EFFECTS OF INTER AND INTRA ROW SPACING ON YIELD AND YIELD RELATED TRAITS OF SORGHUM [*Sorghum bicolor* (L) Moench] IN BABILE DISTRIC, ETHIOPIA

M.Sc. THESIS

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Effects of Inter and Intra Row Spacing on Yield and Yield Related Trait of Sorghum [*Sorghum bicolor (*L*) Moench]*In BabileDistrict , Ethiopia.

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As research Advisors, We hereby certify that we have read and evaluated this Thesis prepared under our guidance by AbdiAbrahimBakajjo entitled “EFFECTS OF INTER AND INTRA ROW SPACING ON YIELD AND YIELD RELATED TRAIT OF SORGHUM [*Sorghumbicolor* (L) MOENCH] and recommended that it be accepted as fulfilling the thesis requirement for the degree of: MASTER OF SCIENCE IN AGRICULTURE (AGRONOMY)

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The candidate, we recommended that the thesis be accepted as fulfilling the thesis requirement for the degree of Master of Science in Agriculture (Plant science).

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DEDICATION

This thesis manuscript is dedicated to my wife MayramaFiqadu and my family for their selfless sacrifices throughout my educational career.

STATEMENT OF THE AUTHOR

I declare that this thesis is my bonafide work and that all sources of materials used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for the award of M.Sc. degree in plant science at Haramaya University It is shelved at the University library to be made available to users under rules of the library. I solemnly declare that this thesis is not submitted to any other higher institution anywhere for the award of any academic degree.

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BIOGRAPHICAL SKETH

The author, AbdiAbrahimBakkajjo, was born in chelenko District in ruler kebeleBikkiyye, East Hararghe Zone, Oromia Regional state in Ethiopia, on the 15 may 1989 to his father AbrahimBakkajjo and his mother Zeyni Yusuf. When he reached school age in 1996, he attended his primary education at Bikkiyye elementary School from 1997 to 2002. Then, he joined grade 7th -10thchelenkoDistrict secondary School in 2003-2006 when he completed high school education in 2006. After completing high school education, he joined preparatory education from 2007-2008 year at Dader district. Then he joined at Makalle University in 2009 to pursue a study leading to the Degree of Bachelor of Sciences in plant Science, and graduated on 15 After July 2011.

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ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
CEC	Cat ion Exchange Capacity
CSA	Central Statistical Authority
CV	Coefficient of Variance
DAE	Days after Emergence
FAO	Food and Agricultural Organization
FARC	Fades Agricultural Research Center
ICRISAT	International Crop Research Institute for the Semi-Arid Tropics
LSD	List significant difference
m.a.s.l	Meters Above Sea Level
MoA	Ministry of Agriculture
MoARC	Ministry of Agriculture and Research Center
MoARD	Ministry of Agriculture & Rural Development
NPS	Nitrogen, Phosphorus and Sulphur
RCBD	Randomized Complete Block Design
SE	Standard Error
GC	Gregorian colander

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ABSTRACT

A field experiment was conducted inBabile District during the main cropping season of 2019 to evaluate the effect of plant spacing (inter- and intra-row spacing) on yield and yield related traits of sorghum (Sorghum bicolor(L.)Moench].Four inter-row spacing (65 cm,75 cm,80 cm and 90cm) and four intra-row spacing (15, 20, 25 and 30 cm) were evaluated as treatments using a randomized complete block design with three replications. Yield and yield related parameterswere collected and analyzed.Results of the experiment showed that out of the parameters measured, The highest productive tillers per plant (4.3 (no)), and total number of tillers per plant (4.6 (no)), were observed from the interaction effect of 90 cm inter-row and 30 cm intra-row spacing respectively. The maximum Panicle weight (96.1g),was obtained from the interaction effect of 90 cm inter-row and 30 cm. intra-row spacing.The highest grain yield (4,87kgh^{-1}) and the highest above ground biomass weight (11,356 kgh^{-1})were also obtained from the interaction of 65 cm inter-row with 15cm intra-row spacing respectively.The Maximum plant height (152.8 cm, 156 cm)was recorded from65 cm inter-row and15cm intra-row spacing respectively. Maximum and minimum number of initial stand count (76 no,37no)and final stand count(35.83no, 75 no) were obtained from 30 cm intra-row and 15 cm intra-row spacing respectively. Theeffects of plant spacing on 100 seed weight and panicle length were found non-significantlyaffected.Generally, intermediate spacing resulted in remarkable yield while widely spaced plants produced low yields. Therefore, 65 cm inter-row and 15 cm intra-row spacing can be recommended for short duration or early maturing improved sorghum variety in Babile district, and other areas with similar agro-ecologies to sustain sorghum productivity. However, this tentative generalization should be validated by testing more spacing for more than one season and location to give a valid recommendation.

Keywords:Intra-row spacing, Inter-row spacing,sorghum, yield, early maturity.

1. INTRODUCTION

Sorghum (*Sorghum bicolor*(L) Moench) is among the leading staple cereals for the majority of the world particularly in the arid and semiarid areas. It is the fifth major cereal crop in the world in terms of tonnage after maize, wheat, rice and barley (FAO, 2012). According to MoA (2010),in Ethiopia sorghum is widely produced more than any other crops in the areas where there is moisture stress. It is one of the most important Ethiopian food crops, which is second to teff for making, “injera”, and also used for “Kitta”, “Nifro”, infant food, syrup, and local beverages such as “Tella”, and “Areke”. Besides to animal feed, the stalk is used for construction of houses and fence, and as fuel wood (Birhane and Yilma, 1979; MoA, 2010).

Sorghum grain has a high nutritive value, with 70-80% carbohydrate, 11-13% protein, 2-5% fat, 1-3% fiber, and 1-2% ash. Protein in sorghum is gluten free and thus, it is a specialty food for people who suffer from celiac disease, including diabetic patients and is a good substitute for cereal grains such as wheat, barley, and rye (Dial, 2012).

In Ethiopia, during cropping season, sorghum covered 14.58 % (1,831,600.45 hectares) of the total of 80.78 % (10,144,252.30 hectares) area fixed to cereal crop production (teff, maize, sorghum, and wheat). Similarly, during the same year, sorghum took 16.05% (43,391,342.61 quintals) of the total production 87.31% (about 236,076,624.39 quintals) allocated for major cereals (maize, teff, wheat, and sorghum). In that year, sorghum was ranked 3rd and 4th in area coverage and total production, respectively(CSA, 2016).

In Ethiopia, sorghum is the third important crop after teff and maize in terms of total area production and the fourth most important food crop after maize, wheat and teff (CSA, 2016). In the country, sorghum is grown in almost all regions occupying an estimated total land area of 1.83 million ha and its national average productivity of 2369 kg ha-1 (CSA, 2016). Even though sorghum adapt to wide ecological conditions, the yield still remains low under the traditional farming practice. Optimum plant population with good management increases the yield of sorghum. Optimal plant densities for grain sorghum differ from region to another and grainyields generally increase as plant population’s increase at lower than suggested plant densities, grain sorghum head number per plant or seed number per head increased when compared to the recommended plant density (Staggenborg,1999).

Plant density is dependent on both row width and intra-row spacing and under dry land conditions row width plays an important role in determining plant density (Mashiqaa*et al*., 2011). The row spacing in a crop can also impact crop yield potential land narrow row planting gives grain sorghum a competitive advantage over the wider spacing in sorghum production (Fernandez *et al*., 2012).

Weed-sorghum competition is intensified by open canopy structures, while narrow row planting gives sorghum a competitive advantage over weeds and reducing light transmittance to the soil (Fernandez *et al*., 2012). Sub-standard plant density result in high weeds infestation, poor radiation use efficiency and low yield, while dense plant population on the other hand cause lodging, poor light penetration in the canopy, reduce photosynthesis production due to shading of lower leaves and drastically reduce the yield (Lemerle*et al*., 2004). Plant population can also affect sorghum water use by altering canopy development. Optimizing plant population on the basis of the potential supply of water minimizes the opportunity for plant water stress that could be caused by high water demand (Yaredet al., 2010).

In general, the best way to get uniform plant stands is to plant in regularly spaced rows and at regular intervals within the row. The impact of row spacing on cereal yield varies depending on the rain fall growing season, the time of sowing and the potential yield of the crop(Faisul*et al*., 2013)..

The nationally recommended spacing for sorghum in Ethiopia is 75 cm by 20 cm between rows and plants, respectively (MoARD, 2003). This row spacing is based on study of tall and short maturing sorghum varieties. But, farmers in the semi-arid area of Ethiopia also practice this spacing for both late and early maturing sorghum varieties. This indicates that further study is needed to determine the response of short and early maturing sorghum varieties in terms of plant population densities(MoARD, 2003).In Ethiopia, sorghum is grown as one of the major food cereals and it is third largest sorghum production countries producer in Africa next to Nigeria and Sudan (FAO, 2004).Sorghum is a warm season crop, requiring high temperature for good germination and growth. Temperature ranges for germination are 7^0C to 10^0C, but if there is sufficient moisture, germination occurs well at a soil temperature of 15°C or higher. After germination, temperatures of 27^0C to 30^0C are required for optimum growth development. A temperature of as low as 21^0C can however have a dramatic effect on growth and yield (Vanderlip and Reeves, 1972).

In Ethiopia Sorghum is annually cultivated on 1,896,389.29 ha and contributing 51,692,525.40 quintal to annual grain production in the country (CSA, 2018).In Oromia Sorghum is annually cultivated on 735,263.79 ha.andContributing 20,810,667.34quintal to annual grain production in the region (CSA, 2018).In East Haraghe sorghum is annually cultivated on 23,678 hectare and contributing 662,984 quintal annual grain production in East Hararghe zone (East Hararghe zone Profile, 2011).Babiledistrict sorghum is annually cultivated on------ hectare and contributing ----- quintal annual grain production East Hararghe zone Babile district (Babile district Profile, 2011).The national average productivity of the crop is 27.26 qunt/ha (CSA, 2018).

However, researcher results indicated that 30–60 q/ha can be produced based on the growing environment. However, sorghum production in Ethiopia is negatively affected due to several factors such asMoisture stress, low soil fertility, Strigahermonthica, and the limited access to improved seed and efficientproduction technologies. Plant density selection to allow for expression of maximum grain yield is a management practice that would make sorghum more production. Results indicated that yields of grain sorghum can be improved by increasing the plant densities (Schatz *et al.*, 1990).

Cultivation of plants with desirable density has positive effect on crop yield components, so that the suitable yield would be achieved by optimum plant density (Cox, 1996; Widdicombe and Thelen, 2002). However, maintenance of optimum planting density is always a big problem to the farmers. Substandard plant density results in high weeds infestation, poor radiation use efficiency and low yield, while dense plant population on the other hand may cause lodging, poor light penetration in the canopy, reduce photosynthesis due to shading of lower leaves and drastically reduce the yield (Jettner*et al.,* 1998; Lemerle*et al.,* 2006).

Thus, the objective of this study was to determine the effect of inter and intra row spacing onyield and yield related traitsof sorghum variety.

2. LETERATUREY REVIEW

2.1. Origin, Botany, Distribution and Production of Sorghum

It is believed that sorghum is originated in Africa, more precisely in Ethiopia, between 5000and 7000 years ago (ICRISAT, 2005). Sorghum is one of the crops for which Ethiopia hasbeen credited as being a Vavilovian center of origin (Vavilov, 1951; Harlan, 1971) and/ordiversity (Harlan, 1992).The main races of cultivated sorghum are: bicolor, vulgare, caudatum, kafir, guinea, and durra**(**Deu*et al*., 1994; BSTID-NRC, 1996).

Common names of sorghum vary from continent tocountry levels. The most encountered names are: kafferkoren, soedangras, suikergierst, orsuiker-sorghum (The Netherlands), kaoliang (China), mtatamshallu or feterita (East Africa),durra (Egypt), chicken corn, sorghum or guinea corn (United Kingdom), jola, jowar, jawa,cholam, bisinga,durra or shallu (India), kaffir corn (South Africa), milo, sorgo, Sudan grass orsorghum (USA), milo (Middle East Africa) and great millet, guinea corn, feterita, sorghum or sorgho (West Africa) (Dicko*et al.*, 2006), mashila (Ethiopia).Sorghum is a vigorous grass that reaches up to 6 m in height (Dicko*et al*. 2006). It has deep and spread roots with a solid stem. Leaves are long (0.3-1.4 m) and wide (1-13 cm), with flat or wavy margins. The flower is a panicle, usually erect, but sometimes recurved to form a goose neck.

Grain is usually covered by glumes. Glumes are the maternal plant tissues in the panicle that holds the developing caryopsis after pollination. The caryopsis is rounded and bluntly pointed, from 4–8 mm in diameter and varying in size, shape and color with genotype. Caryopsis color is an important trait that affects grain quality in sorghum. Sorghum caryopsis is composed of three main parts: seed coat (testa or pericarp), germ (embryo) and endosperm (storage tissue). Sorghum was distributed along the trade and shipping routes around the African continent, and through the Middle East to India at least 3000 years ago (Dicko*et al*., 2006). It then journeyed along the Silk Route into China. Sorghum was first taken to North America in the 1700-1800's through the slave trade from West Africa. It was re-introduced in Africa in the late 19th century for commercial cultivation and spread to South America and Australia (Dicko*et al*., 2006). Sorghum is now widely found in the dry areas of Africa, Asia (India and China), the Americas and Australia. Sorghum is genetically diverse. ICRISAT is a major repository for world sorghum germ plasm with a total of

36,774 Accessions from 91countries (Reddy et al., 2006). In 2008/2009, the total world sorghum production was over 64 million tons (CAC, 2011).

2.2. Growth Habits and Stages

Sorghum seed is the smallest of the spring planted crops; therefore, its early growth usually will be slower than that of corn or soybeans. Infect, growth is not very rapid up to the 8-inch height previously mentioned, while the plant establishes a root system and starts to take up nutrients much more rapidly. Shortly after reaching the 8-inch height, the growing point of the plant this time still below or just at the soil surface changes from producing leaves to producing the head. For medium maturity sorghum, this occurs about 30 to 35 days after emergence. This is a critical point in the development of the plant since its total number of leaves will be determined. At this point, when the plant has completed about 5 percent of its growth, it has taken up 10 to 15 Percent of the nutrients it will use during. During the next 30 to 35 days, until flowering, the plant grows rapidly. It produces much of the leaf area, which will be important during the grain-filling period. During this time, the head develops and the stalk grows rapidly. First, the lower portion of the stalk grows, pushing the head up into the flag leaf sheath into the boot stage(JustinusM.andThinus P. 2020)

The sorghum grain varies in color from white, red and brown to pale yellow and deep purple-brown. The most common grain colors are white, bronze and brown. Grains are mainly spherical but vary in size and shape. Sowing of large seeds increased the leaf area and dry matter production in early grown stages and gave seed yield of 15 per cent higher than those with small seeds (Krishnamurthy et al, 1973).

Sorghum grain is as nutritious as other cereal grains; contains about 11% water, 340 k/cal of energy, 11.6% protein, 73% carbohydrate and 3% fat by weight (Hiebsch and O' Hair, 1986). The protein content of the grain is significantly and inversely correlated with its weight and starch content (FAO, 1995).Sorghum grain is rich in antioxidants and is gluten-free, an alternative for people with wheat allergy (Grains Council, 2010). Sorghum is also a principal source of energy, protein, vitamins and minerals to the poorest people of the semi-arid tropics (National Academic Science, 1996; CABI, 2005). Tillering is an important morphological component of grain sorghum development because it affects light capture, water use, grain yield, plant competition and other physical and biological processes (Krishnareddy*et al.,* 2006).

As a C4 crop, sorghum does not tolerate cool temperature regimes. For seed germination, the minimum temperature is about 8 ^{o}C, and optimum temperature, 21–35 ^{o}C (Peacock, 1982). Under field conditions, a minimum soil temperature in the range of 15–18 ^{o}C is required for 80 percent emergence in 10-12 days. Normally in the field emergence takes 5–10 days. Panicle initiation takes place after approximately one-third of the growth cycle, after the last leaf has initiated and about one-third of total leaf area has developed. If temperatures are exceptionally high, grain yields can be reduced. Temperatures below zero can result in death of the plants, especially if plants are older than 3 weeks. Sorghum is mainly a rain fed crop of lowland, semi-arid areas of the tropics (Craufurd*et al*., 1999).

It requires an annual rainfall of 400 to 800 mm, which should be well distributed over the cropping season (Ng'uni*et al.,* 2012). Sorghum needs a rainfall of at least 300-380 mm during its growing period; however, an ideally distributed rainfall of only 175-mm may give a reasonable yield of sorghum (Acland, 1971). In these areas the rains may be intensive for a short while having started late, and/or finishing prematurely (Ashley, 1999). Survival of the crop usually depends on seasonal precipitation pattern and to the large extent on the fluctuations on the onset of rains and supplementary moisture (Kassam*et al.*, 1978, Reddy and Kidane, 1993).

Rapid leaf development and stem elongation follow panicle initiation. Rapid growth of the panicle starts after all but the last two or three leaves emerge. By the time the flag leaf is visible, all but the final 3 to 4 leaves are fully expanded and light interception is approaching its maximum; a few lower leaves may begin to senesce if nitrogen is not plentiful or the crop is planted very densely. The rate of leaf appearance in sorghum is closely related to thermal time. When temperature is not limiting, it takes about 2 days for each new leaf to emerge. For a cultivar with 18 leaves, in India a typical phenology and growth stages of 0 to 9 (as defined by Vanderlip and Reeves,1972) are as follows: emergence (0); 3-leaf stage (6 days after emergence, 6 DAE/6); 5-leaf stage (16 DAE/10); panicle initiation (32 DAE/16, approximately 9 leaf stage); flag leaf appearance (50 DAE/18, tip of final leaf visible in the whorl); boot stage (head enlarges in flag leaf sheath, 60 DAE/10); 50 percent flowering (68 DAE/8, half of the plants complete pollination, from the tip downwards); soft dough stage (80 DAE/12 squeezing kernel between fingers results in little or no milk); hard dough stage (96 DAE/16 when seed cannot be compressed between fingers); and physiological maturity (106 DAE/10 black layer (spot) appearance on the hilum at the base of the seed).

Sorghum leaves are upright when young but blades tend to bend downwards with maturity. Sorghum leaves develop on either side of the stem, exactly opposite to one another. As for all crops, rate of dry matter production is strongly affected by radiation intercepted, which depends on leaf area, especially between emergence and panicle initiation. Number of leaves per plant varies widely, from 7 to 24 depending on cultivar and climatic conditions. Sorghum is a short-day plant and panicle initiation is hastened by short days and longer nights. Since panicle initiates only after all leaves have initiated, if panicle initiation and blooming is earlier, the plant would have fewer leaves. Panicle initiation can be strongly affected by temperature regimes in addition to photoperiod. There are rather complicated interactions between photoperiod and temperature regimes, as well as a dependence on the cultivar's maturity group (Morgan et al., 1987).
Generally within the temperature range favorable for growth, leaf number tends to decrease as temperature decreases in growth Stage I, especially when the decrease is in night temperature (Quinby*et al.*, 1973).

2.3. Agro-ecology of sorghum

Sorghum is a short day plant but a wide genetic variation exists for its adaptation to a wide range of photoperiod and temperature conditions. It requires a deep, well-drained fertile soil, fairly stable rainfall and a warm, frost-free period to grow well. A wide range of soil conditions can be tolerated, but growth on sandy soils is usually poor, unless heavy textured subsoil is present. A pH of between 5.5 and 8.5 is acceptable. Sorghum tolerates water logging better than maize (Craufurd*et al.*, 1999).

2.4. Sorghum Production

Sorghum is usually cultivated as a field crop and has been, for centuries, one of the most important staple foods for millions of people in the semiarid tropics of Africa and Asia (Ali *et al.,* 2011). In most of these areas, sorghum remains the principal source of energy, proteins, vitamins and minerals. Presently, it is a staple food for more than 500 million people in more than 30 countries (Kumar *et al*., 2011).This is probably because it can be cultivated in harsh environments where other crops such as maize and wheat cannot grow

(Ali *et al.,* 2009).Sorghum has its origin in Ethiopia and from here it spread to other parts of Africa, India, Asia, Australia and the US. (Tawanda, 2004; ICRISAT, 2005). It's one of the longest cultivated plants in many arid and semi-arid regions of sub-Saharan Africa and other areas where other crops such as maize would fail (Mamoudou*et, al*., 2006

2.5. Sorghum cultivation and utilization

Sorghum is usually cultivated as a field crop and has been, for centuries, one of the most important staple foods for millions of people in the semiarid tropics of Africa and Asia (Ali *et,al.,* 2011). In most of these areas, sorghum remains the principal source of energy, proteins, vitamins and minerals. Presently, it is a staple food for more than 500 million people in more than 30 countries (Kumar *et al*., 2011).

This is probably because it can be cultivated in harsh environments where other crops such as maize and wheat cannot grow (Ali *et al.,* 2009). Cultivation in these areas is usually done without the application of fertilizers or other inputs (FAO, 1995). Sorghum can also tolerate cultivation on a wide range of soils and grows well on heavy vertisols commonly found in the tropics, where its tolerance to waterlogging is often required (Paterson *et al.,* 2009). It is equally suited to light sandy soils found in the dry areas. It can therefore produce grain on soils where many other crops would fail (FAO, 1995).

Sorghum has several uses. It is used for food, fodder and alcoholic beverages. Its stalks can also be used for fencing, firewood or for making brooms. The fibers can be used commercially to make wallboards and biodegradable packaging material (Delserone, 2007) and even solvents or dye can be extracted from the plant. A more recent use is as a source of ethanol and by-products from the ethanol production are also finding a place in the market (Delserone, 2007). Variation in grain color, shape and size as well as stalk thickness juiciness, sugar content and color often influence the use of the crop. The white, large grains with corneous endosperm are usually preferred for human consumption. Nutritive value is increased if the endosperm is yellow with carotene and xanthophyll (Ng'uni*et al*., 2012).

2.6. Nutritional status of sorghum

Sorghum is a principal source of energy, proteins, vitamins and minerals for people in the semi-arid tropics (Duodu*et al.,* 2003). It is a good energy source because it is about 70%

starch. Proteins are the main constituents of sorghum after starch, making up to 12% dry weight of sorghum grain (Ng'uni*et al.*, 2012).

The essential amino acid profile of sorghum protein differs (3-12% range) between varieties, soil and growing conditions (FAO, 1995). The digestibility of sorghum protein has also been found to vary between varieties, ranging from 30 to 70%. Sorghum's nutritional profile includes several minerals, though unevenly distributed and more concentrated in the germ and seed coat. Sorghum is a good source of the β-complex vitamins and some varieties contain B-carotene which can be converted to vitamin A by the human body. Some fat-soluble vitamins like D, E and K have also been detected, though not in sufficient amount (FAO, 1995)

2.7. Spacing and Optimum Population

Sorghum was indicated that the crop plants should cover the soil as early as possible to intercept maximum sunlight to produce higher dry matter as the intercepted solar radiation and dry matter production are directly related. Closely spaced and quick growing crops like soybean which can intercept more light within a short period of a time gives higher yield as compared to wider spaced crops. As such for the proper light interception at various growth stages, optimum plant population is necessary (Singh and Singh, 2002).

As plant density increases, the amount of dry matter in vegetative parts also increases. Both the biological and economic yields increase with increasing plant population up to a certain point and subsequently no addition in biological yield can be obtained and economic yield decreases. Therefore, the optimum plant population of individual crop should be worked out under suitable environmental conditions (Singh and Singh, 2002).

2.8. Effect of Seed Rate and Row Spacing on Grain Yield of Sorghum.

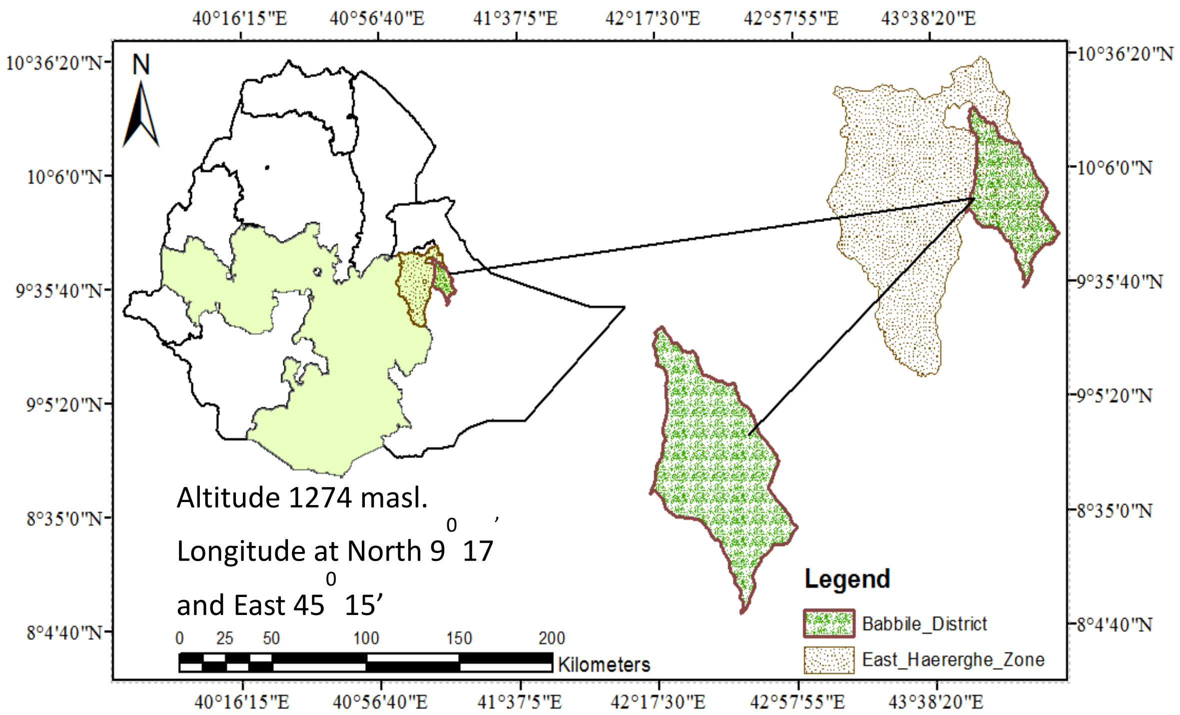
Seed rate and plant spacing were important factors for crop establishment technique that affects the crop stand and other yield parameters in different crops. Maintenance of optimum planting density was always a big problem to the farmers. Lower plant density results in higher weed infestation, poor radiation use efficiency and lower yields. On the other hand, dense plant population may cause lodging, poor light penetration in the canopy, reduction of photosynthesis due to shading of lower leaves and serious reduction in the yield (Lemerle*et al*., 2004; Lemerle*et al*., 2006).Similarly, plant population, on the basis of row spacing and seed rate, affects the crop stand, Sorghum has been reported that increase in plant population results in decrease in number of tillers (Pawlowski*et al*, 1993; Caliskan*et al.,* 2007), plant height (Ayub*et al.,* 2003) and stem diameter (Caravetta*et al.*, 1990) but grain yield per unit area increased (Caliskan*et al*., 2007). Row spacing affects the crop yield potential (Staggenborg, 1999; Bryant *et al*., 1986).Reducing the distance between rows improves weed control (Walker & Buchanan, 1982) by increasing crop competition and reducing light transmission to the soil (Andrade *et al*., 2002). Narrow row spacing results in higher grain yields in soybean (De Bruin & Pederson, 2008) and in other crops (Stickler & Laude, 1960). Narrow row spacing resulting in higher yield is explained by the improved light interception (Steiner, 1986) and decreased plant to plant competition between plants (De Bruin & Pederson, 2008). Johnson *et al*. (2005) reported reduction in total weed density in 30cm apart rows of peanut (A rachis hypogea) as compared to the weed density at greater spacing.

3. MATERIAL and METHODS

3.1. Description of Experimental Site

The fieldexperiment was conducted, at Fades Agricultural Research Center at Erer station in Babile district, East Hararghe zone of Oromia Regional State. The distance was 29 km far from Harar city in the East direction. The experimental site was located at altitude 1274 masl and longitude N 9^0 17' and E42^0 15' at lowland areas.Major cereals crops grown in the study area are sorghum, maize, groundnut, and fruits like mango and vegetables etc. Sorghum is the staple crops cultivated by farmers, in the vicinity of the site. The area gets the annual rainfall of about 600 – 900mm. The temperature of the area is increasing from time to time, ranging from 27 – 32^{o}C (Babile agricultural and natural resource office, (2019)).

Figure:1. Expermental site on map



3.2. Soil Sampling and Analysis

Soil analysis was made for the sample collected from the site before planting soil sample at depth of 0-30cm was taken randomly from the experimental field. The collected soil sample was composite to one sample and air dried

Then the composite soil sample was analyzed at Haramaya University soil laboratory for the determination of the selected physic-chemical properties of the soil .The parameters relevant for the study was soil pH. The total available nitrogen, available phosphorus, and soil texture and cation exchange capacity (CEC) shows that available total nitrogen was 0.096%.

3.3. Description of Experimental Materials

The sorghum variety used wasMelkam variety. It was early maturing types which were obtained from Fades Agricultural Research Center (FARC, 2019)

Table.1.Description of sorghum variety used for the experiment.

Variety of sorghum	Year of released	Area of adaptation		Flowering (days)	Maturing (days)	Plant height (cm)	Yield(qunt/hect.)	
		Altitude (m)	Rain fall (mm)				On research field	On farmers field
Melkam	2001	< 1600	400-800	76-82	118	126-158	37-58	35-43

Source: Fades Agricultural Research Center (FARC, 2019)

3.4. Treatments and Experimental Design

A field experiment was laid out in Randomized Complete Block Design (RCBD) with three replications and 16 treatment combinations consisting of two factors. Four inter-row spacing (90cm, 80cm, 75cm and 65 cm and intra-rows spacing (30 cm, 25 cm, 20 cm and 15 cm) and with one early maturing of sorghum (melkam)variety. The plot size was different for each plot. Therefore plot size was 3 meter in each length and their width was different in each plot such as for 90cm inter row the plot size was ($4 \text{ m} \times 3.6 \text{ m} = 14.4 \text{ m}^2$), (for 80cm inter row 4mx3.2m^2= 12.8 m^2), (for 75cm inter row the plot size was 4mx 3m=12 m^2) and (65cm inter row the plot size was 4 m x 2.6m= 10.4 m^2). The total row for each plot was four and the outer two rows wereserved as border. The middle two rowswere used for data collection.

The total area of the experimental site was 11 m x 57.1m = 628.1 $m^2$and the Spacing of 0.5 m and 1 m were allocated between plots and blocks, respectively. Details of treatment combination and plant population in hectares were listed in Table2.

Table: 2.Details treatment combination and plant population per hectare

Treatments	Inter X Intra-row spacing (cm)	Plant population per hectare(no)
T_1	90 x30	37,037
T_2	90 x 25	44,444
T_3	90 x 20	55,555
T_4	90 x 15	74,074
T_5	80x x30	41,667
T_6	80 x x25	50,000
T_7	80 x 20	62,500
T_8	80 x 15	83,333
T_9	75 x 30	44,444
T_{10}	75 x 25	53,333
T_{11}	75 x 20	66,666
T_{12}	75 x 15	88,888
T_{13}	65 x 30	51,282
T_{14}	65 x 25	61, 538
T_{15}	65 x 20	76,923
T_{16}	65 x 15	102,564

3.5. Management of the Experiment

All agronomic management practice was equally implemented for all plots at appropriate times. The experimental field was ploughed and harrowed by a tractor. Land leveling was done manually prior to planting. The sorghum seed was drilled during planting and thinning at five leaves stage according to the treatment. As per the practice of the experiment of Ministry of Agriculture, fertilizer is applied 100-kg ha^{-1} NPS during the sowing time and 50 kg ha^{-1} urea was applied at the knee height. The above NPS and Urea fertilizer application (ratio) was based on the current recommendation of MoA for lowland, However, Accordingly the amount of fertilizer application require for each experimental plot was different in amount. Therefore, the fertilizer was applied manually.

Hand weeding was done 4, 6 and 8 weeks after sowing the seed. Proper control measure was taken if any pest and disease occurs. Harvesting was performed manually by cutting above ground stock when the foliage, stem and head color of plant changed to red color and fully dried threshing will be done by beating with stick.

3.6. Data Collection

3.6.1. Phenologicaland Growth Parameters

Days to 50% flowering: It was recorded number of days from planting to a stage when 50% of the plants in a plot produced flower.

Days to 90% maturity: It was recorded number of days from planting to a stage when 90% of the plants in a plot produced matured seeds.

Plant Height: It was measured from five randomly selected plants from middle two row at maturity from the ground level to the base of the panicle was taken and the mean of value was recorded

3.6.2. Yield and yield related traits Parameter

Since the sawing type was drilling, the emerged seed number was above the recommended. Therefore, no need to count the emergence seed before thinning.

Initial stand count:-Data on initial stand count after thinning was recorded from the net plot area.

Final stand count:-Final stand count at harvest of the crop was recorded from the net plot area.

Number of productive tiller per plant:-Number of productive tiller was counted from five randomly selected planted at maturity of time from each plots and the mean **o**f five sampled plants ofproductive tillerwas takenper plant.

Total number of tiller per plant:-Number of total tiller was counted from five sampled plants and the mean of five sampled plants from each plot was taken.

Panicle weight (g): Fiveplants'sof panicle weight randomly selected from the central two rows were taken at harvesting time and weighted on the electronic sensitive balance and the mean weight was taken.

Panicle height (cm):-At the time of maturity five plants from each plot were collected randomly from the center two rows and length of panicle height from its base to the tip were measured and recorded and the mean of five sampled plants from each plot was taken.

Hundreds of seed weight (g): Hundred-grain seed were counted from sample taken from the net plot area and prior to measuring the weight of the kernel was adjusted to 12.5% moisture level. The kernels were counted using the hand count and the weights were determined using the sensitive balance.

Grain yield (kg):- All plants inthe net plot area were harvested to determine grain yield per plot and were converted toper hectare bases and were adjusted to 12.5 % moisture level.

Biomass weight (g):-above ground dry biomass weight was determined at harvesting time from the plant taken from the net harvesting area of each plot and converted to hectare bases and were adjusted to 12.5 % moisture level.

3.7. Data Analysis

Data was subjected to analysis of variance (ANOVA) on yield and related yield obtained from the experiment was carried out using {RCBD} Randomized Complete Block Design for two factors following the procedures outlined by Gomez and Gomez (1984). Computation of the ANOVA was conducted with the help of Genstat Eighteenth Edition. Least significant difference (LSD) was used at 5% level for the mean separation.

4. RESULT AND DISCUSSION

4.1. Soil AnalysisResult

1 Table: 3. **Major soil characteristics of the experimental site before planting.**

Soil properties	Values	Ratings	References
A. Physical properties			
sandy (%)	52		
clay (%)	30		
silt (%)	18		
Texture class	Sandy loam		Bouyoucos (1962)
B. Chemical Properties			
pH (H_2O)	7.99	Basic soil	EthioSIS (2014)
Organic carbon (%)	2.065	high	Murthy(2007)
Total nitrogen (%)	0.096	Very low	Tekalign (1991)
Available P (ppm) mg/kg)	20.18	Low	Tekalign(1991)
CEC (meq/100 g soil)	21.09	moderate	Landan(1991))

4.2.Stand Count

Sorghum plants were significantly affected by intra-row spacing but inter-row spacing and their interaction of main effect (intra and inter row) spacing was non-significant on stand count of sorghum in this study. The most likely reason for significantly affected by intra-row spacing was, the number of plants in a plot were different due to difference on spacing which created competition between plants for similar resources like (water, soil nutrients, light).Or the reasons for the reduction of stand count at the narrowest intra row spacing might be due to closing effect and narrow intra row spacing smaller plants crowded out and die due to intense competition for growth resources especially for light energy.

Table: 4.The effect of intra-row spacing on initial and final standcount of sorghum variety.

Plant spacing	Initial stand count	Finalstand count
Intra Row (cm)		
15	76.00[a]	75.00[a]
20	56.42[b]	55.42[b]
25	46.08[c]	45.42[c]
30	37.00[d]	35.83[d]
Significant level	*	*
LSD (0.05)	0.706	0.5020
CV (%)	1.6	1.1

Means with the same letter (s) in the same column are not significantly different at P<0.05; LSD= least significant difference; CV= coefficient of variance; NS= non-significant

4.3. Days to 50% flowering

Plant spacing significantly (P<0.01) affected by intra row spacing. But,interactions of main effect of inter and intra-row spacing and also inter-row spacing was non-significant affected(Table.5). But, it is generally pointed out that sorghum was flowering earlier in narrow plant spacing. In the other side, as intra-row spacing increased days to 50% flowering were also increased.This can be attributed to access for growth resources like water, nutrients and light that contributed forelongation of vegetative growth. This current result is in agreement with the findings of Abdala (2015) who reported that flowering in maize delays as intra-row spacing increases. According to his finding, flowering of maize delayed 40 cm spacing as compared to 25 cm, 30 cm and 35 cm intra-row spacing and also my finding was agreed with Sibhatu*et al* (2017)who reported that planting spacing affected the flowering of sorghum. According to his finding the highest days to flowering (113) of Meko-I variety was recorded from 75 cm inter-row spacing, and also its highest days to flowering (115.3) under 25 cm intra row spacing.

4.4. Days to 90% Physiological Maturity

The maturity of sorghum spacing was significantly (P<0.05) affectedby intra row spacing. But theinteractions of main effect of inter-row and intra-row and also inter-row spacing wasnon-significantly affected (Table 5).But, it was generally pointed out that sorghum matured earlier in narrow planting spacing. In the other side, as intra-row spacing increased days to maturity was also increased which implying that wider intra-row spacing delayed sorghum maturity. This isattributed to access for growth resources like water, nutrients and light which contributed for elongation vegetative growth under wider inter-row spacing.

This current result is in agreement with the findings of Abdala (2015) who reported that maturity in maize delays as intra-row spacing increases.According to his finding, maturity of maize delayed at 40 cm spacing as compared to 25 cm, 30 cm and 35 cm intra-row spacing.the result is also agreed with Sibhatu*et al* (2017)who reported the highest days to maturity (113) of Meko-I variety was under 75 cm inter-row spacing, and (115.3) under 25 cm intra row spacing.

Table: 5.The effect of intra-row spacing on day 50%of flowering and Day 90% of physiological maturity (days).

Plant spacing	Dayto 50%flowering *(days).*	Dayto 90% maturity*(days)*
Intra Row (cm)		
3082.00^{a}	122.0^{a}	
2580.33^{ab}	120.0^{ab}	
2077.88^{bc}	118.5^{b}	
1576.00^{c}	116.5^{c}	
Significant level	****	
LSD (1.05)	3.537	3.577
CV (%)	5.40	3.6

Means with the same letter (s) in the same column are not significantly different at P<0.05; LSD= least significant difference; CV= coefficient of variance

4.5. Total Number of Tiller perplant

Analysis of variance showed that both the main effect of inter-row and intra-row spacing and their interaction had highly significantly ($p<0.01$) affected on total number of tiller per plant.

The highest(3.38)total numbers tiller per plant wasrecorded at 90 cm inter-row spacing and the lowest (2.33) was recorded at 65 cm inter-row spacing.The highesttotal numberof tiller per plant (4.1) was recorded at 30 cm intra row spacing and the lowest total number (1.998) of tillers per plant was recorded at 15 cm intra-row spacing. Total number of tiller per plant was significantly higher by the interaction (4.6)of 90 cm inter row spacing with 30 cm. intra-row spacing (Table: 6).

The increase in number of tillers per plant with increase in inter-row and intra row spacing might be due to the plant nutrients present in the soil were enough for the vegetative growth and tiller formation when there were less number of plants per unit area. They were less competitive for all essential elements as compared to the greater number of plants per unit area.

This result is confirmed with that [Ahmad, *et*,*al*(2002)] who reported that increased in number of tillers per plant is due to increased inter-row spacing. This result can also be confirmed with that reported by [Haussmann, *el*,*al*, (1989)] who reported that increasing inter-row spacing may result in more total number of tillers per plant. However, the mean difference in number of productive tillers per plant between 50, 60, 70 and 80 cm inter-row spacing were not statistically significant or statistically similar with each other.

4.6. Productive Tillers per plant

The analysis of variance showed that both the main effect of inter-row and intra-row spacing and their interaction indicated on productive tillers per plant had highly significant ($p<0.01$) variations (Appendix Table 2).

The main effect of inter-row and intra-row spacing on Productive tillers per plant showed that higher numbers (3.1) were recorded from 90 cm inter-row spacing and the lowest (2.083) at 65 cm. concerning the inter-row spacing. The higher numbers of (3.7) Productive Tillers per plantwere recorded at 30 cm and the lowest Productive Tillers per plant (1.717) were recorded from 15 cm intra-row spacing (Table: 6).

The highest numbers(3.7) onProductive Tillers per plantwere recorded at 30 cm intra-rowand thelowest number (1.717) was recorded at15 cm intra-row spacing (Table: 6).

Productive tillers per plant were found significantly higher number by the interaction (4.3) 90 cm inter row spacing with30 cm.intra-row spacing. The increase in number of tillers per plant with increase in inter-row and intra row spacing might be due to the plant nutrients present in the soil because of reduction among plants for that enhanced the vegetative growth and tiller formation when there were less number of plants per unit area. They were less competitive among plants favor them essential elements as compared to the greater number of plants per unit area.

This result is confirmed with [Ahmad, *et,al.*(2002)]who reported increase in number of tillers per plant due to increased inter-row spacing. This result also confirm with the result of [Haussmann, *et.al*,(1989)] reported that indicated increasing inter-row spacing may result in more productive tillers per plant. However, the mean difference in number of productive tillers per plant between 50, 60, 70 and 80 cm inter-row spacing were not statistically significant or statistically similar with each other.

Similar to the effect of inter-row spacing, analysis of variance also showed that intra-row spacing had highly significant ($p<0.01$) variations onproductive tillers per plant. The main effect of intra-row spacing on productive tillers per plant showed that the higher numbers of tillers (3.35) were observed at 25 cm intra-row spacing while shortest plants (1.95) were recorded at 20 cm intra-row spacing. This could be because of the intra-row plant spacing competition for nutrient, moisture and sun light increases as the intra-row spacing decrease and then results in lower tillers per plant. The four intra-row spacing were statistically similar with each other for their mean number of tillers per plant With respect to interaction effect, analysis of variance showed that the interaction between inter-row spacing and intra-row spacing were found a non-significant ($P <0.01$) variations on number of productive tillers per plant. Comparatively, the interaction effect showed that the higher numbers of Productive Tillers per plant (5.16) were observed at 80x25cm spacing, while shortest plants (1.8) observed at 75 cm x 10 cm spacing.

Table: 6.The effect of inter row and intra row spacing on total number of tillers (no) and productive tillers (no) of sorghum variety.

Plant spacing	Total number of tiller per plant	Productive tiller per plant
Inter row (cm)		
903.375[a]	3.058[a]	
803.082[ab]	2.742[ab]	
75 2.808[b]	2.417[bc]	
65	2.325[c]	2.083[c]
Significant level** **		
LSD (0.05)	0.36240.3516	
Intra Row (cm)		
304.1[a]3.733[a]		
25 3.008[b]2.733[b]		
202.5[c]2.117[c]		
151.998[d]1.717[d]		
Significant level	****	
LSD (1.05)	0.3620.352	
CV (%)	1516.4	

Means with the same letter (s) in the same column are not significantly different at P<0.05; LSD= least significant difference; CV= coefficient of variance;

Table: 7.Effect of Interactionof inter-row and Intra-row spacing on total number of tiller per plant (no) onsorghum variety.

	Intra-row (cm)			
Inter-row (cm)	30	25	20	15
90	4.633^{a}	2.133^{fg}	3.2^{ef}	2.13^{def}
80	4.167^{ab}	3.433^{cd}	2.667^{cd}	2.060^{fg}
75	4.03^{abc}	3.0^{de}	2.2^{fg}	2.0^{fg}
65	3.5^{bcd}	2.067^{fg}	1.933^{g}	1.8^{g}
Significant level **				
LSD (0.05)0.723				
CV% 15				

Means with the same letter (s) in the same column are not significantly different at P<0.05; LSD= least significant difference; CV= coefficient of variance

Table: 8. Effect of Interaction of inter-row and Intra-row spacing on Productive tiller per plant of sorghum variety**.**

	Intra-row (cm)			
Inter-row (cm)	30	25	20	15
90	4.3^{a}	3.33^{bcd}	2.73^{cde}	1.867^{f}
80	3.833^{ab}	3.13^{bcd}	2.2^{ef}	1.8^{f}
75	3.6^{ab}	2.6^{de}	1.8^{f}	1.667^{f}
65	3.2^{bcd}	1.867^{f}	1.733^{f}	1.533^{f}
Significant level **				
LSD (0.05) 0.703				
CV% 16.4				

Means with the same letter (s) in the same column are not significantly different at P<0.05; LSD= least significant difference; CV= coefficient of variance

4.7. Plant Height

Analysis of variance showed thatinter-row spacing and interaction spacing was notstatistically significant but intra–row spacing had highly significant (p<0.01) variations on plant height(Appendix Table 1). The main effect of intra-row spacing on plant height showed that the tallest plants (156 cm) were recorded from 15 cm intra-row spacing while the shortest plants (145 cm) were recorded from 30 cm intra-row spacing (Table 9). In thesame way, the effect of 15 cm intra-row spacing resulted in significantly higher mean values in plant height than, 20, 25 and 30. However, the mean difference in plant height between 20, 25, and 30 cm were not statistically significant (Table 9). The result also showed that, as intra-row spacing increased, plant height tended to increase to a certain level from 15 cm. 20 cm and where, further increasing in row spacing resulted in decreased plant height. Similar to this, Goldsworthy, *et al* (1970) reported, increase in sorghum height with increase in inter-row spacing up to a certain level. Similar to the effect of inter- row spacing, analysis of variance also showed that both inter-row and intra-row spacing had highly significant ($p<0.01$) variations on plant height.

The main effect of intra-row spacing on plant height showed the tallest plants (229.483 cm) 15 cm intra-row spacing while shortest plants (217.108 cm) were recorded at 25 cm intra-row spacing. As Miko S. *et al*, (2008) reported sorghum plant height was significantly affected by intra-row spacing.

In general plant height was gradually increased with increased plant population and denser plant cultivars produced longer stems due to competition for available resources especially of light that penetrates the plant canopy. Further, the mean values of intra-row spacing indicated that plant height increased with each increment of intra-row spacing from 10 cm to 15 cm while further increasing in intra-row spacing resulted in decreasing plant height.

4.8. Panicle Length

Panicle length of sorghum was not significantly influenced ($P>0.05$) byinter-row and intra-row spacingaswell as theirinteraction of main effects of both factors(Appendix Table 2). On the range the sorghum variety was gave 31.33 cm.to32.17cm. panicle length in this study (Table: 9). Similar finding was reported by Adam *et al.*(2013) who showed that head length of pearl millet was not significantly affected due to intra-row spacing of 50 cm, 70 am and 90 cm at Zalingei Area, Sudan (Deressa 2017).

Table: 9.The effect of intra row spacing on plant height of sorghum variety.

Plant spacing	Plant height
Intra-row spacing	
30	145[a]
25	147.8[b]
20	150.8[c]
15	156[d]
Significant level	**
LSD (0.05)	6.64
CV%	5.3

Means with the same letter (s) in the same column are not significantly different at P<0.05; LSD= least significant difference; CV= coefficient of variance; NS= non-significant

4.9.100 seed weight

Analysis of variance table indicated non-significant effect on 100 seed weight due to intra and inter row spacing and their interaction (Appendix Table 2). According to table:-14.Neither inter-row nor intra-row spacing significantly affected hundreds seed weights of sorghum. Similarly, it was not affected by the interaction of the main effects of inter and intra-row spacing. The mean hundredsof seedweight were ranged from 2.78g to 2.83g(table: 14). This may be most probably due to Equal benefit of environmental resources such as water, solar radiation, and soil nutrients. This result is confirmed with the report of Abdala (2015) who indicated that hundred kernel weight of maize not significantly influenced by intra-row spacing. In contrast, Lakew*et al.* (2016), on effect of intra and inter-row spacing of maize, reported that with increase inter-row spacing, thousand kernels weight increased where the highest thousand kernels weight(382.7 g) was recorded at the widest inter-row spacing of 85 cm whereas, the lowest (336.2 g) was recorded at the narrowest inter-row spacing of 45 cm.

4.10. Panicle Weight

Panicle weight analysis of variance revealed that both the main effect of(inter-row and intra-row spacing)and their interaction indicated highly significant ($p<0.01$) variations on panicle weight(Appendix Table 2).

The main effect of inter-row and intra-row spacing on panicle weight showed, higher panicle weight (87.53) at 90 cm inter-row and the lowest (82.84) at 65 cm inter-row spacing concerning intra-row spacing,the higher of panicle weight (94.02) andthe lowest (77.72) were recorded at 30 cm intra row spacing and at 15 cm intra-row spacing respectively (Table 12).

Interaction effect of both inter-row and intra row spacing caused a highly significant effect on panicle weight of sorghum(Table: 12).The highest panicle weight (96.1g) was obtained from the interaction of 90 cm inter-rowwith 30 cm. intra-row spacing while the lowest panicle weight (76.8g) was scored from the interaction of 65 cm inter-row to 15 cm. intra-row spacing.

In general the higher number of panicle weight per plant was scored under 90 cm inter row spacing and at 30 cm. intra-row spacing. The above result was obtainedmost probably due to the ability of the plant to use effectively soil nutrients, water and light efficiently as a result of reduced inter and intra-row competition resulted from wider 90 cm inter- row and30 cmintra-row spacing. In addition, there is effective utilization of solar radiation, which is influenced by canopy structure, and directly leadsto produced high panicle weight per plants.

In general, the mean panicle weight of sorghum decreased as inter-row and intra-row spacing increased. This current result was in line with the report of Gobeze*et al*. (2012) which indicated that subjecting plants to reduced row spacing increased the ability of plants for capturing resources which in turn reflected on high panicle weight. Moreover, panicle weight of maize was highly significantly affected due to interaction of number of plants per hill by inter-row and intra-row spacing (Abdala, 2015).

Likewise, this current result was in line with the report of the. KetemaBelete, (1979) wider rows (50 and 75 cm) produced grain of greater panicle Weight of sorghum than the narrow row spacing.

Table: 10.The effect of inter and intra row spacing on panicle weight of sorghum(gm.) variety.

Plant spacing panicle weight (gm.)		
Inter-row (cm)		
9093.5^{a}		
8092.53^{ab}		
7590.0^{b}		
6584.88^{b}		
Significant level	**LSD (0.05)	6.260
Intra Row (cm)		
30	94.88^{a}	
25	92.52^{ab}	
20	90.25^{b}	
15	83.35^{b}	
Significant level		**
LSD (0.05)		6.260
CV (%)		8.3

Means with the same letter (s) in the same column are not significantly different at P<0.05; LSD= least significant difference; CV= coefficient of variance

Table: 11.The effects ofInteraction oninter-row and intra-row spacing onpanicle weight (gm) of sorghum variety**.**

	Intra-row			
Inter-row	30	25	20	15
90	96.10[a]	89.84[abcde]	85.46[cdef]	78.72[fg]
80	93.87[ab]	88.77[abcde]	84.99[defg]	77.84[fg]
75	93.48[abc]	87.32[bcde]	83.05[efg]	77.52[fg]
65	92.61[abcd]	84.87[defg]	77.08[g]	76.80[g]
LSD (0.05) 8.261				
CV % 5.8				
Significant level **				

Means with the same letter (s) in the same column are not significantly different at P<0.05; LSD= least significant difference; CV= coefficient of variance.

4.11. Grain yield

The main factors and interaction effect of both inter-row and intra row spacing caused a highly significant (P<0.01) effect on grain yield of sorghum. Consequently, as indicated on table 15 the highest grain yield (4875 kg ha-^{1}) was obtained from the interaction of 65 cm inter-row combined with15cm. intra-row spacing andthe lowest grain yield (1336 kg ha-1) was obtained from the interaction of 90 cm inter-row versusto 30 cm. intra-row spacing.

This might be due to the ability of closely spaced plants to trap most of the photo synthetically active radiation, more number of leaves per plant that provided more light trapping resulted from wider spacing for photosynthesis and assimilates production as opposed low pant population.

Generally, maximum yield was obtained at closely spaced plants of course to same limits not too narrow. Inagreement with this result Mashiqaa*et, al.*(2011) pointed out that intra-row spacing should not be too narrow as this can increase competition between plants and results in grain yield detrimental effects. This leads most probably to better light utilization, and hence higher assimilates production for grain filling at optimum planting spacing. This is reported Babaji*et al.* (2012) also indicated that each increase in both inter-row and intra-row spacing resulted in corresponding significant decrease in maize grain yield. Similarly, Miko and Manga (2008) confirmed this finding. Ali *et al*. (2017) and Lakew*et al.*(2016), reported that grain yield of maize was highly significantly affected by the interaction of inter and intra row spacing.

4.12. Above Ground Biomass

The main factor and theirinteractioneffect on the above ground biomass yield Thus, the highest biomass yield (11356 kg ha^{-1}) was produced from the interaction of 65 cm inter-row with 15 cm intra-row spacing and while the lowest (2956 kg ha-1) was obtained from the interaction of 90 cm inter-row with 30 cm intra-row spacing. This could be most probably due to the ability of the plant to use soil nutrients, water and light effectively at the above plant spacing that assisted to production of indicated.This is influenced by canopy high dry matter production of the plants.

In general, the mean biomass yield of sorghum decreased as inter-row and intra-row spacing increased. This current result is in line with the report of Gobeze*et al*. (2012) that indicated that subjecting plants to reduced row spacing increased the ability of plants for capturing resources which in turn reflected on high biomass production. Moreover, above ground biomass of maize was highly significantly affected due to interaction of number of plants per hill by inter-row and intra-row spacing (Abdala, 2015).

This result is also supported by the findings of Miko and Manga (2008) which revealed that the closest both inter-row and intra-row spacing (25 cm) produced statistically higher dry matter per plant than 75 cm and 80 cm, 90 cm spacing and cm 20 cm, 25 cm, 30 cm between plant and row spacing respectively

Likewise, a review by Ali *et al*. (2017) showed that significantly higher grain yield and above ground dry biomass yield of hybrid maize were obtained due to intermediate and closer spacing. Similarly,Tollenear and Aguilera (1992) also indicated that adjusting planting geometry to closer row spacing has more radiation use efficiency during grain filling which further results to higher dry matter production.

Table: 12. Effectof main Interaction of inter-row and Intra-row spacing on Grain yield (kg) per hectare of sorghum variety.

		Intra-row(cm)			
Inter-row(cm)		15	20	25	30
65		4878[a]	3389[c]	3026[d]	1991[hi]
75		3870[b]	2807[ef]	2326[fg]	1678[jk]
80		3097[d]	2160[g]	1903[h]	1521[kl]
90		2590[e]	1867[ij]	1614[k]	1336[l]
Significant level	**				
LSD (0.05)	242.5				
CV %	5.9				

Means with the same letter (s) in the same column are not significantly different at P<0.05; LSD= least significant difference; CV=coefficient of variance

Table: 13.Effectof Interaction of inter-row and Intra-row spacing on Above Ground Biomass (kg) of sorghum variety.

		Intra-row(cm)			
Inter-row(cm)		15	20	25	30
65		11356[a]	7691[c]	6867[d]	4520[gh]
75		9712[b]	5691[e]	5279[ef]	3808[ijk]
80		7029[d]	4902[fg]	4319[cd]	3452[kl]
90		5877[e]	4238[hij]	3664[jk]	2956[l]
Significant level	**				
LSD (0.05)	618.7				
CV %	6.6				

Means with the same letter (s) in the same column are not significantly different at P<0.05;

LSD= least significant difference; CV= coefficient of variance

5. SUMMARY AND CONCLUSION

Sorghum (Sorghum bicolor (L) Moench) is among the leading staple cereals for the majority of the world particularly in the arid and semiarid areas.

The productivityof sorghum is low due to moisture stress, low soil fertility, Strigaand the limited access to improved seed, weak agronomic management practice and inefficient production technologies.

The field experiment was conducted in babile district, aiming:

To assessing effects of inter and intra row spacing on yield and yield related trait of sorghum variety at low land area.The treatments consist of:

Four inter-row (90 cm,80 cm,75 cm, 65 cm) and, four intra-rows spacing (30 cm,25 cm,20 cm, and 15 cm) and One variety of sorghum (melkam).

The experiment was laid out as a Randomized Complete Block Design in a 4 x 4 factorial arrangement and Replicated three times per treatment.

Yield and yield related parameters such as initial stand count, final stand count, days 50% of flowering, day of 90% of physiological maturity, plant height, panicle height, panicle weight, productive tillers per plant, total number of tiller per plot from five sampled plants, hundreds of seed weight, above ground biomass weight and grain yield were collected and analyzed using Genstat Eighteenth Edition software.

Results of the experiment showed that maximum and minimum number of initial stand count (76 n$^{\underline{o}}$, 37 n$^{\underline{o}}$) and final stand count (75 n$^{\underline{o}}$, 35.83 n$^{\underline{o}}$).Which were obtained from 15 cm intra-row and 30 cm intra-row spacing respectively,were significantly ($P<0.05$) affected.

The maximumdays of 50% flowering (82 day)wassignificantly affected on the main effect of 30 cm intra-row spacing per plot from five sampled plants, day of 90% of physiological maturity (122 day) also as significantly affected on the main effect of 30 cm intra-row spacing per plot from five sampled plants. Since as inter-row andintra-row spacing increased it increase the day to flowering and days to maturity of the plant.

The maximum plant height (152.8 cm, 156 cm) was highly significantly ($p<0.01$) affected and the main effect of inter-row and intra-row spacing were recorded from 65 cm inter-row and 15 cm intra-row spacing respectively. Plant height was gradually increased with increased plant population and denser plant cultivars produced longer stems due to competition for available resources especially of light that penetrates the plant canopy.

Thehighestpanicle weight (96.1g), was highly significantly (P<0.01) affected, Panicle weight gave significantly higher number of weight per plant at the interaction of 90 cm inter-row and 30 cm. intra-row spacing because of,This could be most probably due to the ability of the plant to use soil nutrients, water and light efficiently and effectively.

The highest productive tillers per plant (4.3 (no)), and total number of tillers per plant (4.6 (no)), were highly significantly (P<0.01) affected, which were obtained from the interaction effect of 90 cm inter-row and 30 cm intra-row spacing respectively.

The maximum grain yield (4,875 kgh-1), and above ground biomass weight (11,356 kgh-1) were obtained from planting spacing of 65 cm inter-row with 15 cm intra-row spacing respectively.This might be due to the ability of closely spaced plants to trap most of the photo synthetically active radiation, more number of leaves per plant that provided more surfaces for photosynthesis and assimilates production. The 100 of seed weight and panicle length were not statistically significant.

Generally in appropriate use of inter and intra row spacing have influence on the growth parameters and also production of the plant. Many researchers observed that the reduction in plant height and number of tiller have effect on the total yield of the plant. Therefore, it is recommended that using 65 cm inter-row spacing with 15cm intra-row spacing is recommended for higher yield in the district where grain yield wasmaximum, and sorghum producing farmers in the district should adopt appropriately recommended inter-row spacing and intra-row spacing for enhanced productivity in the area. However, this tentative generalization should be validated by testing more spacing for more than one season and location to give a valid recommendation.

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7. APPENDICES

Table: 1 Mean square values of phenology and growth parameters of sorghum as influenced by Intra Row Spacing**.**

		Mean square		
Source of variation	Degree of freedom	Days to flowering (days)	Days to physiological maturity	Plant height (cm)
Replication	2	63.06	72.77	183.13
Inter row	3	12.19 ns	8.47 ns	61.43ns
Intra row	3	68.69**	65.87**	267.31**
Inter x intra- row	9	2.85ns	1.52ns	4.97ns
Error	30	27.8	18.41	63.43
Total	47			
CV (%)		5.4	3.6	5.3

Where, ** = highly significant; * = significant; ns = Non-significant.

Appendix Table 2: Analysis of variance showing mean squares for grain yield, above ground dry biomass yield of sorghum as influenced by Inter and Intra Row Spacing.

		Mean square	
Source of variation	Degree of freedom	Grain yield (kg ha^{-1})	Dry biomass yield (kg ha^{-1})
Replication	2	13751	185202.
Inter row	3	4840533**	26241417**
Intra row	3	8246430**	43900013**
Inter x intra row	9	265520**	1522326**
Error	30	21149.	137655.
Total	47		
CV (%)		5.9	6.6

Where, ** = highly significant; * = significant; ns = Non-significant

Appendix Table3: Mean square values of yield components of sorghum as influenced byInter and Intra Row Spacing.

Mean square						
Source of variation	Degree of freedom	Panicle weight(gm)	Initial stands count (%)	Final stand count (%)	No tiller /plant	productive tiller/plant
Replication	2	393.48	3.2500	3.1458	1.3127	1.3019
Inter	3	47.80**	0.97ns	0.47ns	2.390 **	2.112 **
Intra	3	584.2**	3365.9*	3363*	9.54**	9.254 **
Inter x intra	9	6.37 **	0.12 ns	0.23ns	0.1983**	0.169**
Error	30	24.54	0.7167	0.3681	0.1889	0.1779
Total	47					
CV (%)		8.3	1.6	1.1	15.0	16.4

Where, ** = highly significant; * = significant; ns = Non-significant