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Effect of Row Spacing on Yield and Yield Components of Teff [Eragrostis tef (Zucc.) Trotter] Varieties in Gonji Kolela District, North Western Ethiopia

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Abstract
Low productivity of tef [Eragrostis tef (Zucc.) Trotter] in Ethiopia is mainly attributed to lack of improved agronomic practices. Row planting should be in place to increase the productivity of the crop. An experiment was done at Gonji kebele, with the objectives of evaluating the effect of row spacing on yield and yield components and to determine the appropriate row spacing for maximum productivity of teff varieties. It was designed in RCBD consisting of four levels of row spacing (15, 20, 25 and 30cm) and four teff varieties (Buseye, Quncho, Etsub and Tsedey) a total of 16 treatments with three replications. The analysis of variance showed that days to 50% panicle emergence, lodging percentage, total number of tillers, number of effective tillers, grain yield, biomass yield, straw yield, and harvest index were influenced by both the main effects (P<0.01) and the interaction of row spacing and variety (P<0.05). On the other hand 90% physiological maturity, plant height, panicle length and thousand kernel weights were influenced by the main effect of row spacing and variety, whereas number of panicles per plant was influenced only by the main effect of variety (P<0.01). The highest grain yield was recorded from 20cm row spacing with Etsub (3148.1 kg ha^{-1}) and the lowest grain yield was obtained from 15cm with Buseye (2108.3 kg ha^{-1}). Even if there were no significance mean difference between 20 and 25cm for Etsub and between 20,25 and 30 cm for Buseye, Quncho and Tsedey varieties, it may be tentatively concluded that a combination of 20cm with Estub, 25 cm with Quncho and Tsedey and 30cm spacing with Buseye responded favorably in attaining higher grain yield of teff.
Keywords: Row spacing , Teff , Grain yield

1. INTRODUCTION

Teff [*Eragrostis tef* (Zucc.) Trotter] is an allotetraploid (2n=4x=40) crop belonging to the grass family poaceae and it is among the major cereals of Ethiopia. It has the largest value in terms of both production and consumption in Ethiopia and the value of the commercial surplus of teff is second only to coffee (Minten *et al*., 2013). It also provides over two-thirds of the human nutrition in the country (Lacey and Llewellyn, 2005). It is also the most desirable crop because of its straw quality for livestock feed, best "*Injera*"quality, and the ability to provide more satisfaction from a small weight of the grain (Dejene and Lemelem, 2012). In Ethiopia it occupies about 3.016 million hectares (24.03% of the grain crop area) of land which is more than any other major cereals such as maize and sorghum. It covers 17.58% of the total production next to maize from cereal production. In the country 37.9 % in area coverage, 38% in production and also 38.56% of the house holdings which grow teff is found in Amhara National Regional State. It is a leading cereal crop both in area coverage and grain production volume dominant over any other cereals produced in Amhara region as well as in West Gojam Zone even in Gonji Kolela District that covers more than 35.87% of the total arable land in the district (Gonji Kolela District BoA, 2014). However, despite its importance in Ethiopia, its productivity is low. In the 2015 cropping season, yields were 1.57 t ha^{-1} (CSA, 2015). Since teff is the staple food of most Ethiopian people, the current production system cannot satisfy the consumers' demand. This is because of agronomic constraints that include lodging, low modern input utilization, and high post-harvest losses and sowing method, etc. (Aamre and Adane, 2015). The national average grain yield of teff is about 1.57 t ha^{-1} (CSA, 2015). The above mentioned problems are real challenges in Gonji Kolela.

Since, teff improved seed, reduced seed rate and row planting (*TIRR*) package (ATA, 2014) is a new breakthrough in the country and also there is a blanket recommendation of row spacing (20 cm) by Ministry of Agriculture for all teff varieties that have different growing habit and characteristics for different agro ecologies and soil types, the agronomic components like row spacing and seed rate for different varieties should be optimized. The blanket row spacing has limitation on the productivity of teff which is influenced by the fertility status of the soil and yield potential of specific variety. Different research findings recommended different row spacing of teff. Tareke & Nigusse (2008) and Alemat *et al.* (2016) recommended a row spacing of 20 cm, while Fekeremariam *et al*. (2014) concluded that the row spacing of 15 cm, on the other hand the row spacing of 15-30 cm for transplanting and drilling of growing teff to enhance its productivity (Amare and Adane, 2015). Moreover, there is a trend by farmers use broadcasting and there is not clear recommendation of row spacing to drill or transplant teff seed for different varieties. However, limited research has been done to evaluate appropriate row spacing of teff varieties in the study area. Therefore, this study was initiated with the following objectives: To evaluate the effect of row spacing on yield and yield components of teff varieties and to determine the appropriate row spacing for maximum productivity of teff varieties.

2. MATERIALS AND METHODS

2.1. Description of the Study Area

The experiment was carried out at Farmers Training Center (FTC) in Gonji Kolela district, north- western Ethiopia during the 2016/2017 main cropping season. The site was located at $11^0 13'$ North latitude and $37^0 40'$ East longitudes and 67 km Southeast from Bahir Dar town. The altitude of the experimental area is 2160 meter above sea level. The mean annual rainfall was ranged from 820-1514 mm. Mean monthly minimum and maximum temperature of 30 years data is 9.2 and 24.8 °C respectively. The soil type of the study area is nitosols with the pH of 5.25.

2.2. Treatments, Experimental Design and Procedures

The experiment were laid in RCBD in a factorial arrangement consisting of four level of row spacing (15, 20, 25 and 30cm) and four varieties namely DZ-Cr-387-RIL 355 (Quncho), DZ-CR-37 (Tseday), DZ-CR-3186 (Etsub) and the local variety Buseye. Each treatment was replicated three times. The gross size of each plot was 1.5m length and 2.25 m width ($3.38m^2$) and net plot size of 1.8 m width and 1.3m length ($2.34\ m^2$). The row spacing of 15, 20, 25 and 30 cm had 15, 11, 9 and 7 rows, respectively. Spacing between plots and between replications were 0.5 m and 1m, respectively. Land preparation were done according to farmers practice in the area (oxen-plough) and the seed were sown by mixing the seed with the same sized sand to reduce the sowing problem in the rows and for optimum distribution of seeds. The seed were sown on the rate of 5 kg ha^{-1} at a row spacing as per treatments and fertilizers were applied at the rate of 100 kg NPSB and 50 kg Urea ha^{-1} as recommended by ANRS BoA (2015). Nitrogen fertilizer was applied in split so as to reduce leaching. All NPSB were applied during sowing time and half of the urea fertilizer was applied at 15-18 days after sowing. The remaining half of urea was applied at tillering stage of the crop. Weeding was done two times manually by hand similar to farmers practice.

2.3. Data Collection and Measurements

The necessary data were collected from central 12 rows of 15 cm, 9 rows of 20 cm, 7 rows of 25 cm and 6 rows of 30 cm row spacing in 1.3 meter length from each plot. Days to 50% panicle emergence , days to 90% physiological maturity, plant height , panicle length , number of panicles per plant, total number of tillers per plant , number of effective tillers, biomass yield (kg ha^{-1}), grain yield (kg ha^{-1}), straw yield (kg ha^{-1}), thousand-kernel weight (g) , harvest Index (%) and lodging percentage data were taken.

2.4. Statistical Analysis

Data were subjected to analysis of variances (ANOVA) procedures which are recommended to randomize complete block design by using SAS version 9.2 with a general linear model procedures (SAS Institute, 2003). Mean separation were undertaken by Duncan's Multiple Range Test (Duncan, 1955) at 5 percent level of probability. Correlation analysis was carried out by calculating simple correlation coefficients between yields and yield components.

3. RESULTS AND DISSCUTION

3.1.1. Days to 50 % panicle emergence

The analysis of variance revealed that days to 50 % panicle emergence was significantly ($P < 0.01$) influenced by the main effects of variety and row spacing. The interaction effect of those factors also significantly ($P < 0.05$) influenced days to 50% panicle emergence. Days to 50 % panicle emergence was significantly increased with the increase in row spacing. Days to 50 % panicle emergence ranged from 52.8 to 67.1 days at narrow (15 cm) row spacing and from 57.8 to 73.2 days at wider (30 cm) row spacing (Table 1). Varieties differed significantly in days to 50 % panicle emergence across different row spacing's.

At all range of row spacing, variety Tsedey had significantly fastest panicle emergence than the other varieties, whereas late panicle emergence was observed on Quncho variety. However, there was not significance mean difference between the means of 15 and 20 cm for Quncho and between the means of 25 and 30 cm for Tsedey variety. There was also non significance mean difference of days to 50 % panicle emergence between the means of Etsub variety at 20, 25 and 30 cm row spacing (Table 1). The earliness in panicle emergence of teff plants in response to decreasing row spacing might be due to competition of plants for resources in closer inter row spacing that might have led the plants to suffer from resource shortage resulting in earlier panicle to escape the stressful condition instead of having prolonged vegetative growth and biomass accumulation and attributed to the genetic factor (Bekalu and Tenaw, 2015).

Table 1: Interaction effect of row spacing and variety on days to 50 % panicle emergence and lodging percentage of teff

Row Spacing (cm)	Days to 50 % panicle emergence				Lodging percentage (%)			
	Buseye	Etsub	Quncho	Tsedey	Buseye	Etsub	Quncho	Tsedey
15	62.9[e]	64.9[d]	67.1[c]	52.8[h]	77.58[a]	76.58[a]	80.75[a]	67.83[bc]
20	65.3[d]	66.6[cd]	67.4[c]	55.2[g]	67.83[bc]	68.56[bc]	70.75[b]	56.83[ef]
25	67.1[c]	67.3[c]	70.3[b]	57.6[f]	59.42[de]	57.00[ef]	70.25[b]	55.17[ef]
30	69.5[b]	67.5[c]	73.2[a]	57.8[f]	58.33[ef]	52.33[f]	64.10[cd]	52.67[f]
LCR (0.05)	1.67				5.42			
CV (%)	1.55				5.02			

Means within a column and row of treatment followed by unlike letter (s) are significantly different using DMRT.
LCR= Least Critical Range

3.1.2. Days to 90 % physiological maturity

Days to 90 % physiological maturity was significantly ($P < 0.01$) affected by the main effect of variety and row spacing but the interaction of both factors was not significantly ($P > 0.05$) influenced days to 90 % physiological maturity. In general, increasing the row spacing from 15 to 30 cm prolonged the days to 90 % physiological maturity of teff. Over all, plants grown at 15 cm row spacing significantly shortened days to 90 % physiological maturity than those grown at the wider row spacing (Table 5). However, no significant mean difference existed between the plants grown under 20 and 25 cm row spacing for days to 90 % physiological maturity. This could be due to the presence of intense inter plant competition at the narrow row spacing that might have led to depletion of the available nutrient and as a results plants tended to mature earlier (Yordanos, 2013).

The mean days required to 90 % physiological maturity by local variety Buseye exceeded those required by Tsedye, Quncho and Etsub about by 19.48 %, 4.54 % and 3.38 % respectively (Table 5). Tsedey was significantly the earliest maturing variety (97.42) while local variety Buseye matured late (121.0) compared to the other tested varieties. However there were no significance difference between the means of Etsub and Quncho varieties for days to 90% physiological maturity. The significant difference in days to 90 % physiological maturity between the varieties might have occurred due to genetic differences and adaption of the varieties to different components of the environment (Temesegen, 2012).

3.2. Lodging Percentage

Lodging percentage was significantly ($P < 0.01$) affected by both the main effect of variety and row spacing. The interaction effect of the two factors also significantly ($P < 0.05$) affected lodging percentage. The interaction effect of variety and row spacing had significantly influenced lodging percentage. The highest lodging percentage was observed when 15 cm row spacing with Quncho variety (80.75 %) followed by 15 cm with local variety Buseye (77.58 %) and Etsub (76.58 %) variety and they were not significantly different each other. The lowest lodging percentage was recorded for plants sown at row spacing of 30 cm with Etsub variety which was 52.33 % followed by 52.67 % with Tsedey and 58.33% with Buseye variety in the same row spacing and they were all statistically in par (Table 1). Lodging percentage decreased consistently in response to increasing the row spacing from 15 to 30 cm for all varieties under study. This indicates that narrow row spacing had a pronounced effect on the production of high number of plant population which may cause stiff inter-row competition that might have week stock which led to lodging of teff and the genetic difference of the varieties (Amare and Adane, 2015). The present result is in agreement with Alemat *et al*. (2016).

3.3.1. Plant height

The analysis of variance showed that plant height was significantly ($P < 0.01$) affected by variety and row spacing, but was not significantly ($P > 0.05$) affected by the interaction of the two factors. Quncho had significantly longest plant height (130.94 cm) followed by Etsub variety (126.62 cm) whereas Tsedey had shortest plant height (98.35 cm)(Table 5). The difference in plant height of the varieties could be attributed to the difference in their genetic makeup (Jemal *et al., 2*015). Similar finding was reported by Shahzad *et al*. (2007). Over all, plants grown at 15 cm row spacing had significantly shortest plant height than those grown at the other row spacing's (Table 5) but it is statistically in par with 20 cm row spacing. This might have resulted due to the availability of growth factors with increased spacing and the indeterminate growth habit of the crop might encourage vegetative growth (Haile *et al.*,2016). The result is line with Gebre (2006) but disagrees with Khakwani *et al*. (2012) reported that narrow space produced the tallest plants in wheat and rice crops. The increase in plant height with the narrow hill space might be due to the role of shading in increasing cells elongation and hence increasing plant height (Kandil *et al.,* 2010).

3.3.2. Panicle length

Panicle length was significantly ($P < 0.01$) affected by the main effects of variety and significantly ($P < 0.05$) by the main effect of row spacing but was not significantly (P > 0.05) affected by the interaction effect of the two factors. Quncho had significantly longest panicle length (48.34 cm), over the panicle length of Tsedey variety (33.96 cm). Having a long panicle is a great advantage since the length of the panicle is directly proportional with the yield of the crop in teff. The mean significant difference in panicle length between the varieties might have occurred due to genetic differences (Daniel *et al.,* 2016). This result is in agreement with Hussain *et al.* (2016).

Row spacing of 30 cm had the longest panicle length (43.6 cm) and it was found in par with the mean panicle length obtained at 20 and 25 cm row spacing (Table 5). An increase of row spacing from 15 to 25 cm did not resulted in significance difference in panicle length. This could be probably due to the reduced interplant competition at the intermediate inter-row spacing, which encourages panicle growth of the plant (Alemat *et al*., 2016). But in disagreement with this result Mondal *et al*. (2012) and Hussain *et al.* (2016) who reported that there was no significant effect of row spacing on spike length of rice and wheat.

3.4.1. Number of panicles per plant

The number of panicles per plant was significantly (P < 0.01) affected by the main effect of variety but was not significant (P > 0.05) in the main effect of row spacing and the interaction effect of the two factors. Quncho variety had significantly highest number of panicles per plant (27.67). However there were no significance mean difference of number of panicles per plant between Buseye and Etsub varieties. The differences in number of panicles per plant were probably due to variation in genetic potential from variety to variety (Hussain *et al.*, 2016). This finding is in line with the report of Buri *et al.* (2016) who found that the number of spikes per hill showed a significant difference between the three varieties and from the different row spacing's used in rice crop. But, Bisheshwor *et al*. (2013) reported that there was no difference in varieties of wheat in terms of number of florets per spike.

3.4.2. Total number of tillers

Total number of tillers was significantly (P < 0.01) affected by the main effects of varieties, row spacing. The interaction effect of variety and row spacing had also significantly (P < 0.01) influenced total number of tillers. The maximum total number of tillers was recorded with 30 cm row spacing with Etsub (17.63) and the lowest total number of tillers was recorded under 15 cm with Buseye variety (3.6) (Table 2). Total tiller number increased consistently in response to increasing the row spacing from 15 to 30 cm. There is no significance mean difference between Quncho and Etsub varieties at 25 and 30 cm row spacing. As the distance between plant stands decreases competition for space, light and soil nutrients increase, resulting in lower tiller production.

The total number of tillers formed is a major factor that affects grain yield in teff hence grain yield decreases with decreasing number of tillers per hill (Fekeremariam *et al*., 2014). So it can be concluded from these results that total tiller number is a genetic characters of teff, which is highly influenced by agronomic practices like inter-row spacing. This is due to better access to space, nutrient, water and light in wider spacing than narrow spacing between rows and varietal characteristic is of major significance in the tillering ability of the crop (Garba *et al.,* 2013). The current result is not in consonance with those of John and Russell (2012) .

Table 2: Interaction effect of row spacing and variety on total number of tillers and effective tillers of teff

Row Spacing (cm)	Total number of tillers				Number of effective tillers			
	Buseye	Etsub	Quncho	Tsedey	Buseye	Etsub	Quncho	Tsedey
15	3.60^{k}	8.23^{i}	9.06^{h}	6.60^{j}	2.60^{j}	7.50^{h}	8.97^{g}	5.00^{i}
20	8.30^{i}	10.97^{f}	11.80^{e}	9.83^{g}	7.50^{h}	10.17^{ef}	11.10^{e}	8.50^{gh}
25	10.60^{f}	15.13^{bc}	14.50^{c}	13.13^{d}	9.53^{fg}	13.9^{c}	13.57^{c}	12.23^{d}
30	11.87^{e}	17.63^{a}	17.57^{a}	15.83^{b}	10.57^{ef}	16.53^{a}	16.07^{ab}	15.07^{b}
LCR (0.05)	0.75				1.05			
C V (%)	3.89				5.95			

Means within a column and row of treatment followed by unlike letter (s) are significantly different using DMRT.
LCR= Least Critical Range

3.4.3. Number of effective tillers

The analysis of variance showed that the number of effective tillers was significantly (P < 0.01) affected by the main effect of variety, row spacing and by the interaction effect of the two factors. Similar to total number of tillers the interaction effect of variety and row spacing had significantly influence number of effective tillers. The maximum number of effective tillers was recorded when 30 cm row spacing with Etsub variety (16.53) which was in par with Quncho variety (16.07) at the same level of row spacing and the lowest number of tillers was recorded under teff plants sown at row spacing of 15 cm with Buseye variety (2.6) (Table 2).

Number of effective tillers was significantly increased in response to increasing the row spacing from 15 to 30 cm for all varieties. This indicates that narrow row spacing had a negative effect on the production of high number of effective tillers. However, there were no significance mean difference in effective tiller number between Etsub and Quncho varieties at 20, 25 and 30 cm row spacing. Similar result was reported by Mondal *et al*. (2013)

and Tuhin *et al.* (2014) in rice. In addition Pandey *et al.* (2013) and Abreham *et al.* (2014) who reported that there was significant difference at ($P < 0.05$) of row spacing for the number of effective tillers per plant in wheat and teff crop. But in disagreement with this result Iqbal *et al*. (2010) shows that different row spacing affected significantly the number of effective tillers per square meter of wheat.

3.4.4. Biomass yield

The analysis of variance showed that biomass yield was significantly ($P < 0.01$) affected by both the main effect of variety and row spacing and by the interaction of the two factors. Biomass yield decreased significantly in response to the increasing level of row spacing. The maximum weight of biomass yield was obtained with 15 cm spacing, which was 14886 kg ha^{-1} of Quncho and the minimum weight of biomass yield was recorded when 30 cm row spacing, which was 10059.8 kg ha^{-1} of Tsedey variety (Table 3). These result also clearly showed that the widest row spacing treatments scored the lowest biomass yield result and in contrast the narrowest row spacing' treatments scored the highest biomass yield. The significant increase in biomass yields of varieties in response to decreasing the row spacing may be attributed to increased plant population (Yordanos, 2013). The result of the present study is in line with Chen *et al.* (2008) and Kebebew *et al.* (2012) . The finding of this result disagrees with Ali *et al.* (2011) .

Table 3: The interaction effect of row spacing and variety on biomass yield (kg ha^{-1}) and grain yield (kg ha^{-1}) of teff

Row spacing(cm)	Biomass yield (kg ha^{-1})				Grain yield (kg ha^{-1})			
	Buseye	Etsub	Quncho	Tsedey	Buseye	Etsub	Quncho	Tsedey
15	14104.5^{ab}	14316.2^{ab}	14886.0^{a}	11752.1^{ef}	2108.3^{g}	2393.2^{efg}	2350.4^{fg}	2151.0^{g}
20	12968.7^{cd}	12504.3^{de}	13911.6^{b}	11324.7^{fg}	2521.4^{def}	3148.1^{a}	2777.8^{bcd}	2435.9^{defg}
25	10666.5^{gh}	11911.8^{ef}	13558.3^{bc}	10723.3^{gh}	2578.3^{cdef}	2877.5^{abc}	2977.2^{ab}	2720.8^{bcde}
30	10392.9^{h}	11817.6^{ef}	12573.4^{de}	10059.8^{h}	2606.8^{cdef}	2378.9^{efg}	2621.1^{cdef}	2678.1^{bcdef}
LCR (0.05)	753.9				300.2			
CV (%)	3.66				6.97			

Means within a column and row of treatment followed by unlike letter (s) are significantly different using DMRT. LCR= Least Critical Range

3.4.5. Grain yield

The analysis of variance revealed that grain yield was significantly ($P < 0.01$) affected by the main effect row spacing. It was also significantly ($P < 0.05$) affected by the main effect of variety and the interaction of the two factors. The grain yields of varieties increased across the increasing of the row spacing exhibited except Etsub. As it is depicted in (Table 3), the highest grain yield was recorded from Etsub (3148.1 kg ha $^{-1}$) at 20 cm inter row spacing followed by Quncho (2977.2 kg ha^{-1}) at 25 cm inter row spacing which had statistically similar result. Whereas, the lowest grain yield was found from Buseye (2108.3 kg ha $^{-1}$) and Tsedey (2151.0 kg ha^{-1}) at 15 cm inter row spacing. This could be in wider spacing there is less competition for nutrients, moisture and light, more photosynthesis may be produced at the source and in turn translocate to the sink, thus resulting in higher yield (Mondal *et al*., 2013). The present study is in line with Buri *et al*. (2016) . On the other hand the result of Frizzell *et al.* (2006) and Hussain *et al.* (2012) shows that the narrow row spacing have higher grain yield than the wider row spacing in rice and wheat crops respectively.

3.4.6. Straw yield

Straw yield was significantly ($P < 0.01$) affected by the main effect of variety, row spacing and significantly influenced by the interaction effect of two factors. Increasing row spacing significantly decreased straw yields of all teff varieties. Except for Etsub variety, whose straw yield remained statistically the same across the three row spacing (20, 25 and 30 cm), increasing the row spacing significantly decreased the straw yields of all the other teff varieties.

The highest straw yield was obtained when 15 cm row spacing with Quncho (12535.6 kg ha^{-1}) followed by Buseye (11996.2 kg ha^{-1}) with the same row spacing and the lowest straw yield was recorded under teff plants sown at row spacing of 30 cm with Tsedey (7381.8 kg ha^{-1}) followed by Buseye (7786.0 kg ha^{-1}) (Table 4). The significant increase in straw yields of the varieties in response to decreasing the row spacing may be attributed to increased plant population. Similarly result was reported by Bhowmik *et al.* (2012). This result disagrees with the result of Yordanos (2013). Row spacing might have influenced vegetative growth in terms of plant height and number of tillers per meter row length (effective and non-effective tillers) which resulted in increased straw yield (Sultana *et al.,* 2012).

Table 4: Interaction effect of row spacing and variety on straw yield (kg ha^{-1}) and harvest index (%) of teff

Row Spacing (cm)	Straw yield (kg ha^{-1})				Harvest Index (%)			
	Buseye	Etsub	Quncho	Tsedey	Buseye	Etsub	Quncho	Tsedey
15	11996.2^{ab}	11923.1^{ab}	12535.6^{a}	9601.1^{efg}	14.93^{i}	16.72^{ghi}	15.8^{hi}	18.3^{fgh}
20	10447.3^{cde}	9356.1^{fg}	11133.8^{bc}	8888.8^{gh}	19.45^{efg}	25.16^{ab}	19.98^{efg}	21.52^{cdef}
25	8088.2^{hi}	9034.3^{fg}	10581.1^{cd}	8002.5^{hi}	24.2^{abcd}	24.28^{abc}	21.97^{bcde}	25.45^{ab}
30	7786.0^{i}	9438.6^{fg}	9952.3^{def}	7381.8^{i}	25.1^{ab}	20.21^{ef}	20.86^{def}	26.62^{a}
LCR (0.05)	844				3.09			
CV (%)	5.19				8.72			

Means within a column and row of treatment followed by unlike letter (s) are significantly different using DMRT. LCR= Least Critical Range

3.4.7. Harvest index

The analysis of variance revealed that harvest index was significantly ($P < 0.01$) affected by row spacing and significantly ($P < 0.05$) by the main effect of variety and the interaction of the two factors. The maximum percentage of harvest index was observed when 30 cm row spacing with Tsedey variety (26.62 %) followed by 25 cm with the same variety which was 25.45 % and the lowest harvest index was recorded under teff plants sown at row spacing of 15 cm with Buseye variety (14.93 %) followed by 15 cm spacing with Quncho variety which was 15.8 % (Table 4). This indicates that narrow row spacing have no a pronounced effect on high percentage of harvest index (Table 4).

The result of this study suggested that wider row spacing generally increased the harvest index, which may be attributed to increased utilization of available sunlight for production of higher dry matter production and yield. Similarly result was reported by Baloch *et al.* (2002) and Mondal *et al*. (2013). Significant varietal differences on harvest index in rice and teff crops were also reported by Ottis and Talbert (2005) and Alemayehu (2014) respectively. In the contrary Temesgen (2012) reported that harvest index was not significantly ($P < 0.05$) influenced by the main effects of variety in teff.

3.4.8. Thousand kernel weight

Thousand kernel weight was significantly ($P < 0.01$) affected by the main effect of row spacing. It was also significantly ($P < 0.05$) influenced by the main effect of variety. But thousand kernel weight was not significantly ($P > 0.05$) influenced by the interaction of the two factors. Row spacing of 25 cm had significantly the highest thousand kernel weight (0.352 g) over 15 and 30 cm row spacing. However, no significant difference were found between the means of thousand kernel weight of plants grown under 15 and 30 cm as well as between 20 and 25 cm row spacing (Table 5).

The result of the present study is in line with that of Awan *et al*. (2011) and Alam *et al.* (2012) . The current result did not agree with that of Bhowmik *et al*. (2012). Thousand kernel weight was also significantly influenced by the main effect of variety. Quncho had the highest thousand kernel weight (0.352 g) and it exceeds the thousand kernels weight of Etsub, Buseye and Tseday varieties by an additional percentage of 6.25 %, 7.95 % and 10.52 % respectively. The result of this study is in consistence with the result of Tuhin *et al.* (2014) that show there was a significance difference of thousand kernel weight in rice varieties. On the contrary, Bisheshwor *et al.* (2013) reported that there was no significant effect of variety on thousand kernel weight of wheat.

Table 5: The main effects of row spacing and variety on days to 90% physiological maturity, plant height(cm), panicle length(cm),number of panicles per plant and thousand kernel weight (g) of teff

	Days to 90% physiological maturity	Plant height (cm)	Panicle Length (cm)	Number of Panicles Per plant	Thousand kernel weight(g)
Variety					
Buseye	121.00^{a}	119.58^{c}	42.17^{c}	24.64^{b}	0.324^{b}
Etsub	116.91^{b}	126.62^{b}	45.07^{b}	25.42^{b}	0.330^{ab}
Quncho	115.50^{b}	130.94^{a}	48.34^{a}	27.67^{a}	0.352^{a}
Tsedey	97.42^{c}	98.35^{d}	33.96^{d}	19.73^{c}	0.315^{b}
LCR (0.05)	2.22	3.08	1.66	1.35	0.0235
Row Spacing (cm)					
15	109.33^{c}	114.36^{b}	41.18^{b}	23.67^{ns}	0.301^{b}
20	112.58^{b}	116.94^{b}	42.85^{ab}	24.52^{ns}	0.349^{a}
25	113.08^{b}	120.78^{a}	41.90^{ab}	24.42^{ns}	0.352^{a}
30	115.83^{a}	123.41^{a}	43.60^{a}	24.84^{ns}	0.320^{b}
LCR (0.05)	2.22	3.08	1.66	1.35	0.0235
CV (%)	2.36	3.11	4.7	6.65	8.55

Means within a column of treatment followed by unlike letter (s) are significantly different using DMRT. LCR= Least Critical Range

3.5. Correlation Analysis

Grain yield had significant positive correlations with plant height, total number of tillers, number of effective tillers , thousand kernel weight and strong correlation with harvest index, but negatively correlated with straw yield , lodging percentage and biomass yield . Grain yield had non-significant positive correlation with panicle length and number of panicles per plant. In agreement with the present result, Alemate *et al.* (2016) reported that grain yield was positively correlated with plant height and number of tillers per plant and negatively correlated with lodging percentage. On the other hand, Ashraf *et al.* (2012) and Solomon (2010) indicated that there is a negative and highly significant correlation between plant height and grain yield. This may be attributed to yield loss due to lodging as a result of greater plant height and peduncle length. The strong correlation of thousand kernel weight with grain yield.

4. CONCLUSIONS

Generally, the overall yield performance of the crop was good. Moreover, 20 cm inter-row spacing and Etsub variety gave relatively better yield and further widening, the inter-row spacing above 25cm, failed to increase yield in all varieties except local variety Buseye. Therefore, taking the result of the present study into consideration, even if there were no significance mean difference between the row spacing of 20 and 25cm for Etsub and between the row spacing of 20,25 and 30 cm for Buseye, Quncho and Tsedey varieties, it may be tentatively concluded that a combination of 20 cm row spacing with Estub, 25 cm row spacing with Quncho and Tsedey and 30 cm row spacing with Buseye responded favorably in attaining higher grain yield of teff. Moreover, depending on the agronomic performance and yield of this study variety Etsub at 20 cm row spacing was advantageous. However, since the present investigation was made at one location and for one season, it is too early to recommend the practice. Therefore, to increase the productivity of teff, future research directions have to be focused on verifying the present investigation across years and locations in order to reach on conclusion for the impact of row spacing and variety.

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