academicresearchJournals

Vol. 5(7), pp. 480-488, November 2017
DOI: 10.14662/ARJASR2017.077

ISSN: 2360-7874
http://www.academicresearchjournals.org/ARJASR/Index.htm

Academic Research Journal of Agricultural Science and Research

Full Length Research

Response of Short Duration and Small Size Improved Sorghum Variety to Inter and Intra-row Spacing in Raya Azebo District, Northern Ethiopia

Berhane Sibhatu[*1], Gebremeskel Gebrekorkos[1], Kasaye Abera[1] and Hayelom Berhe[2]

[1]Department of field crops, Ethiopian Institute of Agricultural Research, Mehoni Agricultural Research Center, P.O.Box, 71Maichew, Ethiopia.
[2]Natural Resources Management Research Process, Ethiopian Institute of Agricultural Research, Mehoni Agricultural Research Center, P.O. Box,71 Maichew, Ethiopia
*Corresponding author: E-mail: berhane76@gmail.com; phone: +251-914111020; P.O.Box: 71, Maichew, Ethiopia

Accepted 16 October 2017

This experiment was conducted at Fachagama, Tigray Region in 2015 and 2016 cropping seasons to determine optimum planting spacing for sorghum productivity under irrigation conditions. The experiment having factorial arrangement of three inter-row spacing levels (55 cm, 65 cm and 75 cm) and four intra-row levels (10 cm, 15 cm, 20 cm and 25 cm) was laid out in randomized complete block design (RCBD) with three replications. According to the current result, maturities of sorghum delayed at wider inter and intra-row spacing. Plant height decreased as intra-row spacing increased. Grain yield was significantly (P<0.05) influenced due to interaction effect of inter and intra-row spacing. Thus, maximum grain yield (4618.00 kg ha^{-1}) was obtained from planting spacing of 65 cm by 15 cm. Similarly, significantly high biomass yield (10481.00 kg ha^{-1}) from main effect of 65 cm inter-row spacing was produced. The economic analysis also showed that optimum net profit of birr 40238.36 and marginal rate of return (3494.41%) were obtained at inter and intra-row spacing of 65 cm and 15 cm. Generally, intermediate spacing gave remarkable yield while widely spaced plants produced low yields. This is, therefore, 65 cm inter-row spacing and 15 cm intra-row spacing can be recommended for short duration and small size improved sorghum varieties in Raya valley and other areas with similar agro-ecologies to sustain sorghum productivity.

Key words: Economic analysis, Inter-row spacing, Intra-row spacing, Sorghum, Variety, Yield, Yield components

Cite this article as: Sibhatu B, Gebrekorkos G, Abera K, Berhe H (2017). Response of Short Duration and Small Size Improved Sorghum Variety to Inter and Intra-row Spacing in Raya Azebo District, Northern Ethiopia. Acad. Res. J. Agri. Sci. Res. Vol. 5(7), pp. 480-488

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). It is used as human food, animal feed and fire wood. According to MoA (2010), 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 2014/15, sorghum covered14.58 % (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. 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, 2015). 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, 2015). 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 grain yields 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 and 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 (Yared *et 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 (Faisul *et al*., 2013).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. 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 late maturing sorghum varieties. But, farmers in the semi-arid area of Northern 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. Therefore, the objective of this study was to determine optimum planting spacing for small size sorghum varieties productivity under irrigation conditions in the study area.

MATERIAL AND METHODS

Description of the Study Area

The experiment was carried out at Mehoni Agricultural Research Center (MeARC) testing station, Fachagama, under irrigation conditions in 2015 and 2016 cropping seasons. It is located 668 km from Addis Ababa, the capital city of Ethiopia and about 120 km south of Mekelle, the capital city of Tigray Regional state. Geographically, the experimental site is located at 12.70° North latitude and 39.70° East longitude with an altitude of 1578 m.a.s.l. The site received a mean annual rainfall of 539 mm with an average minimum and maximum temperature of 12.81 and 23.24°C, respectively. The soil textural class of the experimental site was clay with neutral pH of 6.89 (Haileslassie *et al*., 2015).

Treatments and Experimental Procedures

The experiment was laid out in randomized complete block design (RCBD) with three replications. Improved, early matured sorghum variety (Meko-I) was used for the trial. Factorial combination of four intra-row spacing levels (10, 15, 20 and 25 cm) and three inter-row spacing levels (55, 65 and 75 cm) were applied as treatments. Each treatment was assigned to a plot size of 4.5 m * 4.5 m having plot and block spacing of 1m and 1.5 m, respectively. Nitrogen in the form of Urea at a rate of 41kg N ha^{-1} and phosphorus in the form of Di Ammonium

Phosphate (DAP) at a rate of 46 kg P_2O_5 ha^{-1} were applied to each treatments,where DAP was applied during planting while 50% of urea during planting and the remained 50% urea was applied at knee height. Prior to sowing, the land was finely prepared using a tractor. Sorghum seeds were planted as per proposed inter and intra row spacing. Initially two seeds per hill were planted and latter thinned to one plant at 3 to 4 leaf stage. All other appropriate agronomic practices such as weeding, thinning, watering and hoeing were conducted uniformly to the experimental field.

Data Collection and Statistical Analysis

Data on days to 90% maturity, plant height (cm), panicle length (cm), thousand kernel weight (g), grain yield (kg ha^{-1}), dry biomass yield (kg ha^{-1}) were collected and analyzed. The data were collected from middle rows of a net plot area where the two outer most rows of each treatment were left as border effects. Five plants from the net plot area were pre tagged to collect data of plant height and panicle length. Dry matter was measured using an electronic balance after the net plot area plants had been harvested and oven dried at 70 ^{0}C until constant dry weight was attained. Similarly, grain yield was weighed using electronic sensitive balance from the harvested plants of net plot area.

Economic analysis was also performed to investigate the economic feasibility of the treatments by using partial and marginal budget analysis. Marginal rate of return (MRR) was calculated as the change in net benefit (NB) divided by the change in total variable cost (TVC) of the successive net benefit and total variable cost levels (CIMMYT, 1988).

$$A = \left(\frac{N}{W}\right) * 100$$

Where, A= Marginal rate of return (MRR); N=Marginal increase in net benefit; W= marginal increase in cost

Dominated treatment (D): when the total cost exceeds the net income or with the increase in total cost, there is a decrease in net income, and it is called dominated treatment.

Net income = Gross income - total variable cost (Shah *et al.,* 2011). Total variable cost was calculated from purchasing costs of seed rate of the treatments, labor cost for row making, planting, weeding, and harvesting. To estimate the economic benefit, yields of sorghum was valued at an average existing local market price of Birr 9 kg^{-1} and Birr 0.45 kg^{-1} for biomass yields of sorghum from November 2016 to February 2017. In the economic analysis, the average yields were adjusted down wards by 10%, taking in to consideration those farmers could obtain 10% less than the experiment yield (CIMMYT, 1998).

The collected agronomic data were subjected to the analysis of variance (ANOVA) using the Gen Stat software computer package version 15.0 (VSN International, 2012) and significance difference among the treatment means was computed with least significant difference (LSD) at 5% probability level (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Days to maturity

Planting spacing significantly (P<0.01) affected the maturity of sorghum. Table 1 showed that the highest days to maturity (113) of Meko-I variety was recorded from 75 cm inter-row spacing, and also its highest days to maturity (115.3) was recorded at 25 cm intra row spacing. But, it is generally pointed out that sorghum was matured earlier in narrow planting spacing. In the other side, as inter-row spacing increased days to maturity was also increased which implied that wider inter-row spacing delayed sorghum maturity. Similar trend also observed in intra-row spacing. This attributed to fee access for growth resources like water, nutrients and light which contributed for vegetative growth elongation. This current result was 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.

Thousand kernel weight

According to Table 1, neither inter-row nor intra-row spacing of sorghum significantly affected thousand kernel weights of sorghum. Similarly, it was not affected by the interaction of the main effects of inter and intra-row spacing. It was not also affected due to cropping year. The mean thousand kernel weight was ranged from 39.09 g to 40.36 g. This non-significance may be most probably due to mutual benefit of environmental resources such as water, solar radiation, and soil nutrients. This result was confirmed to the report of Abdala (2015) who indicated that thousand kernel weight of maize was 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. These authors also added that with respect to intra-row spacing, the kernel weights increased with increase in intra-row spacing

Table 1. Effect of intra and inter-row spacing on days to maturity and thousand kernel weight of sorghum crop

Planting spacing	Days to 90% maturity	Thousand kernel weight (g)
Inter (cm)		
55	111.40b	39.27
65	112.80a	40.22
75	113.00a	39.46
Significance level	**	-
LSD (0.05)	0.85	NS
Intra (cm)		
10	109.90c	39.09
15	110.60c	40.36
20	113.80b	40.04
25	115.30a	39.11
Significance level	**	-
LSD (0.05)	0.99	NS
Year		
Y_1	110.45b	39.35
Y_2	114.33a	39.94
Significance level	**	-
LSD (0.05)	0.70	NS
CV (%)	1.30	5.40

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; Y_1= 2015; Y_2=2016

where the lowest thousand kernel weight (340.8 g) was recorded at 20 cm intra-row spacing and the highest weight (373.8 g) was at 30 cm intra-row spacing

Plant height

Inter-row spacing and cropping year did not cause significant effect on plant height of sorghum. However, plant height was significantly influenced due to intra-row spacing. Accordingly, the highest value (153.70 cm) of plant height for Meko-I was recorded from 10 cm while its lowest value was obtained from 25 cm though significantly at par with the 15 cm and 20 cm intra-row spacing (Table 2). According to Table 2, plant height of sorghum decreased as intra-row spacing increased. This ascribed to solar radiation that falls between crop rows and other soil nutrients remain unutilized.

The current result was in conformity with the work of Babaji *et al.* (2012) who reported that taller plants from the highest density because of higher competition for light. Likewise, Ibeawuchi *et al.* (2008) reported that closely spaced plants compete for nutrient and other growth factors, which tend to grow taller than those with wider spacing. Moreover, Miko and Manga (2008) noted that competition for light might be responsible for increase in height due to closer intra-row spacing of sorghum.

Panicle length

Like to plant height, panicle length of sorghum was not significantly influenced (P>0.05) by inter-row spacing and

Table 2. Effect of intra and inter-row spacing on plant height and panicle length of sorghum variety

Planting spacing	Plant height (cm)	Panicle length (cm)
Inter (cm)		
55	147.80	24.07
65	147.80	24.71
75	144.60	24.82
LSD (0.05)	NS	NS
Intra (cm)		
10	153.70a	23.92
15	146.60b	24.54
20	143.50b	24.69
25	143.20b	24.98
Significance level	**	-
LSD (0.05)	6.61	NS
Year		
Y_1	148.20	24.26
Y_2	145.30	24.81
LSD (0.05)	NS	NS
CV (%)	6.7	5.20

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; Y_1= 2015; Y_2=2016

cropping year. Similarly, it was not affected due to intra-row spacing and interaction of main effects (Table 2). Meko-I sorghum variety gave panicle length ranged from 23.92 cm to 24.98 cm. A 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.

Grain yield

Planting spacing caused a significant effect on grain yield of sorghum. According to Table 3, the interaction of inter and intra-row spacing significantly ($P<0.05$) affect grain yield of Meko-I. Consequently, the highest yield (4618.00 kg ha^{-1}) was obtained from the interaction of 65 cm by 15 cm while the lowest yields obtained at a wider inter-row and intra-row spacing interactions. 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. Generally, maximum yield was produced at closely spaced plants but not too narrow. 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 yield detrimental effects. This could be most probably due better light utilization, and hence higher assimilates production for grain filling at optimum planting spacing. This current report was in agreement with Babaji *et al.* (2012) who found that each increase in intra-row spacing has resulted in corresponding significant decrease in maize grain yield. Similarly, Miko and Manga (2008) confirmed this finding. According to Ali *et al.* (2017) and Lakew *et al.* (2016), grain yield of maize was highly significantly affected by the interaction of inter and intra-row spacing.

Table 3. Effect of year, intra*inter-row spacing on grain yield of Meko-I sorghum variety

Year	Grain yield (kg ha^{-1})			
Y_1		3468.00		
Y_2		3669.00		
LSD (0.05)		NS		
Inter-row spacing (cm)	Intra-row spacing (cm)			
	10	15	20	25
55	4233.00abc	4300.00ab	3785.00bcd	3396.00de
65	3574.00d	4618.00a	3750.00cd	2907.00ef
75	3473.00d	3355.00de	2678.00f	2753.00f
Significance level		*		
LSD (0.05)		550.80		
CV (%)		13.40		

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; Y_1= 2015; Y_2=2016

Biomass yield

According to Table 4, biomass yield of Meko-I was also highly significantly (P<0.01) influenced by inter-row spacing. Thus, the highest yield (10481.00 kg ha^{-1}) was produced from 65 cm while the other inter-row spacing treatments were statistically inferior. This could be most probably due to the ability of the plant to use soil nutrients, water and light efficiently and effectively at 65 cm inter-row spacing. In addition, there is effective utilization of solar radiation, which is influenced by canopy structure, and directly leads to high dry matter production in crop plants.

Intra-row spacing and cropping year did not give a response on biomass yield of this variety. In general, the mean biomass yields of sorghum decreased as intra and inter-row spacing increased. This current result was in line with the report of Gobeze *et al.* (2012) who found that subjecting plants to reduced row spacing increased the ability of plants for capturing resources which inturn 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 intra-row spacing (Abdala, 2015). It was also supported by the findings of Miko and Manga (2008) which revealed that the closest intra-row spacing (25cm) produced statistically higher dry matter per plant than 50 and 75cm spacing. 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. Other report by 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.

Economic analysis

Farmers need economically feasible technologies. According to Table 5, the highest net profit (birr 40238.36) and MRR (3494.41%) were recorded from the planting spacing of 65*15cm. Thus, sorghum farmers can plant short duration sorghum varieties at inter and intra row spacing of 65 by 15 m to obtain optimum yield under full irrigation conditions. From this analysis, it is generally observed that wider inter and intra row spacing gave minimum net benefit in relative to narrow planting spacing.

CONCLUSION

Plant spacing plays an important role on growth, development and yield of cereal crops. Particularly, optimum plant density is important to grow plants properly with their aerial and underground parts by

Table 4. Mean result for biomass yields of Meko-I sorghum variety as influenced by intra and inter-row spacing

Planting spacing	Biomass yield (kg ha^{-1})
Inter (cm)	
55	10467.00b
65	10481.00a
75	8767.00b
Significance level	**
LSD (0.05)	1006.00
Intra (cm)	
10	10436.00
15	10357.00
20	9543.00
25	9283.00
Significance level	-
LSD (0.05)	NS
Year	
Y_1	9961.00
Y_2	9849.00
LSD (0.05)	NS
CV (%)	17.50

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; Y_1= 2015; Y_2=2016

utilizing more sunlight and soil nutrients. It increases the capture of solar radiation within the canopy which in turn increases yield production. According to the current result, the highest grain and biomass yields were obtained at inter and intra-row spacing of 65 cm and 15 cm, respectively. Furthermore, the interaction of 65 cm by 15 cm gave maximum grain yield. The economic analysis also showed that optimum net profit and MRR were obtained at inter and intra-row spacing of 65 cm and 15 cm, respectively. Thus, the optimum planting spacing for sorghum under irrigation condition is at inter-row spacing of 65 cm and intra-row spacing of 15 cm. As a conclusion, sorghum farmers in the study area and other areas with similar agro-ecology are recommended to use 65 cm for inter-row and 15 cm intra-row spacing of sorghum to enhance the productivity of short duration and small size improved sorghum varieties in a sustainable mode.

ACKNOWLEDGEMENTS

The authors are thankful to Ethiopian Institute of Agricultural Research (EIAR) for funding this research project. The authors are also genuinely acknowledging for field assistants of Mehoni Agricultural Research Center for excellent field management till the execution of the experiment.

Table 5. Marginal budget analysis of sorghum as affected by inter and intra-row spacing

	Treatment combination											
	75*25cm	**75*20cm**	**65*25cm**	**65*20cm**	**75*15cm**	**55*25cm**	**65*15cm**	**75*10cm**	**55*20cm**	**65*10cm**	**55*15cm**	**55*10cm**
Average grain yield (kg ha^{-1})	2753.00	2678.00	2907.00	3750.00	3355.00	3396.00	4618.00	3473.00	3785.00	3574.00	4300.00	4233.00
Adjusted grain yield (kg ha^{-1})	2477.70	2410.20	2616.30	3375.00	3019.50	3056.40	4156.20	3125.70	3406.50	3216.60	3870.00	3809.70
Benefit from grain yield (birr ha^{-1})	22299.30	21691.80	23546.70	30375.00	27175.50	27507.60	37405.80	28131.30	30658.50	28949.40	34830.00	34287.30
Adjusted biomass yield (kg ha^{-1})	6663.60	7847.10	8626.50	8883.90	8359.20	9773.10	10436.40	8690.40	9036.00	9783.00	9169.20	9704.70
Benefit Biomass yield (birr ha^{-1})	2998.62	3531.20	3881.93	3997.76	3761.64	4397.89	4696.38	3910.68	4066.20	4402.35	4126.14	4367.16
Gross field benefits (birr ha^{-1})	25297.92	25223.00	27428.63	34372.76	30937.14	31905.50	42102.18	32041.98	34724.70	33351.75	38956.14	38654.42
TVC (birr ha^{-1})	1285.63	1318.96	1435.17	1648.78	1661.74	1831.42	1863.82	2018.91	2245.15	2416.05	2474.70	2737.18
Net benefit (birr)	24012.29	23904.04	25993.46	32723.98	29275.4	30074.08	40238.36	30023.07	32479.55	30935.7	36481.44	35917.24
MRR (%)	-	D	1324.84	3150.84	D	D	**3494.41**	D	D	D	D	D

TVC= total variable cost; MRR= marginal rate of return; D= Dominated treatment

REFERENCES

Abdala AA (2015). The Effect of Intra-Row Spacing and Number of Plants Per Hill on Irrigated Maize (*Zea mays* L.) Production at Gode, Eastern Ethiopia. M.Sc Thesis.Haramaya University, Haramaya, Ethiopia

Adam IK, Siddig AMA, Ali HB, Thabit AH (2013). Effect of Plant Spacing and Variety on Performance of Rain-Fed PearlMillet (*PennisetumGlaucum* L.) Grown on Two SoilTypes at Zalingei Area, Sudan. *ARPN Journal of Science and Technology*, 3(5): 512-517.

Ali A, Muhammad ES, Muhammad I, Rafi Q, Muhammad AA, Bashrat A, Muhammad AJ (2017). Inter- and Intra- Row and plant spacing impact on maize (Zea mays L.) growth and productivity: A review. *International Journal of Advanced Science and Research*, 2(1):10-14.

Babaji BA, Ibrahim YB, Mahadi MA, Jaliya MM, Yahaya RA, Sharifai AI, Mukhtar AA, Sani BM, Ibrahim A, Muhammad AA (2012). Response of extra-early maize (Z*ea mays)* to varying intra-row spacing and hill density.*Global Journal of Bio-Science and Biotechnology*, 1(1): 110-115.

Birhane G, and Yilma K (1979). The traditional culture and yield potentials of the Ethiopian high lysine sorghums Ethiopian. *Journal of Agricultural Science,*1(1):29-40.

CIMMYT (1988). From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely revised edition, *Mexico. D.F* conference held at International Livestock Centre for Africa *(ILCA)*, 31 August - 4 September 1987

CSA (2015). Central Statistical Agency, Agricultural sample survey.Statistical bulletin 578

Dial HL (2012). Plant guide for sorghum (*Sorghum bicolor* L.). USDA-Natural Resources conservation service, Tucson Plant Materials Center, Tucson, AZ.

Faisul UR, Raihana H and Bhat MI (2013). Agronomic evaluation of rice (*Oryza sativa* L.) for plant spacing and seedlings per hill under temperate conditions.*African Journal Agriculture Research,* 8 (37): 4650-4653.

FAO (Food and Agricultural Organization) (2012). Database of agricultural production.FAO Statistical Databases (FAOSTAT)

Fernandez CJ, Fromme DD and Grichar WJ (2012). Grain sorghum response to row spacing and plant populations in the Texas Coastal Bend Region. *International Journal of Agronomy,* 2012: 1-6, doi:10.1155/2012/238634.

Gobeze YL, Gert MC and Van Rensburg LD (2012). Effect of Row Spacing and Plant Density on Yield and Yield Component of Maize (*Zea mays* L.) under Irrigation. *Journal of Agricultural Science and Technology,* 2: 263-271.

Gomez KA and Gomez AA (1984). *Statistical Procedures for Agricultural Research*, John Wiley and Sons Inc., New York.

Haileslassie G, Haile A, Wakuma B, and Kedir J (2015). Performance evaluation of hot pepper (*Capsicum annum* L.) varieties for productivity under irrigation at Raya Valley, Northern, Ethiopia. *Basic Research Journal of Agricultural Science and Review*, 4(7): 211-216

Ibeawuchi II, Matthews-Njoku EO, Miriam OA, Chinyere P and Onyia VN (2008). Plant Spacing, Dry Matter Accumulation and Yield of Local and Improved Maize Cultivars. *Journal of American Science*, 4:1545-1003.

Lakew G, Ketema B, Tamado T (2016). Growth and Productivity of Maize (*Zea mays* L.) as Influenced by Inter- and Intra-Row Spacing in Kombolcha, Eastern Ethiopia. *Journal of Biology, Agriculture and Healthcare,* 6(13): 90-101.

Lemerle D, Causens RD, Gill LS, Peltzer SJ, Moerkerk M, Murphy CE, Collins D and Cullis BR (2004). Reliability of higher seeding rates of wheat for increased competitiveness with weeds in low rainfall environment. *Journal of Agriculture Science,* 142: 395-409.

Mashiqaa P, Lekgaria L and Ngwako S (2011). Effect of plant density on yield and yield components of maize in Botswana. *World of Sciences Journal,* 7: 173-179.

Miko A and Manga AA (2008). Effect of Intra–Spacing and Nitrogen Rates on Growth and Yield of Sorghum (*Sorghum bicolor L.*) Var. ICSV 400. *Patnsuk Journal,* 4 (2): 66-73.

MoA (Ministry of Agriculture) (2010). Animal and Plant Health Regulatory Directorate, Crop variety register issue no13. Addis Ababa, Ethiopia

MoARD (Ministry of Agriculture and Rural Development). 2003. Crop variety registers. Crop development department, MoARD, Issue No. 5, Addis Ababa.

Shah WA, Khan HU, Anwar S and Nawab K (2011). Yield and yield components of wheat as affected by different seed rates and nitrogen levels. *Sarhad J. Agric*. 27(1): 17-25

Staggenborg SA (1999).Grain sorghum response to row spacing and seeding rates in Kansas. *Journal of Production Agriculture*, 12(3):390–395

Tollenaar M, Aguilera A (1992). Radiations used efficiency of old and new maize hybrids. *Agronomy Journal*, 84:536-541.

VSN International (2012). *Gen Stat Reference Manual (Release 15), Part 1 Summary*. VSN International, Hemel Hempstead, UK.

Yared A, Staggenborg YSA and Prasad VPV (2010). Grain sorghum water requirement and responses to drought stress: A review. PMN.www.mssoy.org/uploads/files/crop-mgmt-nov-2010.pdf. Accepted on June 27, 2017