of resistance lima bean accessions (Faleiro *et al.*, 2004). Characterizing new germplasm and introducing new resistance genes into enhanced cultivars are two of the most effective and affordable ways to manage the *Colletotrichum lindemuthianum*-caused anthracnose and ALS of Lima bean disease.

Among the nine lima bean accession evaluated, six accessions namely, acc-02, acc-005, acc-010, acc-008, acc-009, and acc-006 showed highly resistant to ALS and the checks (check-1 and check-2) (55.6%) showed moderately susceptible to ALS at Teppi district. Among the accession, one (accession check-2) showed that highly susceptible to anthracnose, and seven accessions (acc-004, acc-010, acc-006, acc-009, acc-008, acc-002, acc-005) were moderately resistance The most lima bean disease in Ethiopia is anthracnose, which can completely wipe out a cultivar's output when the contaminated seed is planted and The pathogen's host range, favorable climatic factors including temperature, precipitation, and relative humidity, and characteristics of the host plant that affect its survival are all linked to its dispersion and success.

Table 4. The number of Lima bean accessions evaluated against anthracnose (ANT), and angular leaf spot (ALS), in 2022 at the Teppi experimental site (%).

Accessions	Reaction of lima bean accession,2022/2023	
	ALS	ANT
acc-004	18.517^{b}	11.850^{c}
acc-010	3.703^{c}	12.590^{c}
acc-006	7.407^{c}	16.293^{c}
Kibat(C-1)	55.56^{a}	55.560^{b}
Wako(C-2)	55.56^{a}	70.373^{a}
acc-009	7.407^{c}	11.850^{c}
acc-008	3.703^{c}	13.330^{c}
acc-002	0.0^{c}	12.960^{c}
acc-005	0.0^{c}	13.330^{c}
SEM(±)	6.094581	4.464650
$LSD_{(0.05)}$	10.549***	7.7278***
CV (%)	36.12040	18.42049
Means	16.87296	24.23741

Means in the same column followed by the same letters are not significantly different at a 5% level of significance ALS=angular leaf spot ANT=anthracnose SEM = Standard Error LSD=least significant difference CV=coefficient of variations ***= highly significant,

5. PROXIMATE AND MINERAL COMPOSITIONS OF LIMA BEAN ACCESSIONS

5.1. Crude Protein Compositions of Lima Beans Accessions

The protein content among the nine lima bean accessions varied from 14.58 to 20.924% with an average protein mean of 17.95% considered as high protein content. The effect of the accessions on the crude protein contents was a statistically significant ($p<0.05$) and the findings of the nine Lima bean accessions' proximate (crude protein contents) are shown in (Table 5 and appendix V). The crude protein content varied from 20.924 to 14.578; with (acc-008) indicating the greatest and (C-2) resulted the lowest with mean protein concentration of all lima bean accessions evaluated was 17.95759%. Similar findings were reported by(Owolabi *et al.*, 2020). but comparatively less than what Moses et al. reported,(Ojukwu, Olawuni and Iwouno, 2012)

The total calorie requirements will determine how much protein you should eat. Protein should make up 10% to 35% of a healthy adult's daily caloric requirements. A gram of protein has four calories in it. Thus, consuming 100 grams of protein, or 400 calories, would provide 20% of an individual's daily caloric intake on a 2000 calorie diet. The amount of protein you need in your diet will depend on your overall calorie needs. The daily recommended intake of protein for healthy adults is 10% to 35% of your total calorie needs. One gram of protein supplies 4 calories. Therefore, a person on a 2000 calorie diet could eat 100 grams of protein, or 400 calories from protein, which would supply 20% of their total daily calories. (Snetselaar, *et al* 2021).The present finding of protein in lima bean accessions varied from 20.924 to 14.578%. Therefore Lima bean accession is a good source of protein in order to obtain a better balance of protein.

Table 5. Crude protein (%) Composition of Lima bean Accessions at Teppi in, 2022/2023

Accessions	protein composition of Lima bean seeds
	Crude protein (%)
acc-004	18.451[ba]
acc-010	19.746[a]
acc-006	17.296[ba]
C1	14.770[b]
C2	14.578[b]
acc-009	19.023[ba]
acc-008	20.924[a]
acc-002	19.413[a]
acc-005	17.418[ba]
SEM(±)	2.6
LSD($_{0.05}$)	4.5164*
CV (%)	14.53

Means with the same letter(S) with columns are not significantly different at p<0.05 level of significance ns=Non-significant SEM = Standard Error LSD=least significant difference, CV=coefficient of variation.

5.2 Mineral Compositions of Lima Beans Accession

Potassium, magnesium, iron, manganese, and other important minerals for the pulse family, such as calcium, are typically found in high concentrations in legumes (FAO, 2016). Numerous factors, such as accession or cultivar and growing environment, influence the mineral composition of pulses, according to (Hall, Hillen, and Robinson, 2017) Lima bean seeds that have been dried have a significant mineral content of calcium (126.53 mg/100 g), and phosphorus (431.4mg/100 g), sodium (1.19mg/100g), potassium (1133.5 mg/100 g) Magnesium (121.16mg/100g), iron (10.93mg/100g), copper (1.05mg/100g), manganese(0.31mg/100g), Zinc (2.89mg/100g) and were found in dry lima bean seed similar study was reported by (Yellavila *et al.*, 2015) the Lima bean accessions were observed to contain fairly good amounts of minerals such as potassium, sodium, phosphorous and iron Mineral composition in mg/100 g of the lima bean flours is shown. The abundant mineral in the studied varieties was potassium which agrees with the observation of (Seidu, Osundahunsi and Osamudiamen, 2018).

5.2.1 Macro minerals contents of lima beans accessions
5.2.1.1 Calcium

The effect of the accessions was statistically Significant difference (P<.001) were observed among the accessions evaluated for their Calcium contents (Table 6 and Appendix X). The calcium concentrations varied from 165.45 to 104.44mg/100g. The calcium concentration was high in C-2 (Wako) (165.45 mg/100g) followed by "C-1" (Kibat) (161.78mg/100g), and low calcium content on dry weight basis was observed in "acc-010" (104.44mg/100g). The mean calcium contents of the accessions were 126.5274 mg/100g. The present study result with higher mean calcium concentration (129.84mg/100g) than reported on some bean accessions (Golam Masum Akond et al., 2011).

Humans need calcium for a variety of reasons, including the development and maintenance of bones and teeth, helping in the contraction and relaxation of muscles, blood coagulation, nerve impulse transmission, hormone production, and enzyme activation. Supports in preserving appropriate blood pressure.(Harvard Medical School, 2014) The calcium content ranged from 165.45 to 104.44mg100g-1. Present findings regarding calcium content are lower than the recommended daily intake and hence there is a need to complement these flours mixes with of higher calcium contents like milk products.

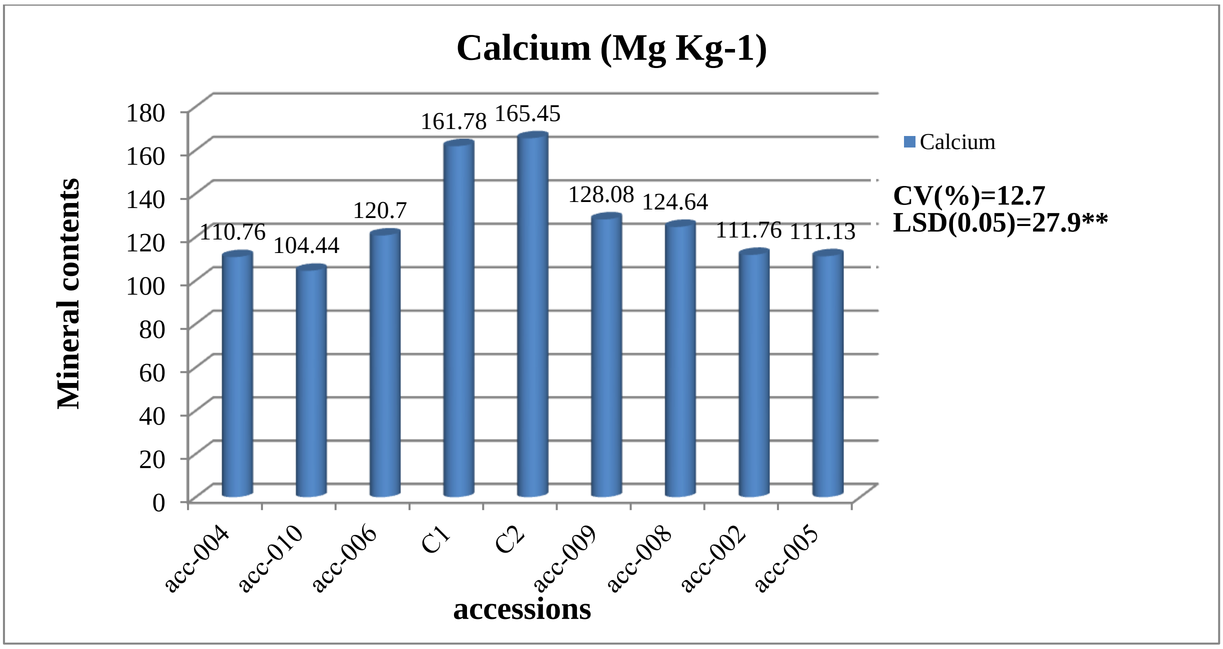

Figure II Amount of Ca (mg per kg-1) lima bean accessions

7.2.1.2 Potassium

The effect of the accessions on the Potassium contents was statistically significant (Table 6 and Appendix XI). The potassium contents of studied accessions in this study varied from 1210.01mg/100g (C-2) to 1042.91mg/100g (acc-002). The potassium content of the lima bean accession was not significantly different ($P<0.05$) the mean potassium concentration of lima bean accessions was 1133.500mg/100g. The mean was greater than 162 mg/100g for lima bean varieties as reported by was reported by(Sahasakul *et al.*, 2022). Potassium is an essential mineral for maintaining the body's pH balance, cellular water balance, and the metabolism of proteins and carbohydrates. A high-potassium diet appears to decrease blood pressure, and having enough of it may be good for bones. The suggested daily intake of potassium is 4,700 mg. (Onibon, *et al* 2007). Hence, when compared to cereals, lima bean accessions are a rich source of potassium.

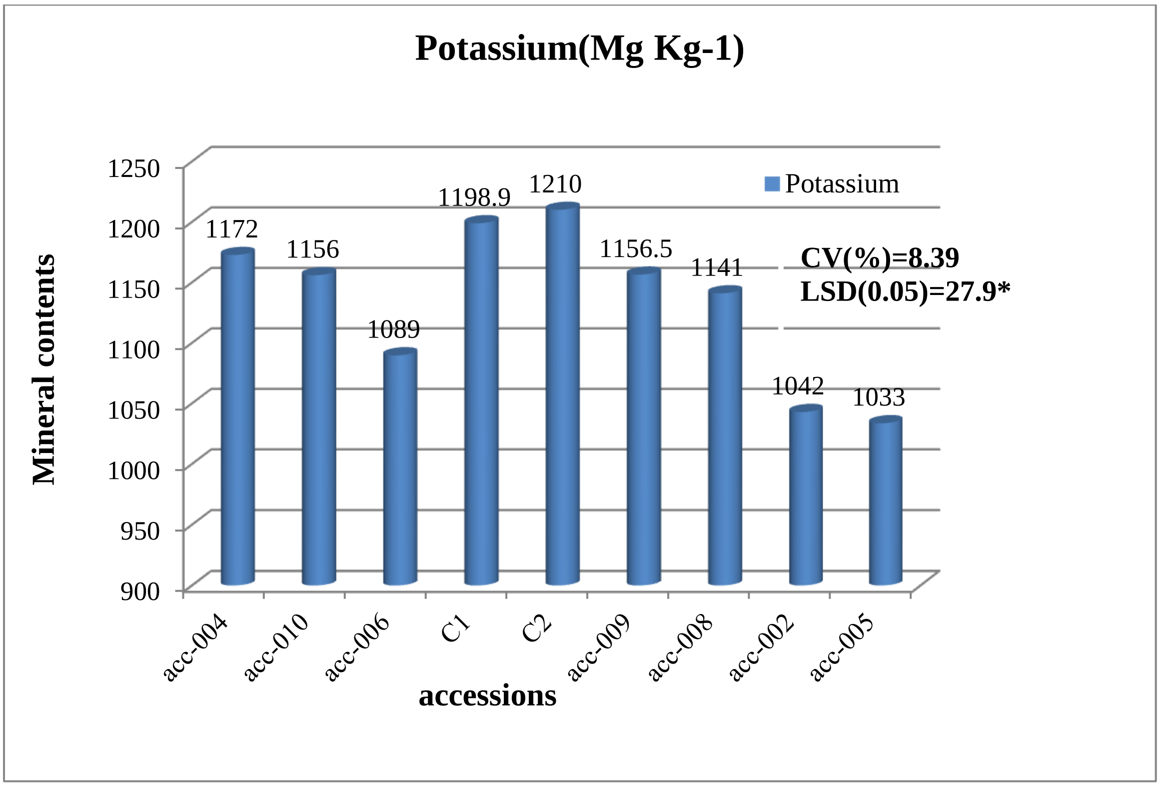

Figure III Amount of K (mg per kg^{-1}) in 9 lima bean accession

7.2.1.3 Magnesium

The Magnesium contents of the tested lima bean accessions was statistically significant ($P<0.05$) (Table 6 and Appendix XII)). The magnesium content of the accessions under study ranged from 141.49mg/100g (C-2) to 109.65mg/100g in “acc-008”. The magnesium content “C-2” accession on a dry weight basis was high 141.49mg /100g) and was trailed by “C1” (132.55mg/100g) and “acc-010” (122.26mg/100g) accessions. However, lima bean “acc-008” accession was low (109.65mg/100g). The mean magnesium concentration of all lima bean accessions was 121.1565mg/100g. The mean magnesium content agreed with the mean 121.1565mg/100g for lima bean varieties (Sahasakul *et al.*, 2022) Beside potassium, magnesium (Mg2) is the second most abundant cation inside cells and the fourth most abundant cation overall in the body, behind sodium, potassium, and calcium. Magnesium dioxide (Mg2) is necessary for life and is involved in hundreds of enzymatic processes. For many biological activities, the majority of which require ATP, magnesium is a crucial co-factor. Magnesium dioxide (Mg2) is a necessary mineral for the mineralization of bones, the relaxing of muscles, neurotransmission, and other cellular processes. The degree of intestinal absorption and renal excretion strictly controls the levels of extra-cellular magnesium.(Martin, González and Slatopolsky, 2009) The United States Food and Nutrition Board states that an adult male's recommended daily allowance of magnesium is 420 mg, while an adult female's is 320 mg(de Baaij, Hoenderop and Bindels, 2015). Therefore, lima beans are excellent sources to receive magnesium when supplemented with other vegetables like spinach and broccoli.

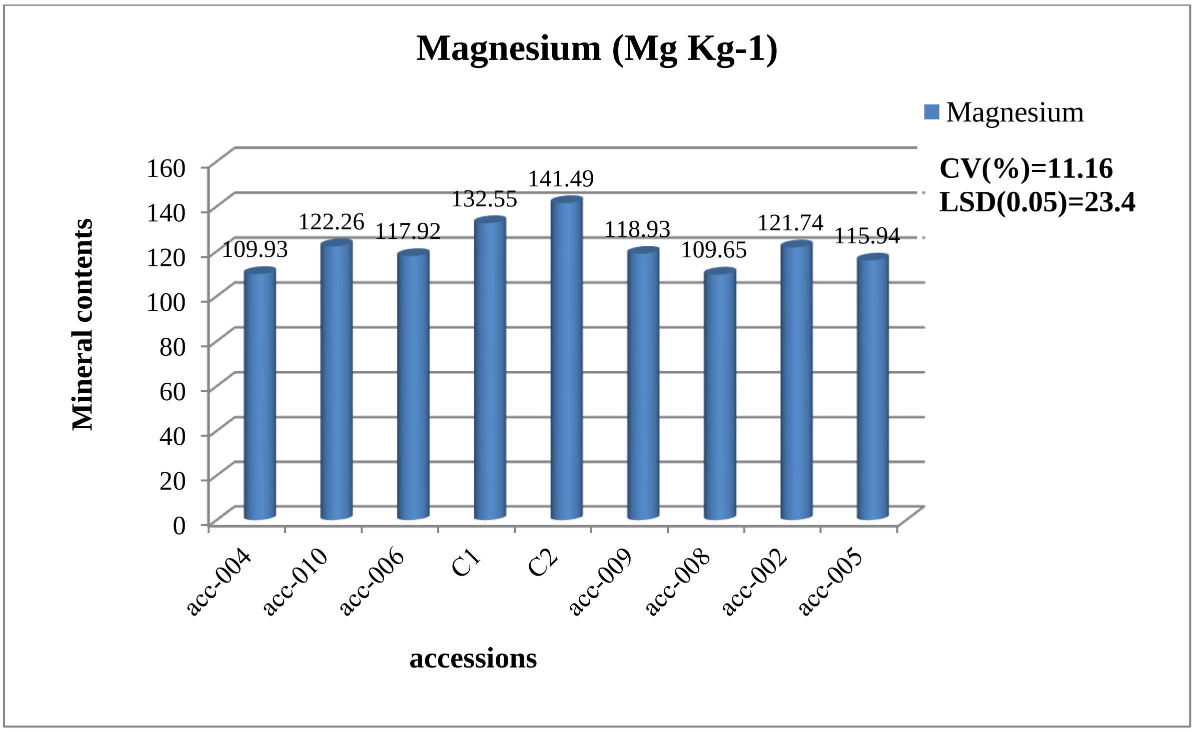

Figure IV. Amount of Mg (mg per kg-1) in 9 lima bean accessions

7.2.1.4 Phosphorus

The effect of the accessions on the Phosphorus contents was a statistically high significance difference (P<0.01) (Table 6 and Appendix XIII)). The phosphorus contents in the present study varied from 559.43mg/100g to 351.16mg/100g in "C-2" and "acc-009", respectively. Accession "C2" was significantly (p<0.05) higher (559.43mg/100g) and was followed by "C1" (551.25mg/100g) and "acc-010" (466.84mg/100g) on dry weight basis. Accession" acc-009" was lower (351.16mg/100g) than other accessions. The mean phosphorus concentration of lima bean accessions was 431.4mg/100g. The mean of the accessions was greater than the mean 299 mg/100g for lima bean genotypes(Yellavila *et al.*, 2015). The recommended daily allowance for both men and women is 700 mg of phosphorus, which means that in order for the body to function properly, a lot of these flours, must be consumed. As phosphorous is a component of DNA and RNA and help in the development and protection of bones and teeth, it also helps convert food into energy. Phosphorous helps build and protect bones and teeth, as part of DNA and RNA, helps convert food into energy, the recommended daily allowance for both men and woman is 700mg, which means that one has to take in much of these flours in order to achieve this value for the proper functioning of the body hence there is the need to complement these flours with phosphorous rich sources.(Harvard Medical School, 2014).

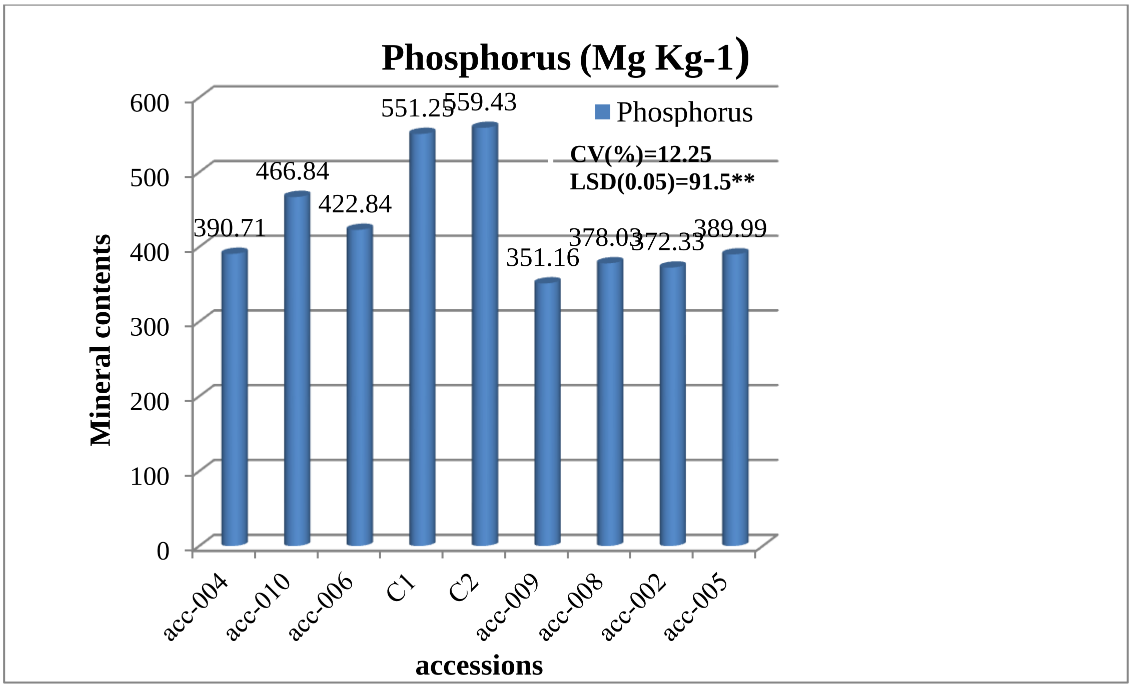

Figure V. Amount of P (mg per kg-1) in lima bean accession

7.2.1.5 Sodium (Na)

The effect of the accessions on the Sodium contents was statistically insignificant (Table 6 and Appendix XIV). The sodium content of lima bean accessions ranged from 2.491mg/100g (acc-010) to 0.007mg/100g (acc-002). Accession (acc-010) was high (2.491mg/100g) in sodium content but did not significantly differ (p>0.05) from (acc-010) (2.491mg/100g), (acc-004) (1.936 mg/100g) and (acc-008) (1.454 mg/100g) on dry weight basis. The sodium mean content of lima bean accession was 1.193963mg/100g. The mean sodium content agreed with the mean for lima bean varieties (seidu et al., 2018). The mean was lower than the value reported by (Owolabi *et al.*, 2020) (6.05 mg/100g) for lima bean seed contents of sodium. Sodium is necessary for Balances fluids in the body, Helps send nerve impulses, needed for muscle contractions, Impacts blood pressure; even modest reductions in salt consumption can lower blood pressure the United States Food and Nutrition Board states that an adult male's recommended daily allowance of Sodium is 2300 mg, while an adult female's is 2300 mg(de Baaij, Hoenderop and Bindels, 2015). Sodium is a necessary food and increased sodium consumption is linked to increase blood pressure, and individuals with hypertension are primarily at higher risk of cardiovascular events related with higher sodium intake (>5 g/d).(O'Donnell, Mente and Yusuf, 2015)Lima bean accession is low in sodium and good for people with high blood pressure to include in their diet.

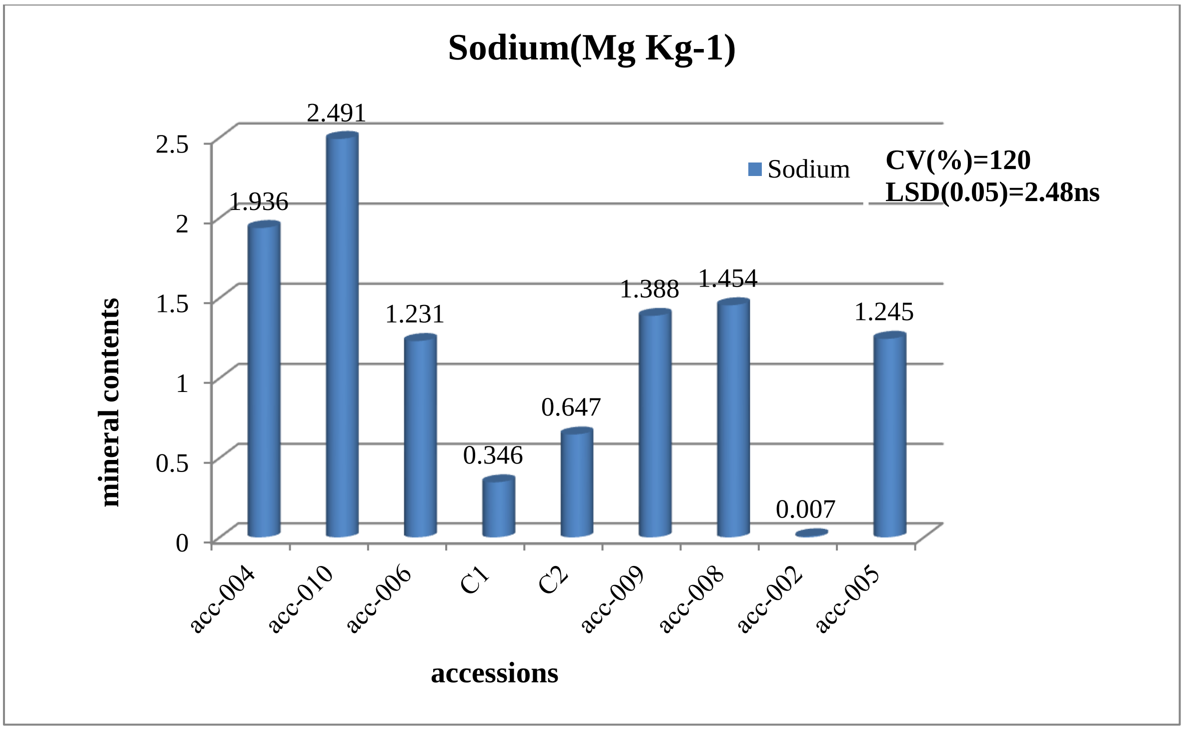

Figure VI Amount of Na (mg per kg-1) in lima bean accessions.

5.2.2 Micro minerals composition of (Fe, Cu, Zn, Mn)

5.2.2.1 Iron (Fe)

The effect of the accessions on the Iron contents was statistically insignificant (P>0.05) (Table 6 and Appendix XV)) difference. The iron content of lima bean accessions varied from 13.548mg/100g to 9.560mg/100g in "acc-008" and "acc-006" accessions, respectively. The iron concentration of the accession "acc-008" was not significantly different (13.548mg/100g) and was followed by "acc-009" (11.783mg/100g) and (acc-010) (11.396mg/100g). However, the "acc-006" accession had the low iron contents (9.560mg/100g). The mean iron contents of the lima bean accessions were 10.93015mg/100g. The same mean result was 11.19 mg/ 100g for some lima bean genotypes obtained and reported by (Brawijaya *et al.*, 2022). Iron is a mineral that can be found as a dietary supplement as well as naturally occurring in a variety of meals and food items. The erythrocyte (red blood cell) protein hemoglobin, which carries oxygen from the lungs to the tissues, requires iron as a necessary component. (Williams & Wilkins; 2014) the average daily iron intake from foods and supplements is 13.7–15.1 mg/day therefore the iron content ranged from 13.5 to 9.5mg100g-1 present findings iron content are similar to recommended daily intake and hence there is butter it should be found in our food every day.

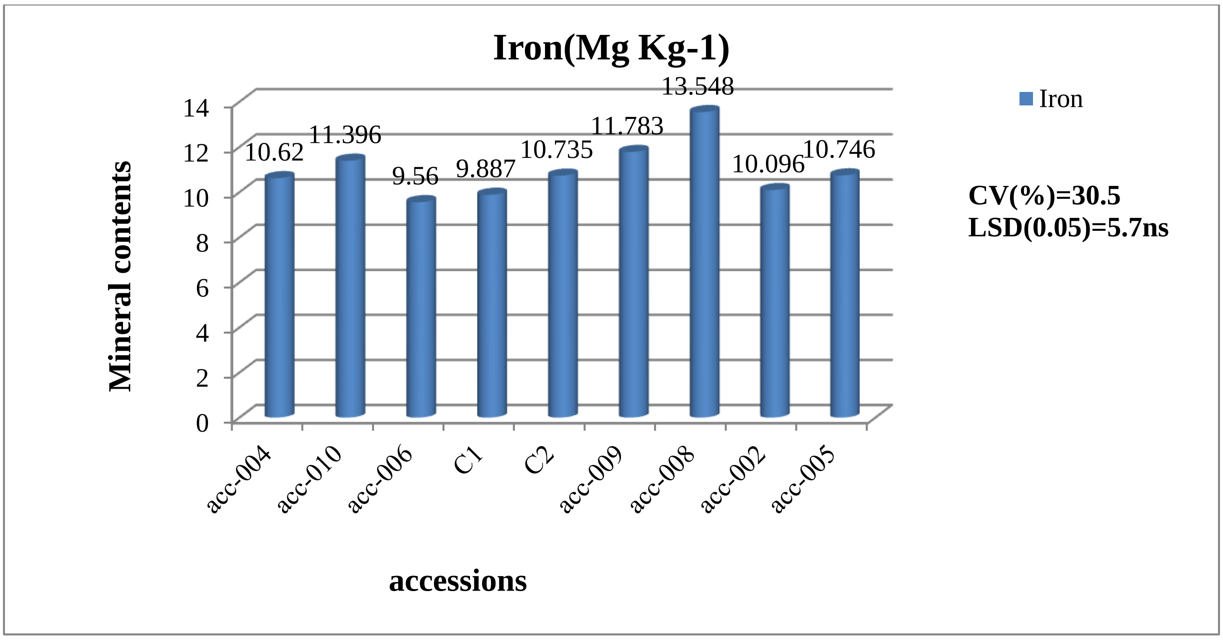

Figure VII Amount of Fe (mg per kg-1) in lima bean accessions

6.2.2.2 Manganese (Mn)

The effect of the accessions on the Manganese contents was statistically insignificant (Table 6 and Appendix XVI). The Manganese (Mn) content of lima bean accessions ranged from 0.4965mg/100g (acc-010) to 0.1565mg/100g in (C2). Accession (acc-010) was high (0.4965mg/100g) in Manganese content but did not significantly different ($p>0.05$) different from (acc-010) (0.4965mg/100g), (acc-005) (0.4903mg/100g) and (acc-004) (0.3842[a] mg/100g) on dry weight basis. The Manganese mean content of lima bean accession was 0.307915mg/100g. The mean was greater than the value reported by (Seidu, Osundahunsi and Osamudiamen, 2018) (0.14 mg/100g) for lima bean seed manganese contents.

Mn is an important mineral required for many metabolic processes, such as those related to healthy human development, the activation of specific metalloenzymes, energy metabolism, the functioning of the immune system, the nervous system, the reproductive hormone system, and antioxidant enzymes that shield cells from damage caused by free radicals. Additionally, Mn is critical for blood coagulation, bone and connective tissue growth, and the regulation of cellular energy. For many enzymes, including those involved in the synthesis and metabolism of neurotransmitters, magnesium is a necessary cofactor.(Standing Committee,2002) the average daily Mn intake from foods and supplements is 1.8–2.3mg/day(Williams & Wilkins; 2014) Therefore, lima beans are excellent sources to receive manganese when supplemented with other grains.

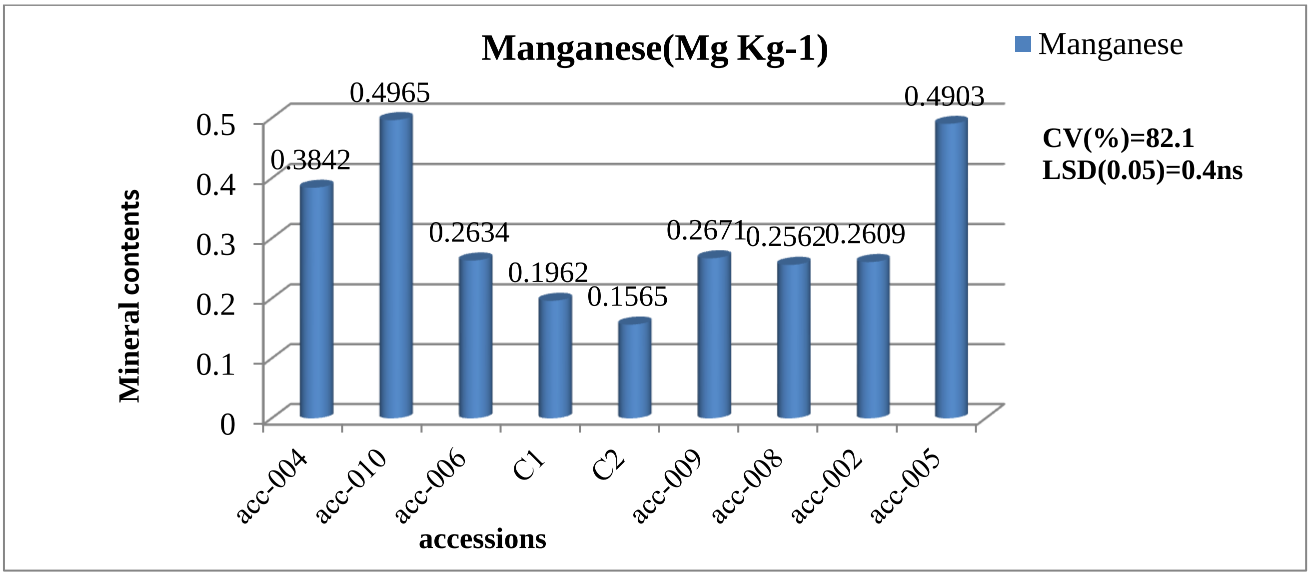

Figure VIII Amount of Mn (mg per kg-1) in lima beans genotypes

6.2.2.3 Copper (Cu)

The effect of the accessions on the Copper contents was statistically insignificant (P>0.05) (Table 6 and Appendix XVII). The Copper (Cu) content of the studied accession in this study varied from 1.3300mg/100g to 0.7806mg/100g in" acc-004" and "acc-006" accessions, respectively. The Copper (Cu) concentration of the accession "acc-004" (1.3300mg/100g) was not significantly different was followed by "acc-008" (1.213mg/100g) and "C1" (1.1428 mg/100g) in that order while low in" acc-006" (0.7806mg/100g) accession. The mean Copper (Cu) content of accessions under study was 1.050111mg/100g. The mean of the accessions was higher than the mean of 0.465 mg/100g for lima bean varieties reported by (Seidu, Osundahunsi and Osamudiamen, 2018).

Copper plays a vital role for humans in the production of connective tissues, blood vessels, and energy in your body. Along with activating genes, copper supports the health of the immunological and neurological systems additionally, for development of your brain also requires copper in your body. The average daily Cu intake from foods and supplements is 0.9mg/day(Williams & Wilkins; 2014) As a result, lima bean accessions comprise 1.3-0.78 mg and are great suppliers of copper nutrients.

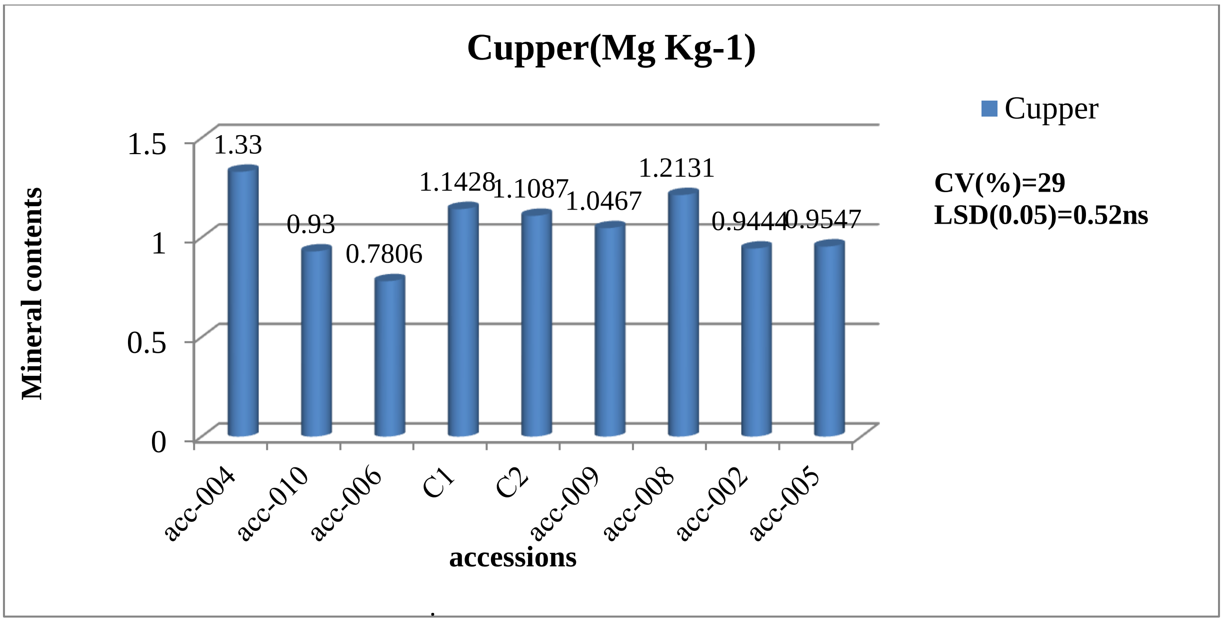

Figure X Amount of Cu (mg per kg-1) in lima bean accessions

6.2.2.4 Zinc (Zn)

The effect of the accessions on the Zinc contents was statistically insignificant (P>0.05) (Table 6 and Appendix XVIII). The zinc content of the studied accession in this study varied from 4.138mg/100g to 2.013mg/100g in" acc-008" and "acc-009" accessions, respectively. The zinc concentration of the accession "acc-008" (4.138mg/100g) was not significantly different and was followed by "acc-010" (3.190mg/100g) and "acc-008" (4.138mg/100g) in that order while low in" acc-006" (2.007mg/100g) accession. The mean zinc content of accessions under study was 2.886496mg/100g. The mean of the accessions was higher than the mean 0.39 mg/100g for lima bean varieties reported by (Seidu, Osundahunsi and Osamudiamen, 2018)

Zinc helps for human health for production of new cells, many enzymes, and proteins. It also removes vitamin A from the liver's storage, which is necessary for the immune system, taste, smell, and wound healing. When supplemented with specific antioxidants, zinc has the potential to slow down the development of age-related macular degeneration and an suitable daily dose of zinc ranges from 11 and 8 mg.(Harvard Medical School, 2014).Lima bean is a good source of Zn in order to obtain a better balance of zinc, it is appropriate to use a mixture of lime bean with cereals.

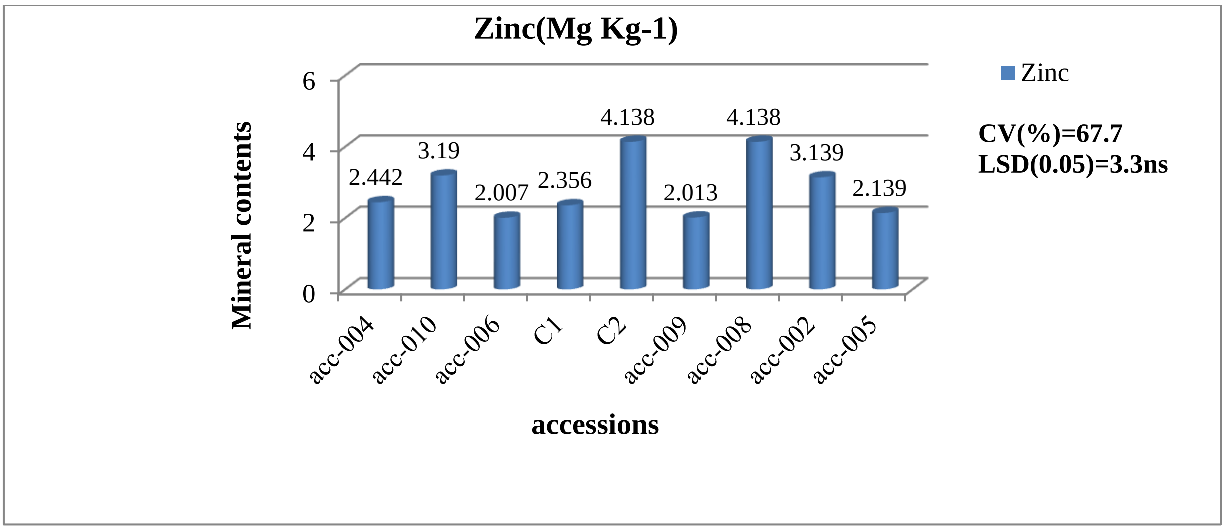

Figure XI Amount of Zn (mg per kg-1) in 9 lima bean accessions

Table 6 Mineral Composition of Lima bean accessions (mg/100 g).

Accessions	Mineral composition of Lima bean seeds								
	Calcium (Ca)	Potassium (K)	Magnesium (Mg)	Phosphorus (P)	Sodium (Na)	Iron (Fe)	Manganese (Mn)	Cupper (Cu)	Zinc (Zn)
acc-004	110.76^{b}	1172.71^{bac}	109.93^{b}	390.71^{dc}	1.936^{ba}	10.620^{a}	0.3842^{a}	1.3300^{a}	2.442^{a}
acc-010	104.44^{b}	1156.02^{bac}	122.26^{ba}	466.84^{bc}	2.491^{a}	11.396^{a}	0.4965^{a}	0.9300^{ba}	3.190^{a}
acc-006	120.70^{b}	1089.76^{bac}	117.92^{b}	422.84^{dc}	1.231^{ba}	9.560^{a}	0.2634^{a}	0.7806^{b}	2.007^{a}
C1	161.78^{a}	1198.95^{ba}	132.55^{ba}	551.25^{ba}	0.346^{ba}	9.887^{a}	0.1962^{a}	1.1428^{ba}	2.356^{a}
C2	165.45^{a}	1210.01^{a}	141.49^{a}	559.43^{a}	0.647^{ba}	10.735^{a}	0.1565^{a}	1.1087^{ba}	4.138^{a}
acc-009	128.08^{b}	1156.51^{bac}	118.93^{b}	351.16^{dc}	1.388^{ba}	11.783^{a}	0.2671^{a}	1.0467^{ba}	2.013^{a}
acc-008	124.64^{b}	1141.01^{bac}	109.65^{b}	378.03^{dc}	1.454^{ba}	13.548^{a}	0.2562^{a}	1.2131^{ba}	4.138^{a}
acc-002	111.76^{b}	1042.91^{bc}	121.74^{ba}	372.33^{dc}	0.007^{b}	10.096^{a}	0.2609^{a}	0.9444^{ba}	3.139^{a}
acc-005	111.13^{b}	1033.64^{c}	115.94^{b}	389.99^{dc}	1.245^{ba}	10.746^{a}	0.4903^{a}	0.9547^{ba}	2.139^{a}
SEM(±)	16.1253	95.1527	13.528	52.87566	1.4334	3.338	0.252830	0.3045	1.9565
Mean	126.5274	1133.500	121.1565	431.3985	1.193963	10.93015	0.307915	1.050111	2.886496
Max	161.78	1210.01	141.49	559.43	2.491	13.548	0.490	1.3300	4.13
Min	110.76	1033.64	109.65	351.16	0.007	9.560	0.1565	0.7806	2.007
CV (%)	12.74451	8.394590	11.16611	12.25680	120.0546	30.54298	82.11024	29.00521	67.78338
LSD(0.05)	27.911**	164.7*	23.416*	91.522**	2.4811^{ns}	5.7784^{ns}	0.4376^{ns}	0.5272^{ns}	3.3866^{ns}

Means in the same column followed by the same letters are not significantly different at 5% level of significance CV= coefficient of variation; SEM = Standard Error LSD= least significance difference, Min = minimum value; Max = maximum value;** high significant Ca = calcium; P = phosphorous; K = potassium; Mg = magnesium; Fe= iron; Mn = manganese; Cu = cupper; Zn = Zinc.

6. ASSOCIATION STUDIES

6.1 Correlation Coefficient of Yield with Other Traits

Table 7 shows the correlation between the yield of lima bean accessions and other trait characteristics for nine different lima bean accessions. Therefore, the relationship between lima bean pod numbers, seed per pod, number of branches per plant, and seed weight with total yields can vary depending on several factors including the lima bean variety, environmental conditions, soil fertility, and pest management practices. The genetic makeup of the bean variety plays a significant role in determining the number of pods per plant number of seeds per pod number of branches and the seed weight it develops (Mulualem, .*et al* 2013) Some varieties naturally have a greater propensity to produce more pods, seeds, seed weight, and branches, while others may have fewer branches but compensate with other yield-contributing traits.

Table 7 Correlation coefficient between traits in lima bean accession at Teppi, in 2022/2023

	Yld	*Ca*	*K*	*Mg*	*P*	*Na*	*Fe*	*Mn*	*Cu*	*Zn*	*Cp*	*PP*	*SP*	*NB*	*DF*	*DM*	*SW*	*SC*
Yld	**1**																	
Ca	**-0.5^{ns}**	**1**																
K	**-0.08^{ns}**	**-0.081**	**1**															
Mg	**0.021^{ns}**	**0.276**	**0.677**	**1**														
P	**-0.32^{ns}**	**0.444**	**0.404**	**0.5784**	**1**													
Na	**0.292^{ns}**	**-0.443**	**0.609**	**0.2793**	**-0.048**	**1**												
Fe	**0.169^{ns}**	**0.146**	**-0.079**	**-0.0737**	**-0.141**	**0.0057**	**1**											
Mn	**0.314**	**-0.643**	**0.539**	**0.3749**	**-0.018**	**0.7546**	**-0.160**	**1**										
Cu	**-0.20^{ns}**	**0.454**	**-0.165**	**-0.1259**	**0.056**	**-0.3519**	**0.551**	**-0.401**	**1**									
Zn	**-0.06^{ns}**	**0.143**	**0.059**	**0.0919**	**0.052**	**-0.0510**	**0.529**	**-0.100**	**0.2345**	**1**								
Cp	**0.231^{ns}**	**-0.224**	**-0.068**	**-0.3327**	**-0.332**	**-0.0471**	**0.111**	**-0.120**	**0.1974**	**-0.299**	**1**							
PP	**0.306****	**0.206**	**-0.015**	**0.4054**	**0.325**	**-0.1145**	**0.001**	**0.022**	**-0.2550**	**0.076**	**-0.365**	**1**						
SP	**0.621****	**-0.409**	**-0.111**	**0.0764**	**-0.048**	**0.0721**	**-0.197**	**0.270**	**-0.3430**	**-0.028**	**0.044**	**0.1805**	**1**					
NB	**0.440****	**-0.185**	**0.000**	**0.3761**	**0.196**	**-0.0872**	**-0.264**	**0.189**	**-0.2883**	**-0.127**	**-0.070**	**0.4685**	**0.7018**	**1**				
DF	**0.320****	**-0.632**	**-0.277**	**-0.6144**	**-0.825**	**0.1788**	**0.173**	**0.170**	**-0.0229**	**-0.122**	**0.574**	**-0.5283**	**0.0948**	**-0.25**	**1**			
DM	**0.299^{ns}**	**-0.615**	**-0.304**	**-0.6388**	**-0.803**	**0.1790**	**0.156**	**0.148**	**0.0433**	**-0.121**	**0.543**	**-0.6092**	**0.1422**	**-0.26**	**0.9719**	**1**		
SW	**-0.60****	**0.424**	**0.311**	**0.0769**	**0.135**	**0.0542**	**0.152**	**-0.165**	**0.4176**	**0.106**	**-0.131**	**-0.2661**	**-0.6476**	**-0.42**	**-0.1668**	**-0.15**	**1**	
SC	**0.600****	**-0.454**	**-0.439**	**-0.2301**	**-0.340**	**0.0968**	**-0.059**	**0.188**	**-0.2493**	**-0.155**	**0.139**	**-0.0281**	**0.6392**	**0.33**	**0.4158**	**0.44**	**-0.68**	**1**

PP=pod per plant SP=seed per NB=number of branch DF=day of flowering DM=day of maturity SW=seed weight SH= stand count at harvest Yd.=yieldCa=calcium,P=phosphorus,Na=sodium,K=potassium,Mg=magnesium,Fe=iron,Cu=cuppur,Mn=manganis,Zn=zinc,CP=crude protein Yd.=yield *=significant**=high significant ns=non-significant.

7. SUMMARY AND CONCLUSION

The present study was carried out in 2022/2023 to examine and evaluate lima bean (*Phaseolus lunatus* L.) accessions for nutritional composition and agronomic performance at Teppi, Southwest Ethiopia. Nine accessions were evaluated at Teppi in a randomized complete block design with three replications. Lima beans are rich in nutrients and an excellent source of necessary amino acids and proteins.

Analysis of variance for traits revealed the presence of a high significant difference among lima bean accessions for most of the traits such as stand count at emergency(140 -36.67 plants per plot) days to flowering (ranging between 41.3 and 73 with an overall mean of 57 days) Days to 50% maturity (97- 213.3 days) Whereas mean Yield and yield components like number of pods per plant, number of seed per pod, number of branches per plant, seed weight, grain yield, mineral (Ca and P) the analysis were statistically significant difference within lima bean accessions and the analysis of mineral except calcium and phosphorus statistically non-significant difference ($p>0.05$) among lima bean accessions.

Considering the association characters, bean yield showed a positive and significant correlation with the number of pods per number (0.3057*), seed per pod (0.627**), branch per plant (0.44008*), and the trait had a negative and significant correlation showed in yield with seed weight (-0.608*). In addition the association characters with bean yield and mineral contents of accessions insignificant and negatively associated Ca (-0.5*), P (-0.32*), Na (0.29), K (-0.08), Mg (0.02), Fe (0.17), Cu (-0.21), Mn (0.31), Zn (-0.06) and CP (0.23).

In comparison to the legumes consumed in Ethiopia, the study's findings demonstrated that lima bean accessions were a good provider of necessary mineral components

Significant differences and genetic divergence were found among the lima bean accessions that were evaluated under Teppi climatic conditions. Breeders and researchers now have a strong chance to increase diversity through breeding, which involves combining accessions with different desirable features such as mineral contents yield performance of accessions and evaluating high-performing accessions. Nevertheless, further research is required to determine suitable genetic backgrounds where lima bean grain protein concentrations are expressed without significantly reducing grain production and to assess breeding lines in multi-environmental experiments before implementing this information in breeding programs.

Generally, the result of this study indicates that accession (acc-002) had the highest grain yield at Teppi agroecology in particular, lima bean accessions "acc-008" and "acc-010" were rich in crude protein, and (Wako, Kibat,acc-002,acc-008,acc-10) rich in Ca, K, Mg, and P, respectively, while (acc-010,acc-008,acc-010,acc-004,acc-008) were rich in Na, Fe, and Mn, Cu and Zn. As a result, these accessions can be used for breeding, the development of new products, and the creation of nutrient-rich alternative sources that can lessen the prevalence of malnutrition in Ethiopia. Thus, there should be encouragement to increase the consumption, cultivation, and promotion of Lima beans. There is no research on the genetic studies traits related to productivity and food nutrient content of lima beans, although they are widely grown in the southwest and certain regions of Ethiopia, and lima bean seeds are sold for purposes of food.

As a result, one year of experimentation at a single site makes it impossible to draw conclusions and give useful recommendations; therefore, more research should be done on the selection and the best lima bean accession along with mineral contents and there are many Indigenous species of lima bean in the southern part of the country, Sample collecting from a wider geographic area will be important for the future in order to identify a butter variety.

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9. APPENDIX

Appendix XIX. Mean values of days to flowering, days to maturity, number of branches per plant, stand count at emergency, stand count at harvest, number of pods per plant, number of seeds per pod, yield, and seed weight affected by the accessions at Teppi in 2020/23.

Accession	DF	DM	NB	SCE	NPP	NSP	SW	Yd.
Acc-002	66.3	187.000	4.7333	135.67	4.7333	3.4000	41.5	1650
Acc-004	72.0	213.333	2.8000	84.33	2.8000	2.2667	143.4	961
Acc-005	67.7	192.667	2.8000	127.00	2.8000	2.2667	45.4	991.7
Acc-006	65.0	185.667	3.3667	140.33	3.3667	2.8000	68.5	1312.5
Acc-008	73.0	213.333	2.5333	83.00	2.5333	1.8667	125.4	645.8
Acc-009	72.0	211.000	2.9333	38.67	2.9333	2.0000	123.5	804.2
Acc-010	63.7	189.667	3.0000	105.33	3.0000	3.0000	68.9	1289.6
C1	41.3	97.000	3.0667	54.00	3.0667	2.3333	115.9	443.8
C2	41.3	94.667	3.0667	36.67	3.0667	1.9333	128.6	705.7
LSD(0.05)	2.8	20.483	0.4999	33.993	0.4999	0.4011	32.31	547.53
CV (%)	2.58	6.722	9.20727	21.95676	9.207270	9.5381	19.51	33.28
Mean	62.4	176.03	3.137037	89.44444	3.137037	2.4296	95.65	950.47

DF= days to flowering DM=days to maturity NBP= number of branches per plant SCE= stand count at emergency NPP= number of pods per plant NSP= number of seeds per pods Yd. = yield SW= seed weight LSD= least significant difference CV=coefficient of variations

Appendix XX. Mean square values of days to 50% flowering, days of 90% maturity, number of branch per plant, stand count at emergency, stand count at harvest, number of pod per plant, number of seed per pod, Total yield, and seed weight as affected by accessions in 2022/2023.

S.V	DF	DF	DM	NB	SCE	SCH	NP	NS	Yd.	SW
Block	2	2.81	103.7	0.16926	51.4	23.59259	0.16926	0.197	88184.174	150.3159
Trt.	8	463.4***	6580.38***	1.23***	4903.8***	2468.426***	1.229***	0.830***	393594***	4631.15***
Error	16	2.606	140.03	0.0834	385.69	233.59259	0.083426	0.05370	100064.47	348.481

S.V= sources of variations DF= days to flowering DM=days to maturity NB= number of branches per plant SCE= stand count at emergency SCH=stand count at harvest NP= number of pods per plant NS= number of seeds per pods Yd. = yield SW= seed weight LSD= least significant difference CV=coefficient of variations Ns=non-significant,*= significant, **= highly significant, ***= very highly significant.

Appendix XXI Mean square values of disease incidence accessions in Teppi 2022/2023

Source of variation	**D.F**	**Disease recorded**	
		ALS	ANT
Block	2	32.0009	34.33027
Accession	8	1534.33***	1492.656***
Error	16	37.14392	19.93310

D.F=degree freedom ALS=angular leaf spot ANT=anthracnose, ***= highly significant,

Appendix XXII Mean square values of macro minerals with genotype in Teppi, 2022/2023.

Source of variation	D.F	Macro Minerals				
		Ca	K	P	Mg	Na
Block	2	3129.2	95532.36	374.3206	375.950699	16.5554
Genotype	8	1495.939***	12322.9544**	18086.606***	317.215450**	1.78873604ns
Error	16	260.02538	9054.0361	2795.8354	183.019324	2.05465695

D.F=degree freedoms, Ca=calcium K=potassium P=phosphorus Mg=magnesium Na=sodium ns=non-significant, ***= high significant

Appendix.V Mean square values of micro minerals and proximate analysis with genotype in 2022/2023.

S.V	D.F	Micro mineral				Proximate analysis
		Fe	Cu	Zn	Mn	CP
Block	2	12.607933	0.323703	1.288507	0.795388	7.3043
Accessions	8	4.359431^{ns}	0.084103^{ns}	2.655037^{ns}	0.044464^{ns}	14.178**
Error	16	11.14486	0.092773	3.8281458	0.063923	6.80833

S.V=sources of variations, D.F= degree freedoms, Fe=iron Cu=copper Zn=zinc Mn=manganese CP=crude proteins ns=non-significant

Appendix Figure 1 (A-L) Photos from site selection, field, and laboratory activities during the study.

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