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DEPARTMENT OF HORTICULTURE

EFFECT OF INTER ROW SPACING AND VARIETIES ON GROWTH AND YIELD OF FENUGREEK (*Trigonella foenum-graecum L.*) AT WOLISO DISTRICT, SOUTH WEST SHOA ZONE, ETHIOPIA

MSc. THESIS

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Effect of Inter Row Spacing and Varieties on Growth and Yield of Fenugreek (*Trigonella foenum-graecum L.*) at Woliso District, South West Shoa Zone, Ethiopia

A Thesis Submitted to the School of Graduate Studies in Partial Fulfillment of the Requirements for the Degree of Master of Science (MSc.) in Horticulture

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We hereby certify that we have read and evaluated this Thesis entitled "**Effect of Inter Row Spacing and Varieties on Growth and Yield of Fenugreek (*Trigonella foenum-graecum L.*) at Woliso District, South West Shoa Zone, Ethiopia**" Prepared under our guidance by Mr. Leta Abebe Bedada. Hence, we hereby recommend that the thesis shall be submitted as fulfilling the requirements for the award of a MSc. Degree in Horticulture.

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DEDICATION

This work is dedicated to my family, especially to my mother Dadhi Megersa Keba and my brother Iticha Abebe as well as my spouse Bontu Negash Mosisa who paved my way towards education and nursing me with heartfelt affection and love for the success of my life at large.

STATEMENT OF THE AUTHOR

I declare and affirm that this thesis is my work and all sources of materials used for this thesis have been dually acknowledged. This thesis has been submitted in partial fulfillment of the requirement for MSc. degree at Wolkite University, College of Agriculture and Natural Resource Management and is deposited at University Library for users under the rules of the Library. I seriously declare that this thesis was not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate. Brief quotations from this thesis are allowable without special permission provided that accurate acknowledgement of source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the department or the dean of the school of graduate studies when in his/her judgment, the proposed use of material is in the interests of scholarship. In all other instances, however, permission must be obtained from the author.

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BIOGRAPHICAL SKETCH

The author, Leta Abebe Bedada, was born on May 13,1988 G.C from his mother Dadhi Megersa and his father Abebe Bedada at Arfinjo Dega kebele in Dire Incinni district, West Shewa Zone, Oromia National Regional State, located 155km West of Addis Ababa. He attended his primary school education at Dire Incinni Elementary School. In the subsequent years, he enrolled Dire Incinni Secondary School and Ambo Preparatory level education at Ambo Preparatory School in Ambo town. Finally he passed the Ethiopian Schools Leaving Certificate Examination in 2010 G.C and joined Samara University, College of Agriculture in 2011 G.C. After three years of his study, he graduated with B.Sc. Degree in Horticulture on June 29, 2013 G.C. He then, employed by Oromia Bureau of job creation and skills in 2016 G.C and assigned to Oromia National Regional State, Jimma Zone, Jimma poly technic college, where he served for two years and four months as crop production and marketing management department. Then, in 2018 G.C, the job creation and skills bureau of Oromia offered him the opportunity to transfer to woliso poly technic college he worked as instructor of crop production and team leader of agriculture department for three years in Woliso poly technic college. In September 2022 G.C, he joined the post graduate program of Wolkite University to pursue his Master of Science degree in Horticulture.

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ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
CIMMYT	International Maize and Wheat Improvement Center
CSA	Central Statistical Agency
DANRO	District Agriculture and Natural Resource Office
DAP	Diammonium Phosphate
DMRT	Duncan's Multiple Range Test
DZARC	Debre-Zeit Agricultural Research Center
EIAR	Ethiopian Institute of Agricultural Research
GLM	General Linear Model
LSD	Least Significant Difference
OARI	Oromia Agricultural Research Institute
RCBD	Randomized Complete Block Design
SARC	South Agricultural Research Center
SAS	Statistical Analysis System
$t\ h^{-1}$	tons per hectare
m.a.s.l	meter above sea level

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ABSTRACT

Fenugreek (Trigonella-foenum-graecum L.) is a legume crop which is used as a spice, vegetable, animal feed and medicinal plant. Inter row spacing is one of the yield limiting factors on fenugreek production. A field experiment was conducted at Woliso Polytechnic College during the 2023/2024 cropping season. To evaluate and determine the combined effect of inter-row spacing (10cm, 20cm, 30cm and 40cm) and varieties (Burqa, Chala, Ebbisa, Wereilu and one local variety for check) on yield and yield components fenugreek. The experiment *was laid out under Randomized Complete Block Design with Factorial arrangement and three replications.* Based on the data analysis, *the higher yield and yield components were recorded from planting of fenugreek with the wider inter-row spacing of 40cm. The shortest days for 50% flowering (44.6 days), the shortest days for 90% maturity(117.9), the highest number of primary branches (6.73), the highest number of pods per plant^{-1} (29.33), the highest number of seeds per pod^{-1}(21.6), the highest pod length (19.3), the highest 1000g seed weight (20.6), the highest above ground biomass (3568.33Kg ha^{-1}), the highest harvesting index (40.2% and the highest seed yield (1586) were recorded from the 40cm inter-row spacing followed by 30cm. On the other hand, the lowest yield (324.66 kg ha^{-1}) and yield attributes were recorded when the crop was grown under the smallest inter-row spacing of 10cm. The higher number of primary branches, number of seeds pod^{-1}(21), pod length (19.3), 1000g seed weight (20g) and seed yield (1586 kg ha^{-1}) were recorded from Burka inter acted with 40cm followed by Chala, Wereilu, and Ebbisa verities whereas the lower grain yield and yield component was recorded from with the interaction of 10cm. From the current research-based yield and yield component planting of Burka variety with 40 cm inter row spacing is performing well and recommended to the local farmer to increase the yield of fenugreek crop.*

Keywords: - Fenugreek, varieties, inter-row spacing, yield, yield components

1. INTRODUCTION

Fenugreek (*Trigonella foenum-graecum L),* family -Leguminoceae an annual herb is well known as flavor, curry powder and spice (Dhull *et al.*, 2021). Fenugreek is grown on a wide range of soils but flourishes on well drained loams or sandy loams. Additionally, fenugreek grows well in arid environments, such as marginal or slightly alkaline soils (Minjaro *et al.,* 2023). Ethiopia is home to the fenugreek subspecies, known as the Mediterranean ecotype, its distribution extends from Eritrea to Somalia (Bekele and Geleta 2020). In Ethiopia, fenugreek cultivation covered about 32,507.42 hectares of agricultural land with an annual production of over 28,925.21 tons of fenugreek seeds (CSA 2021).

The production and distribution of fenugreek in Ethiopia is almost similar to that of other cool season food legumes (Roba and Simion 2022). There is a large genetic diversity of the crop in Ethiopia (Fikreselassie *et al.,* 2012). In Oromia region, out of the total land area of 2,549,031.00 hectares planted by pulses, fenugreek covered 2,449.00 hectares, which is 0.06% of the production area covered by all pulses grown in the region in 2015/16 cropping season (CSA 2021). In Woliso district the total production area is 157 ha with productivity of 1.2 ton ha^{-1} during cropping season 2021/2022. In Ethiopia, fenugreek growing regions range from 1800-2300 m.a.s.l. they are characterized by a subtropical climates, including wet and dry seasons (Getu and Biruk 2022; Roba and Wassu 2024*).*

Fenugreek is a multipurpose crop that can be used for food, feed, spices, medicine, and the oil is also used in perfumery in France (Roba and Simion 2022). It enriches soil through symbiosis with microorganisms, which fix atmospheric nitrogen (Meena *et al.,* 2017). In Ethiopia, the crop is produced either as a spice or for other special purposes, such as food for nursing mothers and infants as a breakfast beverage for others (Roba and Simion 2022). It is known as "Abish" and has been considered as a rotation crop, it improves both the soil structure and fertility, flavoring of the traditional bread, medicinal plant to lower blood glucose level, treat gastric disease and abdominal discomfort, boost milk production in lactating mothers, and to increase body weight (Roba and Tana 2018).

The crop is rich in protein (25.5%), fats (5-10%), and carbohydrate (45-60%) (Sharma 2021; Roba and Wassu *et al.,* 2024). In some parts of the country such as south western Ethiopia, fenugreek is used in income generation (Agize and Zouwen 2016). It is also used as green manuring; green leaves have been used as vegetable and seed production for the international market of condiments or feed (Aasim *et al.,* 2018; Camlica and Gulsum 2021). Currently, its seeds are highly demanded in the market and it can have great economic value for both producers and countries (Kebede 2020).

Fenugreek productivity in Ethiopia is very low compared to world average which is 1.29 ton ha^{-1} (Getu and Hirko 2022). Shortage of improved varieties, lack of certified seed, inadequate fertilizer, inadequate knowledge on production and management systems, poor agronomic practices, poor marketing system and presence of diseases and insect pests are the major factors have contributed to the lower crop yield in the country (Kebede 2020). Although different improved Fenugreek varieties such as Burka, Chala, Ebbisa, and Wereilu are released by different Agricultural Research Centers, agronomic factors affecting growth and seed yield of fenugreek like row spacing are not well studied in the study area. Row spacing has significant influence on majority of agronomic traits of Fenugreek varieties (Minjaro *et al.,* 2023).

Row spacing also modifies plant architecture, leaf photosynthetic capacity, and dry matter partitioning in many spice crops (Seyedi *et al.,* 2024). Proper row spacing helps to avoid the development of foliar diseases, because wider rows increase air penetration to minimize moisture through the crop canopy, thus making the environment suboptimal for disease infestation (de Souza Jaccoud-Filho *et al*., 2016). Optimum spacing to promote healthy growth of aerial and underground parts of the plant allows for the efficient use of solar radiation, branch capacity, better light interception and penetration into the crop canopy and enhances light utilization efficiency, nutrients and land as well as air spaces and water enhance fenugreek yield (Ouji *et al.,* 2016; Sarkar 2021).

Sowing fenugreek varieties sowing at the appropriate row spacing significantly enhance the number of branch, number of pod, number of seed per pod, the pod length, seed weight per pod and 1000g- seed weight and then finally produce high seed yield (Zandi *et al*., 2011; Tiwari *et al.,* 2016). A larger row spacing allows the sun radiation that falls between crop

rows to be used; a smaller row spacing causes plants to get crowded and suffer from mutual shading; a narrower row spacing may result in lower yield due to increased competition among plants for moisture and nutrients (Sharanya *et al.*, 2018).

Fenugreek Varieties are generally selected for higher yields and greater tolerance to adverse conditions and early maturity (Meena *et al.*, 2017; Mohammed *et al.*, 2019) also reported significant variety and inter row space interaction on fenugreek's phenology, growth, yield, and yield components. Additionally, it was said that not every variety performed well with the same plant spacing (Tiwari *et al.*, 2016). In this regard, there is no report in study area. Therefore, the study was conducted with the following objectives:

General Objective:

To evaluate and determine the effect of inter row spacing on growth, yield and yield component of fenugreek (*Trigonella foenum-graecum* L.) Varieties under the agro-climatic conditions of Woliso district.

Specific objective:

- To evaluate and determine the effect of inter-row spacing on growth, yield and yield components of fenugreek varieties under the agro-climatic conditions of Woliso district south west shoa zone, Ethiopia
- To evaluate and determine the growth and yield performance of fenugreek varieties.
- To evaluate and determine the interaction effects of inter-row spacing and fenugreek varieties on yield and yield components.

2. LITERATURE REVIEW

2.1. Origin and Distribution of Fenugreek

Understanding of the origin of the agricultural plants is essential for plant breeding in order to identify wild relatives, related species, and new genes, particularly dominant genes, sources of disease resistance, etc. understanding of the origin of the agricultural plant is vitally important in order to preventing genetic erosion, or the loss of germplasm due to the loss of ecotypes and landraces (Paul and Debnath 2018). *Trigonella foenum-graecum L*. is probably native to the eastern Mediterranean region, western Asia, and India, but its natural distribution is difficult to determine, as it has been grown since antiquity, the first written record dates back to 400 BC.

Fenugreek cultivation extended throughout the China, Ethiopia, Europe and the southern part of the former Soviet Union and throughout the Arab world (Shahrajabian *et al.*, 2021). The place of origin of a species, as explained by (Vavilov 1926) is an area that contains the largest amount of genetic variability of that species (Vavilov 2009). According to Vavilov, variation in a species is a function of time, since the region with the highest variation in that species is probably the center of origin or a secondary center of diversity because it has likely supported and sustained that species for a longer period of time than any other region. The Mediterranean region is known to be the natural habitat of the genus Trigonella (Khairnar *et al.*, 2022).

Fenugreek is considered an ancient cultivated plant. Fenugreek is native to and still cultivated in the Near East, Mediterranean and Indian subcontinents. It is proposed that cultivated fenugreek evolved separately and coincidently in the Mediterranean and India, with gradual migration and mingling of the two forms (Boddy 2020). The subspecies Indica is now distributed in India, Sri Lanka, Pakistan, Iran and Central Asia. The other subspecies, Mediterranean includes several sub-series and ecotypes and distributed in Northern Africa, Ethiopia, Armenia, Turkey and western China.

2.2. Botany of Fenugreek

Trigonella comes from the Greek word *Trigon* means „little triangle" and *foenum-graecum* from the Latin *foenum* (meaning hay) and *graecum* (meaning Greek), which together mean "Greek hay"(Roba and Simion 2022*)* noted that fenugreek is known in Ethiopia by various vernacular names such as abish (Amharic); abeakhe or abakte (Tigrigna); ulbata, sunqo, shumifa (Oromiffa), and gararo (Kaffigna). Fenugreek is an annual, dicotyledonous, self-pollinating plant belonging to the Fabaceae family. Its stems are branched, thick, erect, hairy or green to purplish in color. The leaves are trifoliate, composed of the three toothed ovate leaflets (Savchenko and Khazieva 2020). The flowers are solitary or in groups of two, borne on the axils and are white or pale yellow to light purple, presenting a triangular shape.

Fenugreek produces both cleistogamous (closed, self-pollinating) and aneictogamous (open, typically cross-pollinating) flowers. Its matured seeds are very hard, flat, light brown to reddish brown in color, and marked by grooves that delineate two unequal parts (Gupta 2010). As for its growth habit, fenugreek is erect, hairy Lucerne-like (meaning it resembles alfalfa, Medicago sativa), and grows to a height of about 90 cm. The roots form a mass of fingerlike structures. The thin, sword-shaped pods, which are 10-15 cm long and10-20 seeds are contained in the slender and curved tips resembling beaks. The plant emit a spicy smell, which, even after touching, remains on the hands. There are both wild and farmed kinds (Yadav *et al.,* 2019).

On the basis of Vavilov's collection of fenugreek from Yemen and Ethiopia (which he called Abyssinia), cultivated fenugreek were divided into two subspecies: *T. foenumgraecum spp*. iemensis (referring to the Yemen), which has short stems and flowers, entire marginate leaflets, lanceolate and short calyx teeth, erect standard with dots, dried corolla at base of pod, short and lanceolate pods, a small number of leaves and a short vegetation period; and *T. foenum-graecum spp.* culta (Alefeld) Gams, which had been first noted by (Zandi *et al.,* 2017) and are characterized by taller plants with dentate leaflets, long flowers and long calyx teeth, reflexed standard without dots, long and linear pods, many leaves and a long vegetation period.

2.3. Agro-Ecology of Fenugreek

Fenugreek has been cultivated in many different countries across the globe under various environments. This wide distribution of its cultivation in the world is the characteristic of its ability to adapt to a wide range of climatic conditions and growing environments (Mehrafarin *et al.*, 2011). It can be grown under a wide range of climatic conditions. But, mostly it requires cool climate and dry weather at the time of maturity. The reported life zone of fenugreek is 8 to 27 0C with annual precipitation of 400 to 1500 mm and a soil pH of 5.3 to 8.2 (Meena 2009).

Concerning soils fenugreek ca be well cultivate on any kind of soil (from loam to sandy). But the ideal soil is a well-drained loam. Heavy loam soils with good drainage and adequate organic matter can be used. It can also be grown on black soils (Basu *et al.*, 2008). As a dry-land crop, its water requirement is low. Fenugreek growing regions in Ethiopia are the mid-to high plateaus (1800-2300 m.a.s.l.), which are characterized by a subtropical environment featuring wet and dry seasons with moderate or low annual rainfall (Roba *et al.*, 2018)

2.4. Economic Importance of Fenugreek

In Ethiopia, fenugreek is used for different purposes; the whole plants used as an animal feed as well as vegetable for human consumption, while the seed is used as spice and for medicinal purposes. It mainly cultivated for spice crop, and it is considered as good to enhance soil fertility due to fixing of atmospheric nitrogen (Roba and Simion 2022).

2.4.1. Food crop

In south and central Asia, both ripe and unripe seeds as well as green leaves have been eaten as food (Mohammad *et al.*, 2019). The protein content of Fenugreek is high (43.8g/100g) and most of the time it is used to supplement low-protein foods such as cereal crops (Legesse *et al.*, 2020). Fenugreek is consumed by nursing mothers, who consume larger quantities of pulses to maintain the supply of breast milk. The leaf of fenugreek contains 86.1% moisture, 4.4% protein, 0.9% fats, 1.5% minerals, 1.1% fiber and 6.0% carbohydrates (Huggins 2022).

Its mineral and vitamin contents are calcium, phosphorus, iron, carotene, riboflavin, niacin and vitamin C (Kumar et *al.*, 2020). The seed contains 13.7% moisture, 26.2% protein, 5.8% fat, 3.0% mineral, 7.2% fiber and 44.1% carbohydrate (Roba and Mohammed 2024). In

India, Ethiopia and Turkey meatless diets are consumed for prolonged periods because of religious, cultural or economic factors. Fenugreek helps to bridge the nutritional gap brought by such diets because of its high protein content (Ghanghas *et al.,* 2021). In India and North Africa, young plants are cooked and used as vegetables. The leaves and freshly sprouted shoots are an important vegetable (Dar and Kaushik 2022).

2.4.2. Animal Feed

As its species epithet foenum-graecum („Greek hay") implies, fenugreek is used as a forage species. High quality and dry land-adapted forage crops such as fenugreek have potential to help the cattle industry by reducing feed needs by improving feed efficiency and reducing water consummation for fodder production. It can produce a high yield with high quality fodder without putting cattle at risk of bloat. This crop has the potential to decrease the usage of artificial growth promoters since it includes compounds that encourage animal growth that are absent from other forage legumes (Aasim *et al.,* 2018).

At 10% bloom or maturity, fenugreek showed a greater proportion of readily soluble dry matter than alfalfa (Kumar *et al.,* 2019). This indicates that fenugreek can be harvested later in the season without jeopardizing its nutrient quality or digestibility. Fenugreek forage is highly digestible, has a crude protein content of 15-20%, and consistently produces forage of high quality for ruminants (Meena 2017). Fenugreek had a nutritive value, it has been shown to be more digestible and have a higher nutrient content than other competing forages (Alemu and Doepel 2011). Fenugreek has been used as forage due to its stimulating and improving of milk production in mammals (Sevrin *et al.,* 2019)

2.4.3. Spice uses

Fenugreek is known as a spice. It has been used as flavoring agent, curry powder, tea, and as a food preservative (Sarwar *et al.,* 2020). In Ethiopia, the seeds are used for preparing some traditional sauces ("wot"), the seeds are usually roasted, finely ground and the powder is used during non-fasting periods. Moreover, fenugreek flour is used to flavor and soft "injera" (thin pancake-like bread usually made of teff, sorghum, maize, wheat or other cereal) (Terefe 2017). Fenugreek seeds and leaves are mixed with maize and wheat to make food more flavorful (Godebo *et al.,* 2019).

2.4.4. Medicinal uses

Fenugreek is one of oldest medicinal plants; its leaves, seeds and sometimes even the whole plant have been used as medicine (Sun *et al.,* 2021). Powdered fenugreek seed extracts are used to treat a wide range of conditions, including as skin irritations, head lice, wounds, and high blood sugar. (Hamza *et al.,* 2019). Fenugreek seed extract can be used as an anti-diabetic to lower blood sugar and cholesterol levels (Bafadam *et al.,* 2021).

Fenugreek seed extracts can be used to make teas to reduce fever and menstrual pains, or as ointments to treat skin infections and irritation (Kumari *et al.,* 2022). Ground seeds are often used to give a maple flavor to sweets and candies. Taken internally, fenugreek is used to treat bronchitis, coughs, respiratory problems and sinus conditions (Al-Saady *et al.,* 2018). Fenugreek, as most of the species of the genus Trigonella, is strongly anti-fungal and can be used as an insect repellent *(*Ruwali *et al.,* 2022).

2.4.5. Income source

Spices have a significant role in the nation's production system and foreign exchange gains. The spice sub-sector has immense potential for economic development and poverty reduction (Tesfa *et al.,* 2017*)* among which fenugreek is an important one. They have a significant impact on farmers' transition from subsistence to market-oriented production (Tesfa *et al.,* 2017). Among seed spices, fenugreek is one of which provides various purposes in developing and under developed countries as they shouldn‟t stay back for capturing the potential emergent global markets for fenugreek (Basu *et al.,* 2019).

These authors also pointed out that fenugreek can be grown with minimal agronomic inputs (low production cost, require less irrigation, possible to produce in dry arid and semiarid region) and it is high value crop on the international market. Vidyashankar (2014) reported that fenugreek is found in nearly every market in Ethiopia and has been cultivated in Ethiopia since ancient times for use as food, spices and medicinal purpose. Similarly, (Kebede 2020) suggested that fenugreek seed has many benefits for both producers and consumers in Ethiopia. Beriso *et al.,* (2016) also stated in their finding it fetches high revenue for producers.

2.5. Production Status of fenugreek in Ethiopia

Ethiopia has grown and utilized spices from the time of immemorial. Small-scale holder farmers plant a variety of native and exotic spice crops throughout the nation, among which fenugreek serving as a major source of income for farming households (Tesfa *et al.*, 2017). Similar to other cool-season legumes including faba bean, field pea, lentils, chickpea, and grass pea, fenugreek is produced across Ethiopia (Roba and Simion 2022). Despite being ranked sixth among highland pulses at its current production size, it is the most profitable (Fikresillase *et al.*, 2012).

It is produced in different parts of the county like, Oromia, Amhara, south parts of the country and Tigray. In these regions, Hararge, central Shewa, mid and highlands of Bale, Arsi, Wollega, south Wallo and Gonder are the top producing zones (Tesfa *et al.*, 2017; Beriso *et al.*, 2016). According to (CSA 2010-2019) the total area of land under the production and total volume of production of fenugreek has been growing inconsistently over ten years (Table 1). The primary cause of the irregularities in the overall fenugreek production was the underutilization of the spice subsector's potential and the inadequate research and extension given to the crop's production and use. Furthermore, farmers' endeavors to cultivate, utilize, and market the crop have not received adequate assistance from extension agencies (Tesfa *et al.*, 2017).

Table 1: Fenugreek production and area coverage in Ethiopia (2010-2019)

No	Cropping season (years)	Area covered (ha)	Total production (Qnt/ha^{-1})	Productivity (ton ha^{-1})
1	2010	21183.00	271220.00	1.28
2	2011	14670.04	179052.29	1.22
3	2012	39964.54	362939.17	0.9
4	2013	32909.63	293334.93	0. 89
5	2014	24426.24	456266.15	1.87

6	2015	20524.39	251286.63	1.22
7	2016	29837.60	356537.64	1.19
8	2017	34603.35	454807.61	1.3
9	2018	32587.00	436373.92	1.34
10	2019	22344.12	288299.9	1.29

Source: Compiled from CSA, 2010-2019

2.6. Effect of row spacing on growth, yield and yield component of Fenugreek.

Increasing the productivity of spice crops requires adopting the ideal row spacing; plants growing in rows too wide may not utilize available natural resources like light, water, and nutrients efficiently, while plants growing in rows too narrow could lead to intense competition between rows (Abdurrahman 2022). According to (Zandi *et al.*, 2011) row spacing is a significant element that directly affects fenugreek yield. Similarly, row spacing influences fenugreek yield and other yield-related characteristics. It can also alter plant architecture, the photosynthetic capability of leaves, and the dry matter portioning of legume crops (Ullah *et al.*, 2021).

Optimizing the pod capacity of fenugreek may be achieved by planting in rows that are optimally spaced. (Reza *et al.,* 2021). Increased plant density leads to increased competition among plants for growth requirement factors such as sufficient space for shoot and root growth and development, light, nutrients and moisture, the total biological yield per unit area increases due to increased number of plants per unit area (Tiwari *et al.,* 2016; Singh *et al.,* 2021) found that the maximum seed yields were obtained from the closer row spacing treatments. Row spacing was found to enhance the number of branches (Halesh *et al.,* 2000; Gowda *et al.,* 2006; Mohamed 1990). On the other hand, (Singh *et al.*, 2005) found that row spacing was associated with a drop in yield attributes.

2.7. Interaction Effect of varieties and row spacing on Yield Components of Fenugreek

Fenugreek varieties had significant effect on yield and yield related parameters. Days to flowering, days to maturity, pod length, plant height, 1000g-kernel weight and seed yield

were markedly affected by the varieties (Sharanya *et al.,* 2018). In addition, a variety's genetic composition and growth environment impact yield and yield-related characteristics (Al-Maamari *et al.*, 2018). Bekele *et al.*, (2020) also reported on the yield variance of various fenugreek varieties. The standard check chala showed the best yield (quintal/hectare) in comparison to other varieties in both in individual and combined locations.

Similarly, reported a marked different among the fenugreek varieties on seed size and kernel weight due to genotypic variation. More productive branches were identified in 30cm spaced rows than other row spacing, indicating the efficient usage of growth resources including water, nutrients, and solar radiation by fenugreek cultivars of tall and medium structure, while plant height was shown to be more efficient under a narrower row spacing (Wojo *et al.,* 2016). Substantial increases in yield-related traits like productive branch, number of pods, seed per pod and 1000-grain weight are the chief reasons for the better seed yield in fenugreek cultivars (Al-Maamari *et al.,* 2020). Different fenugreek varieties responses to varying row spacing owing to their different genetic makeup, primarily plant stature and branching ability (Sharanya *et al.*, 2018).

Seed weight and number of seed per pods are inherent characters of fenugreek cultivars that are less affected by growing conditions *(*Sindhu *et al.,* 2018). Owing to their diverse genetic makeup, different fenugreek cultivars showed varying yield potential under the same or different environmental conditions (Fikreselassie *et al.,* 2012). Genetic variation among spice crops is very common and different fenugreek genotypes produce various seed yields, shoot biomass and Harvesting Index (Aasim *et al.,* 2018). Therefore, row spacing is a prominent factor that directly influences fenugreek yield, however, different fenugreek cultivars behaved differently in this regard (Granado *et al.,* 2021). Different row spacing had significant effects on the productivity of different fenugreek cultivars to varying degrees due to variations in the plant stature ability of the cultivars (Tiwari *et al.,* 2016). Narrow row spacing favored low pod cultivars, whereas tall cultivars performed better in wider rows (Wegayehu *et al.,* 2022). Furthermore, the interaction effect of variety and row spacing significantly affected thousand kernels weight, number of branch and number of pod and seed yield (Negasa 2018).

3. MATERIALS AND METHODS

3.1. Description of the Study area

The experiment was conducted at Woliso Technical and Vocational Educational and training College research field. South-West Shoa Zone of Oromia Region, Central Ethiopia. The site is about 114 km, from Addis Ababa, Geographically the experimental area is Located at 8º31'60"N latitude with 37º58'60"E longitude and at an elevation of 2049 m.a.s.l. The area receives 1400mm rain fall with mean minimum and maximum temperatures 12.9ºC and 25ºC, respectively.



Figure 1: Location map of the study area

The study area has a bimodal rainfall pattern where the main rainy season starts in June and terminates by the end of September. Leguminous crop including Fenugreek, Chick pea and Vetch are produced on residual soil moisture mainly as sequential crops in the beginning of the dry season, whereas as oil crops such as Noug are growing predominantly during the rainy season.

3.2. Planting material

Five Fenugreek Varieties namely: Burqa, Ebbisa, WereIlu, chala, and Local variety were used in the experiment. They were obtained from Ambo Agricultural research center, their characteristics is as shown in Table 2.

Table 2: The characteristics of the varieties are as shown

Name of variety	Released Research Center	Released Year	Growing Altitude(m)	Rainfall (mm)	Productivity ton/ha
Burka	Sinana Research Center	2016	1650	120-500	2.2
Ebbisa	Sinana Research Center	2012	1650-2400	120-500	1.5
Wereilu	Sirinka Research Center	2016	2300-2800	868-1000	1.2
Chala	Debrezeit Research Center	2005	1650-2400	948	1.65
Local variety					

Source: Ministry of Agriculture (2016**)**

3.3. Treatments and Experimental Design

The treatments consisted of a factorial combination of four inter row space (10cm, 20cm, 30cm and 40cm and five fenugreek varieties (Burqa, Ebbisa, Chala, Wereilu and local variety) making a total of 20 treatment combinations. The experiment was laid out in a randomized complete block design with factorial arrangement in three replications. The gross plot size was $6m^2$ which was 2m wide and 3m long with 0.50m space between plots and 1m between blocks. There was a total of $660m^2$ area for experimental site.

Table 3: Treatment combination in factorial arrangement

Varieties	Inter row spacing	Treatment combination
Ebbisa	10cm	Ebbisa*10cm
Ebbisa	20cm	Ebbisa*20cm
Ebbisa	30cm	Ebbisa*30cm
Ebbisa	40cm	Ebbisa*40cm

Wereilu	10cm	Wereilu*10cm
Wereilu	20cm	Wereilu*20cm
Wereilu	30cm	Wereilu*30cm
Wereilu	40cm	Wereilu*40cm
Chala	10cm	Chala*10cm
Chala	20cm	Chala*20cm
Chala	30cm	Chala*30cm
Chala	40cm	Chala*40cm
Burka	10cm	Burka*10cm
Burka	20cm	Burka*20cm
Burka	30cm	Burka*30cm
Burka	40cm	Burka*40cm
Local Variety	10cm	Local*10cm
Local Variety	20cm	Local*20cm
Local Variety	30cm	Local*30cm
Local Variety	40cm	Local*40cm

3.4. Experimental Procedure and Management

Land preparation of the experimental field was done by oxen driven local plow (Maresha) in accordance with the local farming practices of the farmers. The plots were prepared as per the layout, leveled manually and the treatments were assigned randomly and seeds were drilled in furrows in different row spacing. All agronomic practices including sowing and seeding rate, fertilizing, watering, weeding, soil cultivation and other management practices was applied.

3.5. Sowing and fertilizer application

The sowing was done by hand in different row spacing to achieve a desirable row spacing of fenugreek crop varieties. 25 kg ha^{-1} NPS is recommended. Half of the N, dose and the entire quantity of Nps are applied at the time of sowing and the remaining half of nitrogen was applied as side dressing 30 days after first sowing (Meena 2018).

3.6. Data Collected

Five healthy plants were randomly selected in each plot as per treatment. Plastic coated labels were tagged for identification and recording of various observations. The following data were recorded:

Days to 50 % emergence (DE): Days to 50 % emergence was determined by counting the number of days from sowing to the time when 50 % seedlings emerged.

Days to 50% of flowering (DF): Days to 50% of flowering were determined according to method prescribed by (Tahir *et al.*, 2009) by recording the number of days from date of emergence to the appearance of the first flower in 50% of the plants based on visual observation.

Days to 90% maturity (DM): Days to maturity were recorded by counting days from emergence to days on which about 90% of the plant on plot attained physiological maturity using maturity indices of fenugreek based on visual observation i.e. when leaves and pods of the plants on the plots were turned to yellowish-green color.

Plant height (cm): Height of five randomly taken plants from each plot was measured in centimeter (cm) from the ground to top of the plant by ruler at physiological maturity stage.

Number of primary branches per plant (NB): The number of primary branches was counted from five randomly selected plants were recorded at physiological maturity and their average was expressed as number of primary branches per plant.

Number of pod per plant (NP): The number of pods was counted from five randomly taken plants at harvest and the mean was expressed as number of pod per plant.

Pod length (cm): Length of five randomly taken pods from each plot was measured in centimeter (cm) from the bottom to top of the pods by ruler at physiological maturity stage.

Number of seeds per pod (SPP): Total number of pods from five randomly taken plants were threshed and the number of seeds was counted and total number of seeds was divided by total number of pods to compute average number of seeds per pod.

Thousand seed weight (1000g): Thousand seed weight was determined based on the weight of 1000 seeds sampled from the seed yields of each plot by manual counting and weighed with an electronic balance.

Above ground dry biomass yield (TGBM kg ha^{-1}): Above ground dry biomass yield was determined at physiological maturity from five randomly taken plants from the rows of each plot after sun drying till a constant weight. The dry biomass per plant was then multiplied by the total number of plants per net plot. This value was used to calculate the harvest index as well.

Seed yield (kg ha^{-1}): Harvesting was performed at maturity when the color of leaves and pods changed to yellowish-green. The plants were then threshed and separated into seed and straw to make the seeds ready for laboratory analysis. To determine seed yield, yield was adjusted to moisture level of 10%. Finally, yield per plot was converted to per hectare and average yield was reported in kg ha^{-1}.

Harvest index (HI): Harvest index was recorded as the ratio of dry seed yield to the aboveground biomass yield per plot. Harvest index (HI) of fenugreek was calculated using (Bange *et al*., 1998) equation as follows and expressed by %.

3.7. Data Analysis

All collected data were subjected to analysis of variance (ANOVA) using statistical analysis of software (SAS) procedure of version 9.3 (SAS 2004). The means were compared and separated using Duncan's multiple range tests at 5% level of significance (Steel and Torrie 1980). Correlation between parameters was computed to understand the associations which exist among parameters of phenology, growth, yield and yield components of fenugreek.

4. RESULTS AND DISCUSSION

4.1. Days to 50% Emergence

Analysis of variance showed that both inter row spacing varieties and their interaction are not significant ($p \leq 0.05$) effect on days to 50% emergence of fenugreek (Table 4).

Table 4: Effect of row spacing and varieties on main effect factors of Days of 50% Emergence, Days of 50% flowering, Days of 90% maturity, Number of pods per plants, Ground biomass and harvesting index

Inter row space (cm)	DE 50%	DF 50%	DM 90%	number of pods plant^{-1}	TGBM Kg/ha^{-1}	HI%
10	5.26^{a}	51.86^{a}	128.3^{ab}	20.13^{d}	1588.33^{d}	32.2^{c}
20	5.26^{a}	49.26^{b}	133.1^{a}	23.86^{c}	2215.47^{c}	35.73^{b}
30	5.26^{a}	45.33^{c}	122.6^{bc}	27.066^{b}	3345.67^{b}	39.2^{a}
40	5.27^{a}	44.6^{c}	117.86^{c}	29.33^{a}	3568.33^{a}	40.2^{a}
Mean	5.26	47.76	128.33	25.1	2679.45	36.83
LSD (5%)	0.039^{ns}	2.59**	10*	1.55**	143.84**	1.87*
Varieties						
Ebbisa	5.283^{a}	49^{b}	122^{bc}	26.9^{a}	2611.83^{b}	41.66^{a}
Wereilu	5.266^{a}	53.58^{a}	140^{a}	24.83^{b}	2849.67^{a}	35.25^{c}
Chala	5.250^{a}	46.16^{b}	132^{ab}	25.25^{ab}	2715^{ab}	38.33^{b}
Burka	5.258^{a}	46.83^{b}	121^{bc}	26.25^{ab}	2616.17^{b}	40.58^{a}
Local variety	5.258^{a}	43.25^{c}	112^{c}	22.25^{c}	2604.58^{b}	28.33^{d}
Mean	5.26	47.76	125.48	25.1	2679.45	36.83
LSD (5%)	0.044^{ns}	2.9**	11.2**	1.73**	160.82**	2.09**
CV (%)	1.02	7.35	10.82	8.38	7.26	6.87

Means in a column with the same letter are not significantly different at 5% probability level; **Keys;-** ** significant at $p<0.01$, CV= Coefficient of variation, DE=days of 50% emergency, DF=days of 50% flowering, DM=days of 90% physiological maturity, TGBM=Total ground biomass and HI=harvest index

4.2. Days to flowering 50%

Analysis of variance showed that the effect of inter row spacing and varieties was highly significant ($P<0.01$) on days to 50% flowering, but their interaction was not significant (Table 4). Days to flowering was significantly decreased from (51.86 to 44.6 days) as inter-row spacing increased from 10cm to 40cm (Table 4). The shortest days to 50% flowering was recorded from planting of Fenugreek varieties at 30cm and 40cm which is 45.33 and 44.6 days respectively followed by 20cm whereas the longest days to 50% flowering was recorded from 10cm which is 51.86 days (Table 4). This is may be due to competition for resources such as water, nutreints, and sunlight among plants.

The result line with this result, (Minjaro 2023) who reported that too longest days to 50% flowering (64.25) were recorded at narrow (20 cm) row spacing, while the shortest (60.50) were recorded at wider (30 cm) row spacing of fenugreek. Similarly, (Masa *et al.*, 2017) who reported that the wider plant spacing of 50cm reduced number of days to flower than 40cm plant spacing in broad bean. On other hand, (Sharma 2000) found the earliest flowering at closer spacing (20 cm) of coriander as compared to wider spacing of 30 and 40 cm.

Regarding to varieties Days to 50% flowering were highly significant ($P<0.01$) effect on varieties of Fenugreek. The local variety took the shortest days (43.25 days) to flower, while variety Wereilu took longest number of days (53. 58) to flower (Table 4). The result is in agreement with report of (Sharanya *et al.*, 2018) who reported that days to 50% flowering of fenugreek was highly significantly influenced by varieties. Similarly, (Mekuanint *et al.*, 2018) reported that varieties had significant effect on days to flowering of chickpea. According to (Nchimbi 2010) also noted significant variations in the number of days needed to reach 50% flowering among common bean genotypes

4.3. Days to 90% Physiological Maturity

Analysis of variance showed that inter row spacing significantly ($p<0.05$) influenced the number of days to require to reach physiological maturity of fenugreek plants, while their interaction was not significant to affect days to maturity (Table 4). Increasing the inter row space significantly decreased the duration required to reach physiological maturity. Fenugreek plants treated with the highest inter row spacing (40cm and 30cm) required the shortest number of days (117.86 and 122.6 days) to reach physiological maturity compared to

the plants treated with narrower spacing which took long number of days which is 133.1 and 128.3 respectively (Table 4). Narrower inter row spacing may result in longer days to maturity because to increased competition for resources in the soil, poor light interception, and inadequate air circulation in the canopy caused by wider row spacing. The result is in line with the result of (Oad *et al.,* 2002) who found that safflower maturity was showed significant variation by larger inter- and intra-row spacing. On the other hand, (Holshouser *et al.,* 2002) row spacing has no discernible impact on soybean maturity.

Local varieties took the shortest days (112 days) to 90% physiological maturity, while Wereilu variety and chala varieties took longest number of days (140 and 132 days) to reach physiological maturity (Table 4). The difference in physiological maturity between varieties might be due to different genetic makeups, which can influence their growth rate, development and maturity. The present finding corroborates with the result of (Sharanya *et al*., 2018) who reported significant variation in number of days taken for maturity of different fenugreek varieties.

4.4. Number of Pods per Plant

Variance analysis revealed that inter row spacing and varieties had a highly significant ($p < 0.01$) effect on the number of pods, but their interaction had no significantly influenced on pod number (Table 4). The higher number of pods per plants (29.33) was recorded from wider row spacing (40cm), while the minimum number of pods per plants (20.13) was recorded from narrower row spacing (Table 4). The number of pods increased with increasing row spacing. This could be the effect of having more branches per plant and greater row spacing, which could have created more space for the development of flowers and led to the formation of proflic pods. Additionally, as row spacing increases, shadowing effects are reduced, maximizing sunlight availability for photosynthesis and pod development for individual plants

The result in line with (Tiwari *et al*., 2016) who reported that greater number of pods per plant when the inter and intra row spacing is 30 cm x 10 cm than to 25 cm x 10 cm plant spacing of fenugreek, pod number plant^{-1} increased with increasing row spacing. Similarly, (Mahasi *et al.,* 2010) found that a narrow plant spacing restricts the production of individual plant branches, and increases the number of plant nodes, and increases the leaf area and

vegetative mass of individual plants, all of which lead to the formation of more pods per plant. In addition, (Mohamed 1990; Sharma *et al*., 2008 and Gendy 2013) also observed the seed rates of 30kg ha^{-1} and 30cm inter row spacing, is the highest number of pods per plant of fenugreek. Regarding to the variety Pod number per plants had highly significant ($P \leq 0.01$) effect on the fenugreek varieties. The highest number of pods per plants was recorded from Ebbisa, Burka and Chala variety which is (26.9, 26.25 and 25.25) respectively while, the lowest number of pods per plants (22.25) was recorded from the local variety (Table 4). This might be due to differences in genetic makeup which is indirectly govern the pod formation of the plant.

4.5. Aboveground Biomass

Analysis of variance revealed that the effect of inter row spacing and varieties was had highly significant ($P < 0.01$) on aboveground dry biomass, but their interaction were not significant (Table 4). The highest aboveground biomass yield (3568.33kg ha^{-1}) was obtained from (40cm) inter row spacing, whereas the lowest biomass (1588.33kg ha^{-1}) was notable from (10cm) inter row spacing. The increase in biomass yield at maximum inter row spacing might be due to the presence of optimum plant population at optimum spacing, which brought improvement in vegetative growth.

Regarding the varieties, it was highly significantly ($P<0.01$) influenced the total aboveground biomass (Table 4). The highest yield of total above ground biomass was recorded from Wereilu and Chala varieties which is (2849.67kg ha^{-1} and 2715kg ha^{-1}), whereas the lowest was from Ebbisa, Burka and local variety (2616.17, 2611.83, and 2604.58kg ha^{-1}) respectively. The result in line with the (Dema *et al.*, 2023) who reported that the higher aboveground biomass yield (4152 kg ha^{-1}) was gained with a row spacing of 30 cm as compared with 20 in coriander.

4.6. Harvest index

There were highly significantly ($P<0.01$) difference recorded on the main effects of inter row spacing and varieties. However, significant variation was not observed among their interaction effect of inter row spacing and fenugreek varieties (Table 4). The highest harvest index (40.2 and 39.2) was recorded from the wider inter row spacing at (40cm and 30cm) respectively and whereas, the minimum (32.2) value for harvesting index was obtained from

the narrower inter row spacing at (10cm). The higher plant population per unit area may be the cause of this decrease in the harvest index with narrower spacing, which may have increased floral abortion due to competition for nutrients, moisture, and sunlight. Concerning the varieties, it was highly significantly ($P<0.01$) affected on the harvest index (Table 4). The highest harvest index was recorded from Ebbisa and Burka varieties which is (41.66, and 40.58%), whereas the lowest was from variety Local (28.33). Similar result reported by (Khan *et al.*, 2010) showed a maximum harvest index of 41.66% in the largest row spacing of 45 cm as compared to 15 cm.

4.7. Plant Height (cm)

The results of the analysis of variance showed that the interaction effect of inter row spacing and varieties had highly significant ($P<0.01$) on plant height of fenugreek. The highest plant height (48.6 and 50.6cm) was recorded from the Ebbisa variety treated with narrower inter row spacing (20cm and 10cm), while the shortest plant height (29.6cm) was recorded from the interaction of local variety and 40cm row spacing (Table 5). The increase in plant height of the variety in response to the decreasing inter row space might be due to the fact plants are grown in narrower-row spacing are exposed to increased competition to scarce light resource. This competition triggers a response in the plants to grow taller in an attempt to outcompete neighboring plants for access to sunlight. With limited space available, plants will elongate their stem and increase their height to maximize light interception and ensure their survival.

The results in line with (Minjaro 2023) was reported that highest plant height (58.77 cm) was recorded for the Ebbisa variety at a row spacing of 20 cm followed by 57.13 cm a row spacing of 25 cm and the shortest plant height was recorded row spacing of 30 cm Similarly, (Shamsi and Behrooz 2011; Sharar *et al.*, 2001 and Singh *et al.*, 2013) was reported indicated that plant height significantly increased with increase in plant density, which is mainly caused by a reduction in the amount of light that a single plant is able to intercept resulting into increased inter node length soybean, faba bean and green bean. On the other hand, (Mohamed 1990) reported that plant height of fenugreek was not affected by increase in row spacing.

Table 5**:** Interaction effect of row spacing and fenugreek varieties on, plant height, number of primary branches, pod length, number of seeds per pod, 1000g seed weight and seed yield

Treatment Combination	Plant Height (cm)	Number of Branches	Pod Length (cm)	Number seeds pod^{-1}	1000g seed weight	seed Yield (kg ha^{-1})
Ebbisa*10cm	50.6^{a}	3.03^{fgh}	13.3^{def}	14^{f}	14.3^{bcd}	623^{hi}
Ebbisa*20cm	48.6^{ab}	3.5^{defg}	13.6^{cde}	15.6^{de}	15^{bc}	833.6^{g}
Ebbisa*30cm	47.3^{abc}	5.36^{c}	16.6^{b}	18.3^{b}	20.6^{a}	1439^{cd}
Ebbisa*40cm	46.6^{bcde}	6.46^{ba}	19^{a}	18.6^{b}	20a	1466.7^{bc}
Wereilu*10cm	47^{bcd}	2.9^{gh}	13^{def}	13^{fg}	13.3^{cde}	527.6^{i}
Wereilu*20cm	46^{bcdef}	3.3^{egf}	14^{cde}	14.3^{ef}	14.6^{bcd}	821^{g}
Wereilu*30cm	46.6^{bcde}	6.5^{ba}	17.3^{b}	16.6^{cd}	20.6^{a}	1350^{d}
Wereilu*40cm	43^{fgh}	6.73^{a}	19^{a}	18.6^{b}	20.6^{a}	1434^{cd}
Chala*10cm	45^{cdef}	3.73^{def}	14.3^{cd}	13^{fg}	13^{cde}	525.3^{i}
Chala*20cm	43.6^{defg}	3.73^{def}	15^{c}	14.3^{ef}	14.6^{bcd}	812.6^{g}
Chala*30cm	40.3^{ghij}	6.4^{ab}	17.3^{b}	17.3^{bc}	19.3^{a}	1433^{cd}
Chala*40cm	38.3^{ij}	5.76^{bc}	18^{ab}	18.6^{b}	19.6^{a}	1541^{ab}
Burka*10cm	43.3^{efg}	3.3^{egf}	12.6^{ef}	14.3^{ef}	14.3^{bcd}	558^{hi}
Burka*20cm	40.3^{ghij}	3.96^{de}	15^{c}	16.3^{cd}	15.6^{b}	805^{g}
Burka*30cm	37.6^{j}	5.53^{c}	18^{ab}	18.6^{b}	19^{a}	1386^{cd}
Burka*40cm	38.3^{ij}	6.36^{ab}	19.3^{a}	21.6^{a}	20^{a}	1586^{a}
Local*10cm	41.3^{ghi}	2.23^{h}	10^{h}	10^{i}	10.3^{f}	324.6^{j}
Local*20cm	39.6^{hij}	2.4^{h}	10.6^{gh}	10.6^{hi}	11.6^{ef}	639.3^{h}
Local*30cm	38.6^{ij}	4.16^{d}	12^{fg}	11.3^{hi}	12.6^{de}	971.6^{f}
Local*40cm	29.6^{k}	4.1^{de}	12.6^{ef}	11.6^{gh}	12.6^{de}	1116^{e}
Means	42.61	4.475	15.05	15.36	16.11	1009.73
LSD (5%)	3.49**	0.8**	1.55*	1.47**	2.11**	100.38**
CV	4.95	10.89	6.26	5.82	7.92	6.01

Means followed by the same letter(s) in the table are not significantly different at 5% level of significance; LSD=list significance difference, CV=Coefficient of variation; **= significant at p< 0.01, * =significant at P<0.05.

4.8. Number of Primary Branches per Plant

An analysis of variance revealed that the interaction effect of inter row spacing and varieties had highly significantly (P<0.01) influenced by number of primary branch of fenugreek. The highest number of branches per plant (6.36, 6.4, 6.46, 6.5 and 6.73) was recorded from

Burka, Chala, Ebbisa, Wereilu variety at (40cm and 30 cm) row spacing, while the lowest (2.23 and 2.4) was recorded from the interaction of local variety at a row spacing of 10cm and 20cm (Table 5). When the inter row distance was raised from 10 to 40 cm, there was a notable increase in the number of primary branches.

The variations responses among the inter row spacing and varieties interact may be due to variation in the access to growth factors by the plants grown under their respective environments. Higher sunlight interception for photosynthesis may be the cause of the increased number of branches under greater row spacing. On the other hand, a crop with overlapping plant canopy may have seen less sunlight interception, which would have resulted in reduced photo assimilation. This could explain the decreased number of branches in the tighter plant spacing. This demonstrated the plants' adaptability to varying plant spacing as well.

The result is in line with the result of (Halesh *et al.*, 2000; Gowda *et al.*, 2006 and Mohamed 1990) for the number of branches in fenugreek. Similarly, results were reported by similarly, (Koli 2013 and Dereje 2014) who reported that increased number of branches at the wider plant spacing. Mahama (2011) also reported that soybean variety greater number of branches at wider spacing (60cm and 50cm) than narrow spacing. In addition, (Togay *et al.*, 2005) who obtained that the number of branches decreased with the increase in plant density of chickpea.

4.9. Pod Length (cm)

Analysis of variance revealed that the interaction of inter row spacing and varieties were highly significantly ($P \leq 0.01$) influenced pod length (Table 5). The longest pod length (18cm, 19cm, 19cm, 18cm and 19.3cm) was obtained from the interaction of variety Chala, Ebbisa, WereIlu and Burka threated with 40cm row spacing respectively. On the other hand, when local variety with 10 cm and 20cm row spacing were combined, the shortest pod length (10 cm and 10.6) was seen (Table 5). The wider inter-row spacing resulted in longer pod compared to narrower row spacing. This is may be competition effect among the space, light and moisture.

This result in agreement with (Tuncturk *et al.*, 2011; Habib *et al.*, 2019) who reported significant increases in pod length of fenugreek with increased applications of nitrogen and increased inter row spacing in fenugreek. Similarly, (Kumar *et al.*, 2018) a fenugreek seeded at 40cm row spacing with a seed rate of 16 kg/ha had sowed a significantly increased. Jamal *et al.*, (2010) also noted that the 30x10 cm crop geometry produced a noticeably longer pod (11.28 cm) than the 22.5 cm x 13.3 cm (10.24 cm) crop, in addition to this consistency fenugreek. On the other hand (Brar *et al.*, 2005) reported that sowing date and row spacing (22.5 and 30 cm) the closer spacing resulted in significantly higher pod length.

4.10. Number of seeds per Pod

Analysis of variance revealed that interaction of inter row spacing and varieties significantly ($p<0.01$) influenced the number of seeds per pod (Table 5). When variety Burka was treated with a 40-cm row spacing, the largest number of seeds per pod (21.6) was observed. However the lowest number of seeds per pods (10 and 10.6) was recorded from interaction of local variety and (10cm) inter row spacing. The number of seeds per pods increased as inter row spacing got to wider. This may be due to the number of plants within a row increased, plant competition got increased while light interception reduced and resulted in decreased number of seeds per pod.

The findings of (Minjaro *et al.*, 2023) were supported by the results of this investigation. They discovered that the maximum number of seeds plant^{-1} was 11.9% when the row spacing was 25 cm, while the lowest number of seeds plant^{-1} was 3.75 when the row spacing was 20 cm. Similarly, (Sharma 2000; Abdel *et al.*, 2008 and Almaz *et al.*, 2016) stated that due to higher branches and leaves per plants, the number of seeds per pods increased of fenugreek. According to (Khan *et al.*, 2010) reported that decreased number of seeds pod^{-1} from 1.87 to 1.81 was reported as seed rate increased from 60 kg ha^{-1} to 75 kg ha^{-1} on chickpea.

4.11. Thousand Seed Weight

The analysis of variance showed that the interaction of inter row spacing and varieties significantly ($p<0.01$) influenced thousand seeds weight (Table 5). The highest thousand seeds weight (20.6g, 20.6g, 19.6g and 20g and 19g) was recorded from the interaction of variety Ebbisa, Wereilu, Chala and Burka treated with (30cm and 40cm) row spacing. However the lowest thousand seeds weight (10.3g and 11.6g) was obtained from the

interaction of variety local treated with (10cm and 20cm) row spacing (Table 5). The higher 1000g seeds weight were recorded from lower plant density with wider row spacing, than dense plant populations with narrow row spacing. This may be due to decreasing plant density might have caused more light to get through the canopy that made plants to benefit more from the natural environment. Thus, might have caused an increase in number of branches and the increased level of photosynthesis resulting in more assimilates translocated and stored in seeds.

The results in agreement with the result of (Nandal *et al.*, 2007) who indicated that the crop geometer (30 cm x10 cm) produced the maximum seed weight, while the fenugreek produced the lowest values (5 cm x10 cm). According to, the (Matthews *et al.*, 2008) revealed that there was a negative correlation between the 100 seed weight of faba beans and plant density. This suggest that higher seed were produced by low plant density compared to higher density. Masa (2017) who revealed that the greatest hundred seed weight of 27.47g recorded at and the lowest 24.99 g recorded at the lowest plant population of 133, 333 plants ha^{-1} highest plant population of 333,333 plants ha^{-1} of common bean. On the other hand, (Tuncturk *et al.*, 2011) obtained a non-significant effect of plant density on the hundred seed weight of bean

4.12. Seed Yield (Kg ha^{-1})

Analysis of variance showed that the interaction of inter row spacing and varieties were highly significant ($P<0.01$) effect on seed yield (kg ha^{-1}). The highest seed yield (1541kg ha^{-1} and 1586kg ha^{-1}) was recorded from the interaction of variety Burka and Chala treated with 40cm inter-row spacing whereas, the minimum (324.6 kg ha^{-1}) seed yield was obtained from the interaction of variety local with10cm row spacing (Table 5). The observed data indicated that there was a significant variation among different interaction of inter row spacing and varieties with respect to seed yield per hectare. The value for seed yield per hectare varied from 1586kg ha^{-1} to 324.66 kg ha^{-1}. The seed yield per hectare improved considerably with the increase in inter row spacing. The increase in seed yield per plot and hectare might be due to optimum plant population which improved vegetative growth and proper utilization of light and other resources at wider spacing.

The results in line with (Meena *et al.*, 2003 and Nandal *et al.*, 2007) who recorded that planting of fenugreek at wider spacing of 30cm and 40cm considerably enhanced the seed yield over sowing at narrow spacing 20 cm. Similarly, (Tuncturk 2011) reported the highest seed yield was obtained from sowing of fenugreek seeds at the row of 30 cm significantly increased yield over the sowing at a spacing of 20 cm. According to (Bekele and Geleta 2021) who was reported that higher seed yield of chickpea at wider row spacing than narrower row spacing.

4.13. Correlation Coefficient among Parameters Measured

Correlation analysis result revealed that there were significant positive correlations ($P < 0.05$) among parameters of growth, seed yield and yield components of fenugreek. Seed yield was positive correlated with number of primary branches, number of pod per plant, pod length, number of seed per pod, and thousand seed weight, above ground biomass and harvest index.

The higher +ve correlation was recorded from seed yield with number of primary branch (r=0.89**), number of pod per plant (r=0.84**), pod length (r=0.77**), number of seed per pod (r=0.78**), thousand seed weight (r=0.82**) above ground biomass (r=0.97**) and harvest index (r=0.86**) but seed yield was -ve correlation with days of 50% flowering. Days to 90% physiological maturity also had negative correlation with number of primary branches, number of pods per plant, pod length, number of seeds per pod, and thousand seed weight, above ground biomass, seed yield and harvest index and days of 50% flowering was -ve correlation except plant height and days of 90% maturity (Table 6). The result agrees with (Kasu *et al.*, 2019) the use of appropriate inter row spacing promotes high growth traits and yield components which have positive influence on seed yield.

Table 6: Correlation coefficient among parameters of phonological, growth, yield and yield component of fenugreek at woliso

	DF	DM	PH	NB	NP	PL	SPP	TSW	TGBM	SY	HI
DF	1										
DM	0.42*	1									
PH	0.65**	0.46*	1								
NB	-0.21ns	-0.05ns	-0.21ns	1							
NP	-0.34*	-0.12ns	-0.22*	0.76**	1						
PL	-0.04ns	0.1ns	0.05*	0.82**	0.74**	1					
SPP	-0.005ns	-0.05ns	0.12ns	0.82**	0.75**	0.82**	1				
TSW	-0.07ns	-0.01ns	-0.08ns	0.86**	0.76**	0.82**	0.90**	1			
TGBM	-0.36*	-0.16ns	0.35*	0.90**	0.87**	0.79**	0.80**	0.82**	1		
SY	-0.38*	-0.15ns	0.38*	0.89**	0.84**	0.77**	0.78**	0.82**	0.97**	1	
HI	-0.40*	-0.09ns	0.40*	0.69**	0.61**	0.53**	0.56**	0.65**	0.73**	0.86**	1

Where; *, ** indicate significance and highly significance at 5% and 1% of probability level respectively, NS: non-significance, DF: Days to flowering, PM: physiological maturity, PH: Plant height, NB: Number of primary branches, NP: number Pods per plant, PL: pod length, SPP: number of Seeds per pod, TSW: thousand seed weight, AGBM: above-ground dry biomass, SY: Seed yield, HI: Harvest index

5. SUMMARY AND CONCLUSIONS

The result showed that both inter row spacing and varieties and their interaction significantly ($p \leq 0.05$) affected the yield and yield component of fenugreek crop. The higher yield and yield components were recorded from planting of fenugreek with the wider spacing. The shortest days of 50% flowering, days of 90% maturity, primary branch, number of seeds pod^{-1}, pod length, 1000g seed weight, above ground biomass, harvesting index and seed yield was recorded from planting of fenugreek at 40cm and 30cm followed by 20cm. The highest plant height was recorded from (10cm) narrower inter row spacing whereas the lower yield and yield attributes were recorded from 10cm inter row spacing (Table 4 and 7).

Interaction of row spacing with fenugreek varieties had significantly ($P \leq 0.05$) affect yield and yield component fenugreek crops. The higher primary branch, pod length, seed per pod, 1000g seed weight and seed yield was recorded from the interaction Chala and Burka with 40cm followed by with the interaction of 30cm. From the result Wereilu and Ebbisa moderate performance as compared to Chala and Burka fenugreek varieties. The lower interaction result was recorded at planting of local fenugreek variety with 10cm inter row spacing.

6. RECOMMENDATIONS

Since the shortest days for 50% flowering and for 90% pod maturity as well as the highest number of primary branches, seed pods^{-1}, pod lengths and the highest 1000g seed weight, above ground biomass, harvesting index and seed yield were obtained from Burka variety and the 40 cm inter row spacing, they are recommended for the study area as well as other areas with similar agro-climatic settings/conditions. However, since the experiment was carried out only during one production season and a single location, it is also recommended that it is further tested or verified during more seasons and across more locations

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LIST OF TABLE IN THE APPENDIX

Appendix Table 1: Days 50% flowering

Source	DF	Sum of Square	Mean square	F Value	Pr>F
REP	2	5.2333333	2.614756	0.21	0.8101
RS	3	525.1333333	175.0444444	14.17	<.0001
V	4	710.2333333	177.5583333	14.37	<.0001
RS*V	12	86.7000000	7.2250000	0.58	0.8405

Appendix Table 2: Days to 90% physiological maturity

Source	DF	Sum of Square	Mean square	F Value	Pr>F
REP	2	685.633333	342.816667	1.86	0.1699
RS	3	1994.583333	664.861111	3.60	0.0220
V	4	5585.400000	1396.350000	7.57	0.0001
RS*V	12	2149.000000	179.083333	0.97	0.4926

Appendix Table 3: Plant height

Source	DF	Sum of Square	Mean square	F Value	Pr>F
REP	2	6.9333333	3.4666667	0.78	0.4673
RS	3	316.9833333	105.6611111	23.66	<.0001
V	4	933.6000000	233.4000000	52.25	<.0001
RS*V	12	128.9333333	10.7444444	2.41	0.0198

Appendix Table 4: Branch of primary Number

Source	DF	Sum of Square	Mean square	F Value	Pr>F
REP	2	1.09300000	0.54650000	2.30	0.1140
RS	3	97.52583333	32.50861111	136.85	<.0001
V	4	24.13333333	6.03333333	25.40	<.0001
RS*V	12	8.03333333	0.66944444	2.82	0.0074

Appendix Table 5: Number of pods

Source	DF	Sum of Square	Mean square	F Value	Pr>F
REP	2	21.7000000	10.8500000	2.45	0.0998
RS	3	719.6666667	239.8888889	54.16	<.0001
V	4	154.0666667	38.5166667	8.70	<.0001
RS*V	12	23.6666667	1.9722222	0.45	0.9335

Appendix Table 6: Pods length

Source	DF	Sum of Square	Mean square	F Value	Pr>F
REP	2	4.9000000	2.4500000	2.76	0.0762
RS	3	233.6500000	77.8833333	87.65	<.0001
V	4	209.9333333	52.4833333	59.06	<.0001
RS*V	12	24.6000000	2.0500000	2.31	0.0250

Appendix Table 7: Number of seeds per pods

Source	DF	Sum of Square	Mean square	F Value	Pr>F
REP	2	4.2333333	2.1166667	2.64	0.0842
RS	3	223.8000000	74.6000000	93.15	<.0001
V	4	329.7666667	82.4416667	102.94	<.0001
RS*V	12	33.7000000	2.8083333	3.51	0.0015

Appendix Table 8: Thousand seed weight

Source	DF	Sum of Square	Mean square	F Value	Pr>F
REP	2	16.0333333	8.0166667	4.92	0.0126
RS	3	362.5833333	120.8611111	74.12	<.0001
V	4	279.9333333	69.9833333	42.92	<.0001
RS*V	12	47.6666667	3.9722222	2.44	0.0184

Appendix Table 9: Total ground biomass

Source	DF	Sum of Square	Mean square	F Value	Pr>F
REP	2	138387.10	69193.55	1.83	0.1747
RS	3	39596615.12	13198871.71	348.56	<.0001
V	4	533031.93	133257.98	3.52	0.0154
RS*V	12	732269.80	61022.48	1.61	0.1296

Appendix Table 10: Seed yield

Source	DF	Sum of Square	Mean square	F Value	Pr>F
REP	2	18181.033	9090.517	2.46	0.0985
RS	3	8537576.133	2845858.711	771.61	<.0001
V	4	937418.900	234354.725	63.54	<.0001
RS*V	12	160199.367	13349.947	3.62	0.0012

Appendix Table 11: Harvest index

Source	DF	Sum of Square	Mean square	F Value	Pr>F
REP	2	18.533333	9.266667	1.45	0.2481
RS	3	594.200000	198.066667	30.91	<.0001
V	4	1373.166667	343.291667	53.58	<.0001
RS*V	12	152.966667	12.747222	1.99	0.0534

Appendix Table 12: Effect of row spacing and varieties on DE 50%, DF 50%, DM 90%, PH and NB

Inter row space (cm)	DE 50%	DF 50%	DM 90%	PH	NB
10	5.26a	51.86a	128.3ab	45.46a	3.04
20	5.26a	49.26b	133.1a	43.66b	3.38
30	5.26a	45.33c	122.6bc	42.13b	5.59
40	5.27a	44.6c	117.86c	39.2c	5.88
LSD	0.039	2.59	10	1.5	0.36
Variety					
Ebbisa	5.283a	49b	122bc	48.33a	4.59
Wereilu	5.266a	53.58a	140a	45.66b	4.85
chala	5.250a	46.16b	132ab	41.83c	4.9
Burka	5.258a	46.83b	121bc	39.91d	4.79
Local variety	5.258a	43.25c	112c	37.33e	3.22
LSD	0.044	2.9	11.2	1.7	0.4
CV (%)	1.02	7.35	10.82	4.95	10.89
Significant level					
Inter row space	NS	**	*	**	**
Variety	NS	**	**	**	**
RS*V	NS	NS	NS	**	**

Means followed by the same letter(s) in the table are not significantly different at 5% level of significance;NS= not significant, ** = Significant at p<0.01;*=Significance,LSD=Leat significance difference; CV=Coefficient of variation, RS=Row spacing, V=Variety, DE= days to 50% emergence, DF=days to 50% flowering, DM=days to 90% maturity, PH=plant height, NB=number of branc

Appendix Table 13: Main effect of inter row spacing and varieties on NP, PL, SPP, TSW, TGBM, SY and HI

Inter row Spacing (cm)	NP	PL	SPP	TSW	TGBM	SY	HI
10	20.13d	12.66d	12.82	13.06c	1588.33d	511.73	32.2c
20	23.86c	13.66c	14.26	14.33b	2215.47c	782.33	35.73b
30	27.066b	16.26b	16.46	18.46a	3345.67b	1316.07	39.2a
40	29.33a	17.6a	17.86	18.6a	3568.33a	1428.8	40.2a
LSD	1.55	0.69	0.66	0.94	143.84	44.89	1.87
Variety							
Ebbisa	26.9a	15.66a	16.66	17.5a	2611.83b	1090.58a	41.66a
Wereilu	24.83b	15.83a	15.66	17.33a	2849.67a	1083.83a	35.25c
Chala	25.25ab	16.16a	15.83	16.66a	2715ab	1078ab	38.33b
Burka	26.25ab	16.25a	17.75	17.25a	2616.17b	1033.25b	40.58a
Local variety	22.25c	11.33b	10.91	11.83b	2604.58b	763c	28.33d
LSD	1.73	0.77	0.73	1.05	160.82	50.19	2.09
CV (%)	8.38	6.26	5.82	7.92	7.26	6.01	6.87
Significance level							
Row space	**	**	**	**	**	**	**
Variety	**	**	**	**	**	**	**
RS*V	NS	*	**	**	NS	**	NS

Means followed by the same letter(s) in the table are not significantly different at 5% level of significance;NS= not significant, ** = Significant at p<0.01;*=Significance,LSD=Leat significance difference; CV=Coefficient of variation, RS=Row spacing, V=Variety,

NP= number of pod, PL=pod length, SPP=seeds per pod, TSW=thousand seed weight, TGBM=total aboveground biomass, SY=seed yield and HI=harvest index

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Figure 2: Field layout and blocking of the experiment



Figure 3: Preparation of row spacing



Figure 4: Watering plants at 21 days of seeding



Figure 5: Flower initiation of seedlings



Figure 6: Pod initiation



Figure 7: Plants during 90% physiological maturity



Figure 8: Physiologically matured plants ready for harvesting