



Effect of Intra row Spacing and Number of Seedlings per Hill on Growth and Yield of Finger Millet (*Eleusine coracana* Gaertn.) at Jos Plateau, Nigeria

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ABSTRACT

Field experiment was conducted at the Research Farm of National Root Crops Research Institute, Kuru-Jos during the 2019 and 2020 rainy seasons to determine the effect of intra row spacing and number of seedlings per hill on growth and yield of finger millet. The treatments consisted of three different number of seedlings per hill (1, 2 and 3 seedlings per hill) and four levels of intra row spacings (10, 15, 20 and 25 cm) which were factorially combined and laid out in a Randomized Complete Block Design (RCBD) and replicated three times. The data collected includes plant height, number of leaves, leaf area index, and number of tillers, 1000 grain weight, and length of spike, straw yield, and number of seeds per spike and grain yield per hectare. The data collected were subjected to Analysis of Variance (ANOVA), and the treatments means were separated using Duncan Multiple Range Test (DMRT). The results showed that the effect of intra row spacing significantly ($P \leq 0.05$) affected plant height, number of tillers/plant, number of leaves/plant, leaf area index, and grain yield (kg/ha). The results also showed that the effect intra-row spacing significantly ($P \leq 0.05$) produced higher 1000 grain yield, straw yield (kg/ha) and spike length throughout the period. The result obtained on the effect of spacing and number of seedlings hill⁻¹ showed that one (1) seedling hill⁻¹ significantly ($P \leq 0.05$) enhanced higher plant height, number of tillers, number of leaves/plant, leaf area index, 1000 grain yield (g) and grain yield (kg/ha). It could therefore be concluded that finger millet responded better with 10 cm intra-row spacing and one (1) seedling per hill (10kg/ha) produced higher grain yield and could therefore be recommended to farmers in the study area for sustainable finger millet production.

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INTRODUCTION

Finger millet belongs to the family *poaceae*. In Africa, the production of finger millet is still at subsistence level by small holder farmers whose farm size is mostly between 0.5–3.0ha. Finger millet ranks second among millets cultivated in Africa and accounts for 19% of all millets produced in Africa (Sood *et al.*, 2017). Finger millet, a member of the millet group and also known as *Ragi* or *Tamba*

(Jideani *et al.*, 1996; Ramashia *et al.*, 2018) is so called due to its growth form of panicles which takes the form of several fingers (Sood *et al.*, 2017). Different cultivars of Finger millet grain exist: brown, light brown and white (Devi *et al.*, 2014; Kumar *et al.*, 2016), with grain colour used as the distinct means of cultivar differentiation. The white cultivars have been developed mainly for the baking industry, the brown and light brown types used for porridge

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while the brown cultivar is utilised for brewing traditional opaque beer in Southern Africa (Sood *et al.*, 2017). Finger millet (*Eleusine coracana* (L.) Gaertn.) is a staple cereal food crop for millions of people in the semi-arid region of the world, particularly in Africa and India, and especially those who live by subsistence farming. It is a major staple among the poor in Africa for food security and sources of energy and protein. The crop is thought to have originated from Uganda and Ethiopia (Yayeh and Fekremariam, 2014; Damar, *et al.*, 2016).

In Nigeria, the cultivation of finger millet is done mostly in the Northern part of the country, especially in Plateau and Kaduna States. Finger millet serves several purposes to the grower and other users. Besides the fact that it is being used as energy and protein sources, the straw serves as thatch material in some communities. In other communities, the grain is a major source of income while in others, it serves as animal fodder and medicine for treatment of human ailments, especially the leaves (Damar, *et al.*, 2016).

Fetene, *et al.* (2011) reported that the crop ranks third in cereal production in semi-arid regions of the world after sorghum (*Sorghum bicolor*) and Pearl millet (*Pennisetum glaucum*). Finger millet is widespread in warm temperate regions from Africa to Japan and Australia, but can also be grown in colder regions as far as Northern Ireland, during summer (Heuze and Tan, 2015). This crop is cultivated in wide geographical zone across eastern and southern Africa, through the middle east and into tropical Asia. The world annual production stands at 4.5 million metric tons, of which 2.0 million is produced in Africa from an estimated land area of about 19 million hectares (Tsado, *et al.* 2016). Nigeria with an average yield of 580 – 785Kg ha⁻¹ accounts for about 44% production of this crop in the continent. Finger millet is grown in the Northern parts of Nigeria, mostly in combination with pearl millet. The production of the plant, was not as much as other cereals in Nigeria, is an important crop due to its high nutritive value (Glew, *et al.*, 2008). Its several major uses include the following, the small grains—which are usually brown but occasionally white—are commonly

boiled into a thick porridge. Some finger millet is ground into flour and used for bread and various other baked products. All are relished for their flavor and aroma, malted finger millet (the sprouted seeds) is produced as a food in a few places. It is nutritious, easily digested, and is recommended particularly for infants and the elderly. Beverages. Much finger millet in Africa is used to make beer. Its amylase enzymes readily convert starch to sugar. Indeed, finger millet has much more of this "Saccharifying" power than does sorghum or maize. Finger millet straw makes good fodder—better than that from pearl millet, wheat, or sorghum. It contains up to 61 percent total digestible nutrients. Finger millet can be popped (National Research Council 1996).

MATERIALS AND METHODS

Experimental Site

The experiment was conducted at the National Root Crop Research Institute, Kuru, Jos, Plateau State of Nigeria during the 2019 and 2020 rainy seasons (Latitude 09°44'10" N and longitude 08° 48' 21"E) with an elevation of 1257.0 above sea level. The rainy season last for 6 months spanning between the months of May to October and dry season lasts for 6 months November to April in the study area. Physical and chemical properties of the soil at National Root Crop Research Institute Kuru, Jos in 2019 and 2020 was presented on Table 1.

Treatments and Experimental Design

The treatments consist of three different number of seedlings (1, 2 and 3 seedlings per hill) and four levels of spacing (10cm, 15cm, 20 cm, and 25cm). The treatments were factorially combined and laid out in a Randomized Complete Block Design and replicated three times. Plot size of 9m² was used and a border row of 0.5m was left between plots while 1m was left out as alley between replications. The inter row spacing of 75cm was used.

Cultural Practices

Land preparation

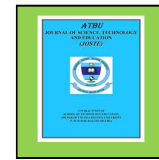
The experimental site was ploughed and harrowed twice mechanically with tractor to obtain a fine tilt. It was then marked out into

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three blocks with each block containing 12 plots, each plot measured 3.0m long and 3.0m wide. Discard of 0.5m and 1.0m was allowed to separate the adjacent plots and replications, respectively. The inter row spacing of 75cm was used.

Planting

Initially 8-10 seeds were sown per hole, after emergence, the seedlings were thinned to maintain the treatments (One, Two and Three seedlings per hill)

The Finger millet seed was planted on the 1st of May in 2019 and 2020 rainy seasons

Weed control

Weeding was carried out manually with hoe at four weeks after planting (WAP) from the beginning and subsequent weeding were done at 2 weeks interval thrice (3 times) throughout the experiment.

Fertilizer application

The fertilizer recommended rate of 90N ha⁻¹ 60 P₂O₅ ha⁻¹ and 45 K₂O ha⁻¹ reported by Sandhya *et al.* (2017) was adopted. During the construction of ridges, 90g of Single Super Phosphate per plot was broadcasted.

At first weeding, 270g of NPK15-15-15 was applied by spot method on each plot. During the last weeding 90g of Urea was also applied by spot method on each plot.

The application of 90g of Single Super Phosphate, 270g of NPK 15-15-15 and 90g of Urea at different phases made the recommended rate of 90kgN ha⁻¹, 60kg P₂O₅ ha⁻¹ and 45 kg K₂O ha⁻¹

Harvesting

The finger millet plants were harvested by sickle followed by cutting the panicle with knife to separate it from the stalk after drying, the plant stalks were tight and weight separate, the panicles were pounded using mutter then winnowed to separate seeds from the chaffs.

Assessment of Growth Characters of Finger millet

The data were collected from randomly 5 sampled plants/plot from the Centre

of each plot and the following data were collected

Plant height (cm)

The data was taken by measuring the height of the plant from the base to the tip of the tallest leaf of the plants using meter rule and tape at two weeks' interval beginning from 6, 8, 10 and 12 weeks after sowing (WAS).

Number of tillers per plant

The number of tillers per plant were also determined by counting on the sampled plants from each plot and recorded at 6, 8, 10, and 12 WAS.

Number of leaves per plant

The number of leaves per plant was also determined by direct counting of leaves on tagged five plants randomly selected from each plot and the average were recorded at 6, 8, 10 and 12 WAS

Leaf area Index (m⁻²)

The length width of leaves from each of the 5 selected plants per plot at 6, 8, 10 and 12 WAS were measured and then averaged to find the leaf area per plant. The result was then multiplied by a constant 0.75 to obtain LAI, following the formula of Yoshida (1981).

$$\text{LAI} = \frac{(\text{leaf area}) \times 0.75}{\text{Unit land area}}$$

Assessment of Yield Characters of Finger millet

Number of finger ear heads per plant

The number of Finger ear heads per plant was also determined by counting the number of fingers on the sampled plants at harvest and average recorded.

1000 grain yield (g)

1000 seed weight was determined by counting 1000 seeds harvested from each plot and was weighted using electronic balance.

Length of Spike (cm)

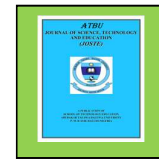
Spike length was measured on five randomly picked spikes from each plant/plot on each net plot at harvest. A measuring tape was placed

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from the tip to the base of each spike and was recorded.

Straw yield (Kgha⁻¹)

The data was collected by weighing the biomass yield in each plot at harvest using a weighing scale from individual plot and then extrapolated to per hectare.

Number of seeds per spike

The number of seeds per spike was also determined by taking 5 plants from each plot. When the spike was plucked and counted, they were threshed and the seeds were counted. The average was then calculated and recorded.

Grain yield kgha⁻¹

The grain yield per unit hectare was determined by first drying the harvested plants from net plot area in the middle rows of each plot in the sun for two weeks, followed by threshing, winnowing and weighing the grain using electronic weighing scale and yield was expressed into kilograms from individual plots and then extrapolated to per hectare.

Data Analysis

All the data collected were subjected to analysis of variance (ANOVA) to test the treatments effect for level of significance using a SPSS version 22 and Duncans Multiple Range Test (DMRT) was adopted during the analysis to separate significantly different means (Fasino, 2003).

RESULTS AND DISCUSSION

Soil Analysis

The results obtained for physical and chemical properties of the soil at the experimental site taken at the commencement of each season is presented in Table 1. The table indicated that the physical composition of the soil is predominantly sandy loam in both years of the investigation because of the composition of clay (g/kg⁻¹) 20.34%, silt (g/kg⁻¹) 17.30% and sand (g/kg⁻¹) 62.30% in 2019, while sand (g/kg⁻¹) 20.05%, silt (g/kg⁻¹) 17.28%, sand (g/kg⁻¹) 62.40% in 2020.

Chemical composition indicated that pH was 6.90 and 6.95 in 2019 and 2020 rainy seasons. For organic carbon (g/kg⁻¹) 1.60 and

0.78% in 2019 and 2020 respectively. Available P (g/kg⁻¹) 5.7 and 5.8%, while Nitrogen (g/kg⁻¹) is 0.048 and 0.024% in 2019 and 2020 respectively. For exchangeable Cation (Cmol⁻¹) indicate calcium 5.60% in 2019, Magnesium 10.8 and 7.2%, Sodium 90 and 97.9%, Potassium (7.98 and 7.90%) and cation exchange capacity (Cmol⁻¹) 3.6 and 3.50% in 2019 and 2020 respectively. However, the cation exchange capacity (Cmol⁻¹) had 3.60 and 3.50% in 2019 and 2020 respectively. From the analysis obtained, CEC (Cmol⁻¹/kg) was higher in 2019 with 3.60 than 2020 with 3.50 (Table 1).

Plant height (cm)

The effect of intra-row spacing and number of seedlings per hill on plant height of finger millet is presented in Table 2. The effect of intra-row spacing significantly influenced plant height except at 10 WAS in 2019 and 6, 10 and 12 WAS in 2020 rainy seasons. Each increase in intra-row spacing from 10 to 25cm led to a significant decrease in intra-row spacing in 2019 season, while at 8 WAS in 2020 season 15 and 25cm intra-row spacing produced taller plants followed by 20 and 10cm intra-row spacing produced shorter plants.

Number of seedlings per hill significantly influenced plant height at all the sampling periods except at 8WAS in 2019 season. One seedling per hill significantly resulted in taller plants at 6 WAS in 2019 which was followed by 6, 10 and 12 WAS respectively in 2020 season; The results agreed with the findings of Bhowmik *et al.* (2012) who reported that the tallest plant was observed in lesser number of seedlings per hill. Asbur (2013) reported that at one seedling per hill there was increased plant height, also Shao-hua *et al.* (2000) reported that one seedling per hill showed well developed root characteristic so that more higher number of tiller per plant and also Gani *et al.* (2016) reported that lower seed rate produces higher growth component of finger millet, this might be due to sufficient utilization of growth resources such as light, space, nutrition and soil moisture due to less plant population per unit area (Tadesse, 1995). Nigus and Melese (2018) also reported that the determination of optimum spacing and seed rate has importance on the growth of the plant

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for better nutrient competition with weeds, available moisture and use of sunlight, as the inner row spacing wider there was increment on both plant height and tiller number per plant. While Shirame *et al.* (2000) observed that two seedlings per hill gave significantly higher number of tillers per hill than three seedlings per hill.

Number of tillers per plant

The effect of intra-row spacing and number of seedlings per hill on number of tillers per plants of finger millet is presented in Table 3. Therefore, 2019 and 2020 seasons, the effect of intra-row spacing significantly influenced number of tillers per plant at all the sampling periods and seasons, except at 10 WAS in 2020 season. Each number of tillers per plant increases as the sampling period's progresses in both seasons, while at 12 WAS in 2019 season 15 and 20cm intra-row spacing produced the highest number of tillers per plants followed by 25 and 10cm intra-row spacing in 2020 season produced the highest number of tillers per plant at 12 WAS.

Number of seedlings per hill significantly influenced number of tillers per plants at all the sampling periods except at 6 WAS in 2019 season, while at 6 and 8 WAS in 2020 season; although, two seedling per hill produced highest number of tillers per plant while the lower were significantly produced by three seedling per hill at 6 and 8 WAS in 2019 rainy seasons. None of the treatment interactions on number of tillers per plant were significant. Shirame *et al.* (2000) reported that total number of tillers per hill was higher at wider spacing Gani *et al.* (2016) and Nyende *et al.* (2001) reported that Dibbling is carried out at 20x10cm inter and intra-row spacing he further reported that dibbled finger millet produced significantly taller plants, higher leaf area index, more number of tillers per plant and higher relative growth rate than broadcasting methods. This is similar to Nyende (2000) in Uganda that row planting gave rise to more vigorous crop growth and taller plants than broadcasting method. The higher number of tillers at wider spacing intercepted more of solar radiation, water and increased nutrient availability helped to produce significantly higher number of tillers.

Again, less competition between plants due to wider space allowed the individual plants to develop massive root system. Better aeration at wider spacing resulted in healthy plant growth with more tillers. These results are in conformity with the finding of Narasimhamurthy and Hedge (1981).

Number of leaves per plant

The effect of intra-row spacing and number of seedlings per hill on number of leaves per plant of finger millet is presented in Table 4. However, 2019 and 2020 seasons, the effect of intra-row spacing significantly influenced number of leaves per plant at all the sampling periods except at 10 and 12 WAS in 2019, and 6, 10 and 12 WAS in 2020 rainy seasons. Each increase intra-row spacing from 10 to 25cm led to a significant decrease in intra-row spacing in 2019 season, while at 8, 10 and 12 WAS in 2020 season, 20 and 10cm intra-row spacing produced the highest number of leaves per plant, followed by 15 and 25cm intra-row spacing in 2019 season produced the least number of leaves per plant.

Number of seedlings per hill significantly influenced number of leaves per plant at all sampling periods except at 6 and 8 WAS in 2019 and 2020 rainy seasons. One seedling per hill resulted in highest number of leaves per plant at 12 WAS in 2019 and 2020 seasons. The least number of leaves were significantly produced by one seedling per hill at 6 WAS in 2019 season. None of the treatment interactions on number of leaves per plant were significant.

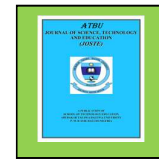
This study in agreement with Shinggu and Gani (2012) that reported that planting method and spacing had significant effect on number of leaves, number of panicle, panicle weight and grain yield. Planting finger millet at row spacing of 10 and 15cm gave highest number of leaves and heavier panicle weight than when planted at 20cm spacing. Nigus and Melese (2018) reported that the determination of optimum spacing and seed rate has importance on the growth of the plant in access of nutrient, competitions with weeds, access available moisture and use of sunlight, as the inner row spacing wider there was increment on both number of leaves, plant height and tiller

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number per plant. Oyedokun (1977) reported that the densities for use in establishment of finger millet will possibly vary depending on the kind of environment that one is dealing with as noted by Ahmad *et al.* (2010). Kidoido *et al.* (2002) also reported that declining yield of finger millet has also been attributed to constraints such as inadequate knowledge about proper sowing method, seed rate, improved varieties and limited use of inputs. Gani *et al.* (2016) reported that the consistency of lower seed rate producing higher growth components might be due to sufficient utilization of growth resources such as light, space, nutrition and soil moisture due to less plant population per unit area.

Leaf area index (cm²)

The effect of intra-row spacing and number of seedlings per hill on leaf area index of finger millet is presented in Table 5. Therefore, 2019 and 2020 seasons, the effect of intra-row spacing significantly influenced plant at all sampling periods in 2019 and 2020 rainy seasons. Each increase in intra-row spacing from 10 to 25cm led to a significant decrease in intra-row spacing in 2019 and 2020 seasons. 10cm intra-row spacing produced highest LAI, followed by 15 and 20cm intra-row spacing 25cm in both seasons produced the smaller LAI.

Number of seedlings per hill significantly influenced LAI at 8 & 12 WAS during the sampling periods except at 6 and 10 WAS in 2019 and in 2020 significant only at 10 WAS rainy seasons. However, one seedling per hill produced the highest LAI at 12 WAS in 2019 and 2020 seasons. The smallest leaf area per plant were significantly produced by three seedlings per hill at 6 WAS in 2019 season. The treatments interactions on LAI was significant at 12 WAS in 2019 season. Rangaraj *et al.* (2007) had reported that increased plants growth as reflected in the leaf area index (LAI) was due to moisture availability and adequate fertilization. According to Gani *et al.* (2016) that at 10cm spacing maximum leaf area index was produced as against minimum at 25cm intra-row. The trend of increases in leaf area index (LAI) at the various intra-rows showed 10cm intra-row spacing was significantly higher. The findings were also in line with Gautam *et al.*

(1982) and Shinggu *et al.* (2009) who reported that increased LAI in finger millet to be due to narrow spacing. Graybill *et al.* (1991) reported that increase in LAI of maize and rice was due to increased plant density resulting from narrow spacing. According to Tekle (2014) that leaf area index (LAI) increases as the seed rate decreases the effectiveness of the existing plant per hole to have maximum plant population gets increasing through increased leaf area index per plant. The reason could be possibly due to low competition for soil nutrients in low plant population from low seed rate that lead to enhanced plant growth.

Spike length (cm) SPL

The effects of the treatments on Spike length in both years are presented in Table 6. Varying intra-row spacing significantly influenced spike length in both years (2019 and 2020). 25cm intra-row spacing gave the longest spike length and were significantly at par with 10 and 15cm intra-row spacing's. The shortest spike length was produced by 15cm intra-row spacing in both seasons.

Number of seedlings per hill significantly influenced spike length in 2020 season except 2019 did not influenced spike length. Three seedling per hill significantly produced longest spike length that was statistically similar with two seedlings per hill. The least spike length was produced by one seedling per hill. There was highly significant interactions on spike length in 2020 season. These findings agreed with Mohamed *et al.* (2011) who found out that increase in spike length of bread wheat (*Triticum aestivum* L.) was associated with spacing and low soil moisture depletion level of 5% as against 60 and 75% respectively. Increase in length of spike ear-head was observed under 30cm spacing (Rajesh, 2011). Nigus and Melese (2018) reported that the lower and higher seed rate did not increase the spike length of finger millet. He also stated that, since the lower seed rate needs high moisture to recover while the higher seed rate also required plenty of rainfall to minimize the competition between the populations per the plot.

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Number of fingers per spike (NFPS)

The effects of the treatments on number of fingers per spike in both years are presented in Table 6. Varying intra-row spacing significantly influenced number of fingers per spike in both years. 20 and 25cm intra-row spacing significantly gave higher number of fingers per spike in 2019 season and there were significantly at par with 10 and 15cm intra-row spacing in 2019 and 2020 rainy seasons. The least number of fingers per spike was produced by 10 and 15cm intra-row spacing in 2019 and 25cm intra-row spacing in 2020 seasons.

Number of seedlings per hill significantly influenced number of fingers per spike in all the years. One seedling per hill significantly produced high number of fingers per spike that was statistically similar with two seedlings per hill. The least number of fingers per spike was produced by three seedlings per hill. None of the treatment interactions on number of fingers per spike were significant. Tariq *et al.* (2007) reported that application of nutrients amends soil, provides nutrients to crops, this consequently increase the number of fingers per spike and increased yield. He further added that the join effect of nitrogen released from the other organic manure, rainfall and warm temperature recorded during the period of study could be other reasons for the high number of spikelet produced (Damar *et al.* 2016). Yayah and Fekremariam (2014) reported that (seed rate) number of seedlings per hill and row-spacing are tied together. If the population is too high, plants compete with each other and often lodge. If the population is too low, a producer is wasting growing space and lowering yields (Robinson and Shawn, 2008).

Number of seeds per spike (NSPS)

The effects of the intra-row spacing and number of seedlings per hill on number of seed per spike in both years are presented in Table 6. Varying intra-row spacing significantly influenced number of seed per spike in 2020 and shown no significant in 2019. 10 and 25cm intra-row spacing significantly gave higher number of seed per spike that were significantly at par with 20 and 15cm in both years. The least number of seed per spike was produced by 15cm intra-row spacing in all the years.

Number of seedlings per hill significantly influenced number of seed per spike in 2020 shown no significant in 2019. One seedling per hill significantly produced high number of seed per spike in 2020 and three seedlings per hill in 2019 seasons that was statistically similar with two seedlings per hill. The least number of seed per spike was produced by two seedlings per hill. None of the treatment interactions on number of seed per spike were significant. This is in line with a study that planting finger millet in rows gives the highest grain yield as compared to broadcasting (Shinggu *et al.*, 2009 and GRDC, 2011).

1000 grain yield (g)

The effects of the treatments on 1000 grain yield in both years are presented in Table 7. Varying intra-row spacing significantly influenced 1000 grain yield in both years. 15 and 20cm intra-row spacing in 2019 and 2020 seasons significantly gave higher 1000 grain yield that were significantly at par with 10 and 25cm intra-row spacing. The least 1000 grain yield was produced by 10cm intra-row spacing in both years.

Number of seedlings per hill significantly influenced 1000 grain yield in all the years. One seedling per hill in both years significantly produced higher 1000 grain yield that statistically were at par with two seedlings per hill. The least 1000 grain yield was produced by three seedlings per hill in 2019 and two seedlings per hill in 2020 seasons. None of the treatments interactions on 1000 grain yield were significant. Damar, *et al.* (2016) reported that 1000 seed weights was neither affected by spacing or seed rate that this phenomena seems to suggest that the size of finger millet may not be affected by environment. This finding aligns with results reported by Mnyenyembe and Gupta (1998) that variability in mean grain yield of men fertile and male sterile finger millet was heridity.

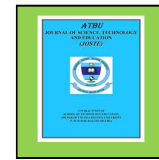
Robinson and Shawn (2008) reported that row planting has many advantageous in contrast to broadcasting. Previous research work on plant population studies on finger millet was observe when finger millet was planted at 20-30cm spacing and 10-15kg seed rate per hectare (Shinggu *et al.*, 2009).

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Straw yield $kg\ ha^{-1}$

The effects of the treatments on straw yield in both years are presented in Table 7. Varying intra-row spacing significantly influenced straw yield in 2019, except in 2020 seasons. 15cm intra-row spacing significantly gave higher straw yield that were significantly at par with 25cm intra-row spacing. The least was produced by 25cm intra-row spacing in both years.

Number of seedlings per hill significantly influenced straw yield in all the years. Three seedlings per hill significantly produced higher straw yield that was statistically similar with two seedlings per hill. The least was produced by one seedling per hill and two seedlings per hill in 2019 season. None of the treatments interactions on straw yield were significant. Shinggu *et al.* (2009) also reported that narrow spacing of 10cm spacing gave a better yield and weed control than wider spacing in finger millet.

Grain yield $kg\ ha^{-1}$

The effect of the treatments on grain yield in both years are presented in Table 7. Varying intra-row spacing significantly influenced grain yield in 2019 except in 2020 rainy seasons. 15 and 10cm intra-row spacing in 2019 and 2020 seasons significantly gave higher grain yield that were significantly at par with 25cm intra-row spacing in both years. The least was produced by 20cm intra-row spacing in both years.

Number of seedlings per hill influenced grain yield in all the years. One seedling per hill significantly produced higher grain yield that was statistically similar with two seedlings per hill. The least was produced by three seedlings per hill. There was highly significant interaction on grain yield in 2020 season. Gani *et al.* (2016) also reported that this dense plant population produced more harvestable panicles which translated into

higher grain yield of finger millet planted at intra-row spacing of 10cm and 15cm produced higher grain yield. Asbur (2013) observed that one seedling per hill increased grain yield of rice. Sanico *et al.* (2002) reported that increasing seedling number per hill decreased grain yield. Rizwan *et al.* (2013) who found a decreasing trend in yield by increasing seedling number per hill. Obulamama and Reddeppa (2002) revealed that one seedling per hill gave the highest grain yield, crop growth rate, and net assimilation rate while three seedlings per hill had the highest dry matter and leaf area index. Shrirame *et al.* (2000) observed that two seedlings per hill gave significantly higher number of tillers per hill than one and three seedlings per hill. In contrary view Bhowmik *et al.* (2012) Observed that the highest number of total tillers m^{-2} number of effective tillers m^{-2} and highest number of grains panicle⁻¹ were found in five seedlings per hill, grain yield decreased progressively with the decreased in number of seedlings per hill.

Shinggu and Gani (2012) reported that planting methods did not have effect on grain yield kg/ha and 1000-grain weights (g). Marshall and Ohm (1987) reported that suitable combination of seed rate and spacing could increase grain yield of wheat. This research is in line with Gani *et al.* (2016) that dense population produced more harvestable panicles which gave higher grain yield of finger millet. This was similar to spanner *et al.* (2005) who found that grain yield increased significantly with increasing seed rate.

It could be therefore be concluded that finger millet responded better with 10 cm Intra-row spacing and one seedling per hill ($10\ kg\ ha^{-1}$) where both growth and yield characters were significantly affected resulting in higher grain yield. The combination of 10 cm intra row spacing and One (1) seedling per hill could be recommended for use in the study area for sustainable finger millet production

Table 1: Physical and chemical Properties of Soil at NRCRI 2019 and 2020

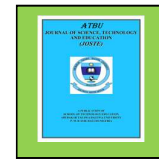
Soil composition	2019	2020
physical composition		
Clay ($g\ kg^{-1}$)	20.34	20.05
Silt ($g\ kg^{-1}$)	17.30	17.28
Sand ($g\ kg^{-1}$)	62.3	62.4
Texture class (used)	Sandy loam	Sandy loam

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chemical composition		
pH	6.90	6.95
Organic carbon (gkg ⁻¹)	1.60	0.78
Available P (gkg ⁻¹)	5.7	5.8
Total nitrogen (gkg ⁻¹)	0.048	0.024
EXCHANGEABLE CATION (CMOL ⁻¹)		
Calcium	5.60	
Magnesium	10.8	7.2
Sodium	90	97.9
Potassium	7.98	7.90
Cation exchange capacity (Cmol ⁻¹)	3.60	3.50

Source: Agricultural services and training Centre Kassa/Voms

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Table 2: Effect of intra row spacing and number of seedlings per hill on plant height (cm) on growth and yield of finger millet in 2019 and 2020 rainy seasons.

Treatment	Plant Height (cm) at weeks after sowing							
	2019				2020			
	6	8	10	12	6	8	10	12
Intra-row spacing (cm)								
10	66.40 ^a	94.56 ^a	100.67	120.89 ^a	68.73	66.22 ^c	119.44	151.78
15	55.23 ^b	77.32 ^b	98.31	151.26 ^b	65.40	94.56 ^a	112.33	148.67
20	51.73 ^c	42.43 ^c	95.27	116.96 ^c	58.33	68.67 ^b	116.67	149.22
25	38.62 ^d	55.07 ^d	94.87	114.81 ^d	68.89	96.44 ^a	115.22	140.08
LS	*	*	NS	*	NS	*	NS	NS
SE±	2.25	3.15	5.01	5.38	3.39	4.74	4.39	7.44
Number of seedlings hill⁻¹								
One seedlinghill ⁻¹	55.59 ^a	77.82	67.91 ^c	106.64 ^b	66.43 ^a	70.00 ^b	119.67 ^a	160.92 ^a
two seedlings hill ⁻¹	53.49 ^b	74.88	99.51 ^a	127.47 ^a	69.29 ^a	97.00 ^a	114.00 ^c	143.50 ^b
three seedlings hill ⁻¹	46.67 ^c	79.33	84.42 ^b	74.83 ^c	60.30 ^b	54.42 ^c	114.08 ^b	137.83 ^c
LS	*	NS	*	*	*	*	*	*
SE±	2.01	2.81	2.59	4.80	2.93	4.11	3.80	6.44
Interaction								
I x S	NS	NS	NS	NS	NS	NS	NS	NS

Mean followed by the same letter (s) in a column are not statistically different at 5% level of probability using DMRT
NS = Not Significant* = significant at (≤ 0.05) WAS= Week After Sowing LS = Level of Significant

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Table 3: Effect of intra row spacing and number of seedlings per hill on number of tillers per plant on growth and yield of finger millet in 2019 and 2020 rainy season.

Treatment	Number of Tillers per Plant							
	2019				2020			
	6	8	10	12	6	8	10	12
Intra-row spacing (cm)								
10	5.22 ^b	6.11 ^c	13.33 ^a	17.00 ^{ab}	8.25 ^{ab}	11.56 ^{ab}	15.67	29.56 ^a
15	4.62 ^c	8.67 ^b	14.37 ^{ab}	16.87 ^a	8.10 ^a	11.33 ^a	14.89	16.17 ^d
20	8.05 ^a	12.97 ^a	15.40 ^a	18.97 ^a	9.13 ^a	12.78 ^a	15.56	24.56 ^b
25	3.02 ^d	4.83 ^d	13.73 ^a	16.38 ^a	7.86 ^a	11.00 ^a	15.44	20.00 ^c
LS	*	*	*	*	*	*	NS	*
SE±	0.53	0.74	0.89	0.74	0.54	0.76	0.86	0.88
Number of seedlings hill⁻¹								
One seedling hill ⁻¹	7.66	7.02 ^b	13.93 ^{ab}	16.35 ^b	8.57	12.00	16.42 ^a	9.67 ^a
Two seedlings hill ⁻¹	7.86	11.00 ^a	14.97 ^a	20.39 ^a	8.39	11.75	15.58 ^b	18.04 ^b
Three seedlings hill ⁻¹	7.29	6.21 ^c	13.75 ^a	15.17 ^c	8.04	11.25	14.17 ^c	17.25 ^c
LS	NS	*	*	*	NS	NS	*	*
SE±	0.47	0.66	0.79	0.66	0.47	0.66	0.74	0.76
Interaction								
I x S	NS	NS	NS	NS	NS	NS	NS	NS

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Table 4: Effect of intra row spacing and number of seedlings per hill on number of leaves per plant on growth and yield of Finger Millet in 2019 and 2020 rainy season

Treatment	Number of Leaf per plant							
	2019				2020			
	6	8	10	12	6	8	10	12
Intra-row spacing (cm)								
10	39.76 ^a	55.67 ^a	88.33	122.44	44.60	62.44 ^a	111.22	149.11
15	26.83 ^a	37.56 ^a	83.83	125.18	33.25	46.56 ^b	104.22	140.78
20	32.86 ^{ab}	46.00 ^{ab}	74.11	114.66	40.64	56.89 ^a	101.56	146.22
25	29.68 ^a	41.55 ^a	69.62	111.81	47.62	66.67 ^a	107.33	132.33
LS	*	*	NS	NS	NS	*	NS	NS
SE±	6.90	9.66	10.49	7.97	6.16	8.63	9.56	8.51
Number of seedlings hill⁻¹								
One seedling hill ⁻¹	31.19	43.67	87.21 ^a	128.91 ^a	40.48	56.67	127.92 ^a	171.17 ^a
two seedlings hill ⁻¹	33.27	46.58	83.04 ^a	113.66 ^{ab}	43.33	60.67	100.50 ^b	132.08 ^b
three seedlings hill ⁻¹	32.38	45.33	66.67 ^b	113.00 ^a	40.77	57.08	89.83 ^c	123.08 ^c
LS	NS	NS	*	*	NS	NS	*	*
SE±	6.17	8.64	9.37	7.13	5.34	7.47	8.28	7.37
Interaction								
I X S	NS	NS	NS	NS	NS	NS	NS	NS

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Table 5: Effect of intra row spacing and number of seedlings per hill on Leaf Area Index on Growth and Yield of Finger Millet in 2019 and 2020 Rainy Seasons

Treatment	Leaf Area Index								
	2019				2020				
	6	8	10	12	6	8	10	12	
Intra-row spacing (cm)									
10		0.99 ^a	1.39 ^a	3.60 ^a	6.23 ^a	1.24 ^a	1.73 ^a	4.87 ^a	8.54 ^a
15		0.34 ^{ab}	0.42 ^{ab}	2.14 ^b	4.15 ^b	0.60 ^a	0.64 ^a	3.00 ^b	5.11 ^b
20		0.29 ^a	0.35 ^a	1.45 ^c	3.06 ^c	0.61 ^{ab}	0.86 ^{ab}	2.28 ^c	4.22 ^c
25		0.15 ^c	0.25 ^a	0.95 ^d	2.12 ^d	0.52 ^a	0.73 ^a	1.80 ^d	2.88 ^b
LS		*	*	*	*	*	*	*	*
SE±		0.12	0.17	0.32	0.36	0.16	0.23	0.34	0.66
Number of seedlings hill⁻¹									
One seedling hill ⁻¹		0.51	1.71 ^a	2.27	4.99 ^a	0.74	1.03	6.81 ^a	7.04
two seedlings hill ⁻¹		0.62	0.82 ^b	2.35	3.01 ^b	0.77	1.08	4.80 ^b	4.25
three seedlings hill ⁻¹		0.43	0.60 ^c	1.48	2.47 ^c	0.71	1.00	2.36 ^c	4.13
LS		NS	*	NS	*	NS	NS	*	NS
SE±		0.11	0.15	0.28	0.33	0.14	0.20	0.30	0.57
Interaction									
I X S		NS	NS	NS	*	NS	NS	NS	NS

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Table 6: Effect of intra-row spacing, and number of seedlings per hill on yield related characters of finger millet in 2019 and 2020

Treatment	Yield related characters					
	SPL		NFPS		NSPS	
	2019	2020	2019	2020	2019	2020
Intra row Spacing (cm)						
10	13.78 ^b	14.56 ^b	9.33 ^{ac}	9.67	313.11	311.22 ^a
15	13.00 ^c	12.08 ^d	9.25 ^a	9.33	295.19	254.89 ^b
20	14.70 ^b	14.11 ^c	10.47 ^a	9.11	307.39	333.22 ^a
25	14.90 ^a	15.00 ^a	10.05 ^{ab}	8.78	310.90	327.67 ^a
LS	*	*	*	NS	NS	*
SE +	0.68	0.35	0.32	0.42	23.06	16.74
Number of seedlings hill⁻¹						
One seedling hill ⁻¹	14.52	14.17 ^b	10.02 ^a	10.08 ^a	303.80	336.58 ^a
two seedlings hill ⁻¹	14.08	12.02 ^c	10.06 ^a	8.67 ^a	294.82	262.83 ^b
three seedlings hill ⁻¹	13.67	15.25 ^a	9.25 ^b	8.92 ^{ab}	321.33	320.83 ^a
LS	NS	*	*	*	NS	*
SE +	0.68	0.35	0.32	0.42	23.06	16.74
Interaction						
I X S	NS	**	NS	NS	NS	NS

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Table 7: Effect of intra-row spacing and number of seedlings per hill on yield characters and yield of finger millet in 2019 and 2020

Treatment	Yield Characters					
	1000 GY(g)		SY kg ^{ha} ⁻¹		GY kg ^{ha} ⁻¹	
	2019	2020	2019	2020	2019	2020
Intra row Spacing (cm)						
10	2.24 ^a	2.28 ^a	318.56 ^a	317.28	621.35 ^a	683.97
15	2.25 ^a	4.76 ^a	320.17 ^a	339.51	659.05 ^a	659.26
20	4.17 ^a	2.31 ^a	261.31 ^{ab}	314.82	499.29 ^b	607.41
25	2.48 ^{ab}	2.32 ^{ab}	232.49 ^a	279.01	654.74 ^a	649.38
LS	*	*	*	NS	*	NS
SE +	1.31	1.20	56.02	58.55	57.39	57.50
Number of seedlings hill⁻¹						
One seedling hill ⁻¹	3.69 ^a	4.11 ^a	263.57 ^{ab}	267.59 ^b	667.52 ^a	706.28 ^a
two seedlings hill ⁻¹	2.38 ^{ab}	2.31 ^a	252.46 ^a	320.37 ^a	608.03 ^{ab}	672.22 ^a
three seedlings hill ⁻¹	2.29 ^a	2.33 ^{ab}	333.33 ^a	350.00 ^a	543.52 ^b	571.30 ^b
LS	*	*	*	NS	*	*
SE +	1.31	1.20	56.02	58.55	57.39	57.50
Interaction						
I X S	NS	NS	NS	NS	NS	**

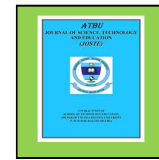
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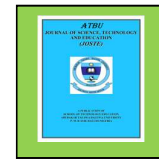
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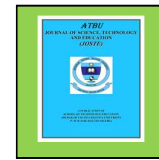
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