Genetic Gain in Yield Potential and Related Traits of Finger millet [*Eleusine coracana* (L.) Gaertn] in Ethiopia

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Abstract

Background: Genetic gains made on crop improvement are important for breeders to develop new crop varieties. However, information on the hitherto genetic gains made in the improvement of finger millet is scant and no assessment of this trait has been done on improved finger millet varieties in Ethiopia.

Objective: A field experiment was conducted to estimate the genetic gain in yield and related traits of finger millet varieties released in Ethiopia between 1999 and 2019.

Materials and Methods: Twenty finger millet varieties were evaluated in 2019/20 main cropping season at Adet and Finoteselam research sites using a randomized complete block design with three replications. Data were collected both on plot and plant basis, and then subjected to variance, correlation and stepwise regression analysis.

Results: The results revealed significant differences among the varieties and locations for almost all traits. The overall increases in grain yield over the oldest varieties were 449.03 kg ha^{-1} (22.49%) and 390.95 kg ha^{-1} (19.22%) at Adet and Finoteselam, respectively. The estimated annual and relative genetic gain was 30.88 kg ha^{-1} year^{-1} and 1.55% year^{-1} at Adet and 24.39 kg ha^{-1} year^{-1} and 1.2% year^{-1} at Finoteselam. Biomass yield and harvest index together contributed 99.74% and 99.42% of the variation in grain yield at Adet and Finoteselam, respectively. In addition, number of tillers plant^{-1} and ears plant^{-1} contributed to the change in grain yield as they were highly correlated with year of variety release.

Conclusion: It is concluded that, a substantial gain has been made in grain yield and related traits of hitherto developed finger millet varieties in the country, which is largely attributed to varietal change during the period 1999 to 2019. However, the gain obtained was low as compared to the gain made on other crops and the crop's potential, suggesting further breeding efforts need to be made in the future as this crop's genetic potential has not yet been fully exploited.

Keywords: *Eleusine coracana;* Finger millet; Genetic gain

1. Introduction

Finger millet [*Eleusine coracana* (L.) Gaertn] is a tetraploid (2n = 4x = 36, AABB) self-pollinating crop belonging to the family *Poaceae*, sub family *Chloridoideae*, genus *Eleusine*. The genus *Eleusine* contains about 10 species, in which some are tetraploids and others are diploids (Hilu *et al*., 1979). *Eleusine coracana* is believed to be a modern finger millet evolved from its wild progenitor, *Eleusine coracana* subsp. *africana* (Goron and Raizada, 2015). Archaeological records revealed that, the primary center of origin for finger millet is East Africa (particularly the Ethiopia highlands and Uganda), domesticated around 5000 years ago (Hilu *et al*., 1979). Subsequently, it is introduced to the Western Ghats of India (Upadhyaya *et al*., 2007). Nowadays, it is extensively cultivated in East and Central Africa (Obilana, 2003), and South Asia especially in India (Upadhyaya *et al*., 2007).

Ethiopia is the center of origin and diversity for finger millet (Hilu *et al*., 1979); however, its genetic potential is not as such exploited (Zigale Semahegn *et al*, 2021). Accordingly, the average productivity of finger millet in Ethiopia is low (2504 kg ha^{-1}) (CSA, 2021) as compared to its potential (4000 kg ha^{-1}) (Kebede Dessalegn *et al*., 2019). This is due to numerous obstacles, including unavailability of improved varieties and poor research attention towards

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the crop (Erenso Degu *et al.*, 2009). This indicates further research effort has to be made in the country and in the world as large. Because, a successful breeding program is likely to increase genetic gain, including grain yield (Heisey *et al.*, 2002). In Ethiopia, research on finger millet was initiated at Debre Zeit agricultural research center in the late 1950s. Much of the early efforts have focused on collection, conservation and characterization of finger millet germplasms. Then, the national sorghum improvement program based at Melkassa re-initiated finger millet research in 1986 (Erenso Degu *et al.*, 2009). Now, research emphasis has been given via national sorghum and millet research program, regional research institutes and higher learning institutions (Zigale Semahegn *et al*, 2021). Since then, efforts have been underway to develop high yielding finger millet varieties (Erenso Degu *et al.*, 2009). Thus, about 26 improved finger millet varieties have been registered and released from different research centers (MoA, 2020). Despite the availability of these varieties, the genetic gain made on finger millet varieties over the year of variety release has not been studied yet.

Estimation and documentation of genetic gain is useful as it helps breeders to make decisions about what breeding strategy they should follow, whether they ought to pursue or if changes are required. It also enables to identify traits of potential value for future breeding enhancement and target them for higher productivity and production. Evaluation of popular cultivars from different years in common environments is thus the most comprehensive and direct method that has been used to estimate progress in yield improvement (Abeledo *et al.*, 2003). In Ethiopia, genetic gain made has been studied in barley (Wondimu Fekadu *et al.*, 2013), teff (Fano Dargo *et al.*, 2016), maize (Michael Kebede, 2016), durum wheat (Mekuria Temtme, 2017) and bread wheat (Endashaw Girma *et al.*, 2019) by comparing old and modern varieties. They all found and documented the level of genetic improvement for grain yield and associated traits. However, there is no study documenting genetic gain on finger millet in the area, elsewhere in Ethiopia and in other countries. Therefore, the objective of this study was to estimate the genetic gain in grain yield and related traits of finger millet varieties of Ethiopia released between 1999 and 2019.

2. Materials and Methods

2.1. Description of the Study Areas

The experiment was conducted during 2019/20 main cropping season at Adet and Finoteselam agricultural research sites. Adet is located at longitude of 37^o 28' E and latitude of 11^o 17' N with an altitude of 2240 meters above sea level. During the study period, the site received an average annual rainfall and temperature of 1335 mm and 17.68 ^{o}C, respectively. Whereas, Finoteselam is located at longitude of 37^o 15' E and latitude of 10^o 41' N in northern highlands of Ethiopia with an altitude of 1820 meters above sea level. The average annual rainfall and temperature were 1263 mm and 22.82 ^{o}C, respectively during the study period [National Meteorological Agency, Bahir Dar Branch (2019)].

2.2. Experimental Materials and Field Management

Twenty finger millet varieties acquired from various agricultural research centers in Ethiopia were used for the study. The experiments were laid out in a randomized complete block design with three replications. Each plot consisted of four rows with row spacing of 0.4 m; and the size of the plot was 5 m x 1.6 m. NPSB blended and Urea fertilizers were applied at the rate of 100 kg ha^{-1} and 50 kg ha^{-1} in that order. The total amount of NPS fertilizer was applied during planting, whereas the total amount of Urea was applied at tillering stage. Other agronomic practices were carried out following the standard procedure.

2.3. Data Collection and Analysis

2.3.1. Data collection

Data were collected both on plot and plant basis. Among the plot basis, days to heading, days to maturity, grain filling period, head blast severity (%), biomass yield (kg), grain yield (kg), harvest index (%), biomass production rate (kg) and seed growth rate (kg) were recorded. However, effective tillers per plant, ears per plant, fingers per ear, plant height (cm) and finger length (cm) were recorded on plant basis.

2.3.2. Data analysis

Data were subjected to analysis of variance using the SAS software. Treatments and replications were class variables, while response variables were the measured traits. Differences between treatment means were determined using Duncan Multiple Range Test, and employed depending on significance of analysis of variance. Tests were made by F-test to confirm the homogeneity of error mean square between the two sites. Data transformation was done for number of tillers per plant, number of ears per plant, and head blast severity as they exhibited heterogeneity of variance. The collected data were computed as follows;

$$Yij = \mu + Gi + Rj + eij$$

Where, Yij = observed value of genotype i in block j; μ = grand mean of the experiment; Gi = effect of variety i; Rj = effect of block; j and eij = random error effect of variety i in block j.

Genotypic correlations were estimated using the standard procedure suggested by Kashiani and Saleh (2010) from the corresponding variance and covariance components. Thus, correlation was calculated as,

$$\text{Genotypic correlation coefficient (rgxy)} = \frac{\text{COVgxy}}{\sqrt{\sigma^2\text{gx}.\sigma^2\text{gy}}}$$

Where, rg (xy) = genotypic correlation coefficient between trait x and y; COVg (xy) = genotypic covariance between trait x and y and Vg (x) and Vg (y) = genotypic variance for trait x and y.

The mean performance of released varieties was regressed on year of release starting from 1999 using the first released variety as a base to calculate the genetic gain for each trait considered in the present study. A linear model (Y = bx + a) was used between response variables as a dependent variable, Y; year of release as an independent variable, X; intercept, a; and regression coefficient (the slope of the line), b (Gomez and Gomez, 1984). The breeding effect was estimated as genetic gain for grain yield and yield related traits in finger millet improvement by regressing mean of each variable for each variety against the year of release of that variety (0 to 20 years) using PROC REG procedure. The year of variety release was determined as the number of years since 1999. Moreover, the relative genetic gain achieved over the last 20 years for finger millet varieties were determined as a ratio of annual genetic gain to the corresponding mean value of oldest variety and expressed as percentage. Likewise, total relative genetic gain was computed as ratio of overall mean minus mean of oldest varieties to the corresponding mean value of oldest variety and expressed as percentage (Rutkoski, 2019). Stepwise regression analysis was carried out on the varietal mean to determine those variables contributing much to yield variation using PROC REG procedure.

3. Results and Discussion

3.1. Analysis of Variance

Homogeneity of error mean squares between the two sites was determined using F-test. The two locations did not show homogeneity of error variance. Consequently, the analysis was done separately for each location. Analysis of variance for the tested varieties at Adet revealed very highly significant ($P \leq 0.001$) differences for all traits except number of tillers per plant and number of ears per plant (Table 1). Likewise, the analysis of variance at Finoteselam revealed very highly significant ($P \leq 0.001$) differences for all traits except grain yield which showed highly significant ($P \leq 0.01$) differences (Table 1). As a result, the performance of the tested varieties were variable, indicating the existence of enormous amounts of genetic variability for growth and yield attributes among them; and among locations. Such phenotypic expressions and yield potential are based on its genetics, the environment and the genotype by environment interactions. They provide breeders with the opportunity to select or develop high yielding varieties, or to combine or transfer genes with desirable traits.

Genetic variations in finger millet have been also revealed in previous studies (Kebere Bezaweletaw *et al.*, 2006; Ganapathy *et al.*, 2011; Hailegebrial Kinfe *et al.*, 2017; Ashok *et al.*, 2018; Manoj *et al.*, 2019; Yaregal Damtie *et al.*, 2019). The authors all reported that, the variations among traits of finger millet genotypes are important for every breeding program as they can either affect yield positively or negatively, depending on the type of variation. High genetic variability brings the much needed information for genetic improvement program of finger millet (Manoj *et al.*, 2019). Moreover, similar results were reported for teff (Fano Dargo *et al.*, 2016), maize (Michael Kebede, 2016), durum wheat (Mekuria Temtme, 2017) and bread wheat (Endashaw Girma *et al.*, 2019). Thus, measurement and evaluation of genetic variability are an essential step in drawing meaningful conclusions from a given set of phenotypic observations (Reddy and Reddy, 2011).

Table 1. Mean and mean square of the traits of the varieties tested at Adet and Finoteselam.

Trait	Adet					Finoteselam				
	Mean	Treatment (DF=19)	Error (DF=38)	CV (%)	R^2 (%)	Mean	Treatment (DF=19)	Error (DF=38)	CV (%)	R^2 (%)
DH	102.13	157.21***	0.41	0.63	99.48	99.13	159.63***	0.89	0.95	98.89
DM	162.78	186.64***	1.83	0.83	98.11	155.92	144.35***	1.43	0.77	98.06
GFP	60.65	51.24***	1.76	2.19	93.67	56.78	74.57***	1.92	2.44	95.10
PH	71.04	152.57***	21.91	6.59	78.50	80.90	204.80***	43.14	8.12	70.61
FL	7.02	15.00***	0.46	9.70	94.24	7.79	12.17***	0.29	6.89	95.47
TPP	4.09	0.17^{ns}	0.11	16.73	47.30	3.34	0.14***	0.04	10.60	65.81
EPP	5.04	0.13^{ns}	0.09	13.53	45.40	4.34	0.11***	0.03	8.07	65.79
FPE	5.72	6.18***	0.44	11.58	87.80	5.84	2.65***	0.17	7.04	88.76
BY	10807.00	5185018.79***	1320080.10	10.63	68.13	9955.00	4194905.10**	1347645.50	11.66	61.14
GY	2397.00	258895.36***	32501.81	7.52	80.66	2386.00	224196.23***	34258.20	7.76	76.74
HI	22.28	5.95***	1.36	5.23	69.29	24.13	10.02***	2.20	6.14	69.90
BPR	66.59	244.66***	48.78	10.49	73.04	64.05	222.52***	56.55	11.74	66.49
SGR	39.67	81.65***	9.69	7.84	81.78	42.29	95.78***	12.59	8.39	79.31
HB	15.65	6.37***	0.38	16.88	89.34	26.71	5.46***	0.19	8.78	93.49

Note: *** = *Very highly significant at* $P \leq 0.001$; ** = *Highly significant at* $P \leq 0.01$; *and ns = Non-significant. DF = Degrees of freedom;* R^2 = *Coefficient of determination (%); CV = Coefficient of variation (%); DH = Days to 50% heading; DM = Days to 50% maturity; GFP = Grain filling period; PH = Plant height (cm); FL = Finger length (cm); TPP = Tillers plant*$^{-1}$; *EPP = Ears plant*$^{-1}$; *FPE = Fingers ear*$^{-1}$; *BY = Biomass yield (kg ha*$^{-1}$ *); GY = Grain yield (kg ha*$^{-1}$ *); HI = Harvest index (%); BPR = Biomass production rate (kg ha*$^{-1}$ *day*$^{-1}$ *); SGR = Seed growth rate (kg ha*$^{-1}$ *day*$^{-1}$ *); and HB = Head blast severity (%).*

3.2. Progress made on Yield and Related Traits of Finger millet

3.2.1. Progress made on grain yield

At Adet, strong positive relationship (y = 30.88x) was observed between mean grain yield and year of variety release (Table 4 and Figure 1). This implies that, the past finger millet breeding efforts in Ethiopia resulted in an average grain yield increment from 1996.4 kg ha^{-1} in 1999 to 2563.3 kg ha^{-1} in 2019 (Table 2). The overall increase in grain yield over the oldest varieties was estimated to be 449.03 kg ha^{-1} (22.49 %). The estimated average annual rate of increase in grain yield was 30.88 kg ha^{-1} year^{-1} with an annual relative genetic gain of 1.55% year^{-1} (Table 4). The maximum grain yield increment was recorded for the variety released in 2017 with a grain yield of 697.80 kg ha^{-1} (34.95%) followed by the varieties released in 2015 with a grain yield of 666.20 kg ha^{-1} (33.37%). However, the minimum grain yield increment was recorded for the variety released in 2009 with a grain yield of 114.70 kg ha^{-1} (5.75%) (Table 2). Generally, the percentage of increment in grain yield was estimated as 11.64% in 2002 and 28.40% in 2019 from the oldest varieties; *Tadese* and *Padet* released in 1999 (Table 2).

At Finoteselam, the regression analysis also depicted a significant correlation (y = 24.39x) of grain yield with the year of variety release (Table 5 and Figure 1). The average grain yield on the varieties released in the year 1999 was 2033.80 kg ha^{-1} and reached 2624.60 kg ha^{-1} in 2019, indicating the overall increase was 390.95 kg ha^{-1} (19.22%) (Table 3). Likewise, the estimated average annual rate of increase in grain yield was 24.39 kg ha^{-1} year^{-1} with an annual relative genetic change of 1.2% year^{-1} (Table 5). Thus, the average grain yield on the varieties released in the year 1999 was 2033.80 kg ha^{-1} and reached 2624.60 kg ha^{-1} in 2019 (Table 3). This result indicates that, finger millet breeders in Ethiopia have made significant efforts to improve grain yield of the crop for the last 20 years.

Generally, the grain yield increment across the year of release in both locations was more or less linear (showed progressive increment) but not consistent (Figure 1). This inconsistent trend could be due to the comparison among the varieties recommended for cultivation across different agro-ecologies and interactions of the varieties with the environments. Such trend indicates that, genotypic change is an important source for increased grain yield. Similarly, Fano Dargo *et al.* (2016) depicted that, the grain yield potential of teff was increased and estimated as 21.53 kg ha^{-1} year^{-1}. In contrast to this result, Michael Kebede (2016) obtained a reduction in the grain yield potential of lowland maize varieties with an annual genetic change of –2.64 kg ha^{-1} year^{-1} and relative genetic gain of –0.16% kg ha^{-1} year^{-1}.

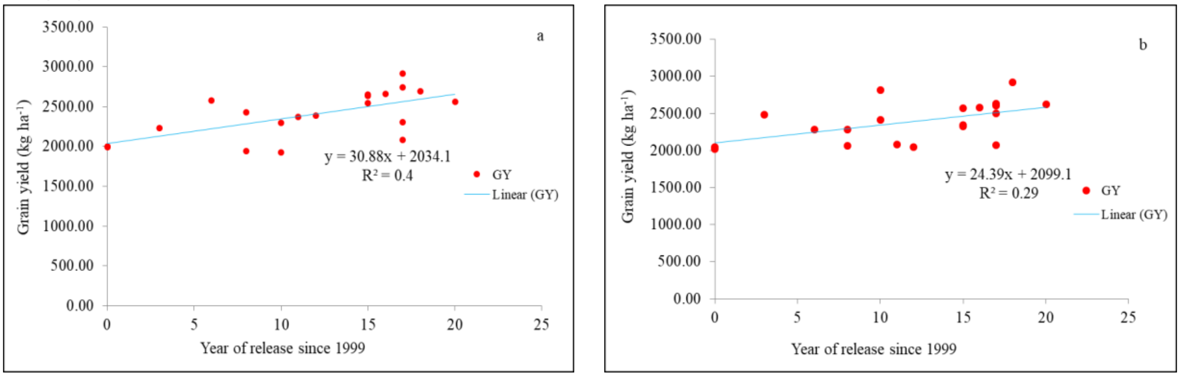

Figure 1. Relationship between grain yield and year of variety release at Adet (a) and Finoteselam (b).

The progress made on finger millet was higher than the progress made on barley, 0.88% ha^{-1} year^{-1} (Wondimu Fekadu *et al.*, 2013). However, there was no indication of yield plateau for the varieties tested on this study (Figure 1), implying the possibility of further increase in yield of finger millet. The huge finger millet potential we have in Ethiopia is not yet exploited due to lack of strong breeding programs that enable collection, characterization, evaluation and identification of desirable traits for genetic improvement (Zigale Semahegn *et al.*, 2021). Thus, the availability of wide genetic resources is a prerequisite to finger millet improvement. In spite of its wide resources, characterization of genetic resources is valuable for efficient and effective utilization in crop improvement programs. Therefore, there is a potential and possibility of developing improved varieties targeting high yield, disease resistance, and other quality traits. Thus, these results serve as a clue for breeders to further increase the yield of finger millet.

Table 2. Temporal trends in mean grain and biomass yield of finger millet at Adet.

Variety	Year of release	GY increment			BY increment		
		Mean	(kg ha^{-1})	(%)	Mean	(kg ha^{-1})	(%)
Tadese	1999						
Padet	1999	1996.40	–	–	9383.30	–	–
Boneya	2002	2228.70	232.30	11.64	10048.30	665.00	7.09
Degu	2005	2577.20	580.80	29.09	11541.70	2158.40	23.00
Wama	2007						
Baruda	2007	2187.60	191.20	9.58	10416.65	1033.35	11.01
Bareda	2009						
Gutie	2009	2111.10	114.70	5.75	9791.70	408.40	4.35
Debatie	2010	2372.70	376.30	18.85	9425.00	41.70	0.44
Necho	2011	2383.80	387.40	19.40	11041.70	1658.40	17.67
Mecha	2014						
Tesema	2014	2607.93	611.53	30.63	11705.57	2322.27	24.75
Gudeta	2014						
Addis-01	2015	2662.60	666.20	33.37	11108.30	1725.00	18.38
Meba	2016						
Axum	2016						
Diga-1	2016	2510.63	514.23	25.76	11104.65	1721.35	18.34
Urji	2016						
Bako-09	2017	2694.20	697.80	34.95	12333.30	2950.00	31.44
Jabi	2019	2563.30	566.90	28.40	11916.70	2533.40	27.00
Overall increment		2445.43	449.03	22.49	10948.51	1565.21	16.68

Note: *GY = Grain yield (kg ha^{-1}); BY = Biomass yield (kg ha^{-1}); and Tadese and Padet were the oldest varieties used as basis for trend analysis.*

Table 3. Temporal trends in mean grain and biomass yield of finger millet at Finoteselam.

Variety	Year of release	GY increment			BY increment		
		Mean	(kg ha^{-1})	(%)	Mean	(kg ha^{-1})	(%)
Tadese	1999						
Padet	1999	2033.80	–	–	8428.15	–	–
Boneya	2002	2486.60	452.80	22.26	9612.50	1184.35	14.05
Degu	2005	2277.90	244.10	12.00	11311.30	2883.15	34.21
Wama	2007						
Baruda	2007	2170.45	136.65	6.72	9075.00	646.85	7.67
Bareda	2009						
Gutie	2009	2616.75	582.95	28.66	9928.15	1500.00	17.80
Debatie	2010	2083.40	49.60	2.44	8718.80	290.65	3.45
Necho	2011	2047.60	13.80	0.68	9675.00	1246.85	14.79
Mecha	2014						
Tesema	2014	2412.27	378.47	18.61	10061.57	1633.42	19.38
Gudeta	2014						
Addis-01	2015	2579.50	545.70	26.83	11962.50	3534.35	41.94
Meba	2016						
Axum	2016						
Diga-1	2016	2453.93	420.13	20.66	10221.38	1793.23	21.28
Urji	2016						
Bako-09	2017	2919.30	885.50	43.54	11635.40	3207.25	38.05
Jabi	2019	2624.60	590.80	29.05	10260.40	1832.25	21.74
Overall increment		2424.75	390.95	19.22	10223.82	1795.67	21.31

Note: *GY = Grain yield (kg ha^{-1}); BY = Biomass yield (kg ha^{-1}); and Tadese and Padet were the oldest varieties used as basis for trend analysis.*

3.2.2. Progress on biomass yield, harvest index and plant height

The analysis of variance revealed that biomass yield showed a highly significant difference among the varieties tested at both locations. Moreover, the regression analysis revealed a significant positive association between biomass yield and year of variety release (Tables 4 and 5). At Adet, the overall increase in biomass yield over the oldest varieties was estimated to be 1565.21 kg ha^{-1} (16.68% year^{-1}) and the estimated average annual rate of increase was 114.04 kg ha^{-1} year^{-1} with an annual relative genetic change of 1.22% year^{-1} (Table 4). Generally, the increment over 20 years was estimated to be 7.09% in 2002 and 27% in 2019 from the oldest varieties, *Tadese* and *Padet* released in 1999 (Table 2).

At Finoteselam, the overall increase in biomass yield over the oldest varieties was 1795.67 kg ha^{-1} (21.31%) (Table 3); and the estimated average annual rate of increase was 97.15 kg ha^{-1} year^{-1} with annual relative genetic change of 1.15% year^{-1} (Table 5). Accordingly, the increment over 20 years was estimated to be 14.05% in 2002 and 21.74% in 2019 from the oldest varieties (Table 3). Herewith, percentage of increment was higher for the varieties released in the year 2015 (41.94% or 3534.35 kg ha^{-1}) and lower for the variety *Debatie* (3.45% or 290.65 kg ha^{-1}), which was released in the year 2010. From this result, it could be understood that there was a positive trend from the old to the latest varieties in biomass yield. This clearly indicates better genetic progress from breeding finger millet for biomass and grain yield than other traits except grain yield.

Similar findings were reported by Wondimu Fekadu *et al.* (2013) who found a significant annual increase in biomass yield for arley varieties released from 1973 to 2006. Likewise, Endashaw Girma *et al.* (2019) reported that, biomass yield of bread wheat increased with ann annual rate of 17.469 kg ha^{-1} and a relative annual gain of 0.3%. Fano Dargo *et al.* (2016) reported that the average biomass yield of teff varieties increased by 73.74 kg ha^{-1} year^{-1}. However, Mekuria Temtme (2017) found a negative trend from the old to the modern varieties in biomass yield of durum wheat varieties with relative annual biomass yield reduction of –0.00036% year^{-1} for 49 years. However, the progress showed a non-consistent trend of increment. This non-consistent and downward trend of increment could be due to making the comparison among varieties recommended for varied agro-ecologies.

The analysis of variance for harvest index also revealed very highly significant differences among the varieties and locations. However, regression analysis depicted a positive but non-significant increment with year of variety release, which was near zero. The annual change and relative genetic gain was 0.07% year^{-1} and 0.33% year^{-1} for Adet and 0.01% year^{-1} and 0.04% year^{-1} for Finoteselam (Tables 4 and 5). From this result, it can be concluded that the grain yield to biomass ratio from oldest to newest varieties was not as such changed. The ratio of grain yield to biomass yield (harvest index) should be expected to increase. Likewise, Fano Dargo *et al.* (2016) found unchanged annual change in harvest index, 0.02% which was not significantly different ($P \leq 0.05$) from zero for teff. Unlike harvest index, annual rate of change in plant height showed a negative trend, estimated to be –0.25 cm year^{-1} (–0.36% year^{-1}) and –0.26 cm year^{-1} (–0.31% year^{-1}) at Adet and Finoteselam, respectively (Tables 4 and 5). This implies that, the varieties being released are becoming shorter in stature. In contrast to this result, Fano Dargo *et al.* (2016) found a non-significant increment in plant height for teff varieties.

3.2.3. Progress on yield related traits

At both locations, finger length and number of fingers per ear showed a positive but non-significant change with the year of variety release. Thus, the annual rate of change in finger length was estimated to be 0.06 cm year^{-1} (1.28% year^{-1}) and 0.09 cm year^{-1} (1.96% year^{-1}) at Adet and Finoteselam, respectively. Fano Dargo *et al.* (2016) also obtained positive but non-significant increment in panicle length of teff varieties. Number of fingers per ear exhibited a non-significant positive change, 0.09 fingers year^{-1} (2.51% year^{-1}) and 0.05 fingers year^{-1} (1.09% year^{-1}) at Adet and Finoteselam, respectively. Therefore, while doing selection, finger length and number of fingers per ear need to be considered as they have direct and positive correlation with grain yield. Number of tillers per plant and ears per plant exhibited a highly significant change with the year of variety release. At Adet, the regression analysis revealed that, the annual change in number of tillers per plant was 0.12 tillers plant^{-1} year^{-1} (5.15% year^{-1}) and ears per plat was 0.11 ears plant^{-1} year^{-1} (3.3% year^{-1}), in the same order. At Finoteselam, the change was 0.09 tillers plant^{-1} (3.96% year^{-1}) and 0.09 ears plant^{-1} (2.75% year^{-1}) (Tables 4 and 5), indicating finger millet yield improvement involved increment in such parameters.

Similarly, Michael Kebede (2016) indicated the improvement made for ear length, kernels per row on maize. Fano Dargo *et al.* (2016) also found a significant change in panicle weight of teff varieties. In addition, Mekuria Temtme (2017) also found that, older varieties had lower number of grain per spike and productive tillers than the newer durum wheat varieties. Thus, the progress made over years on most of the yield related traits of finger millet at both locations was inconsistent and non-significant, indicating that further breeding efforts have to be made to improve the productivity such traits as these traits have direct correlation with grain yield.

Table 4. Estimates of relative genetic gain and regression coefficient of all traits with year of variety release at Adet.

Trait	Overall mean	Mean of old varieties	Total RGG (%)	RGG (% year^{-1})	R^2 (%)	Intercept	Regression coefficient (b)	Correlation coefficient	
								r(BY)	r(GY)
DH	102.13	101.00	1.12	–0.20	2.81	104.50	–0.20^{ns}	–0.12^{ns}	–0.28*
DM	162.78	157.50	3.35	0.03	0.08	162.40	0.04^{ns}	–0.14^{ns}	–0.21^{ns}
GFP	60.65	56.50	7.35	0.42	12.63	57.78	0.24^{ns}	–0.06^{ns}	0.08^{ns}
PH	71.04	69.60	2.07	–0.36	4.37	73.95	–0.25^{ns}	0.35**	0.28*
FL	7.02	4.70	49.36	1.28	2.37	6.35	0.06^{ns}	0.16^{ns}	0.09^{ns}
TPP	4.09	2.33	75.54	5.15	62.47	2.68	0.12**	0.56***	0.60***
EPP	5.04	3.33	51.35	3.30	57.20	3.71	0.11**	0.52***	0.55***
FPE	5.72	3.58	59.78	2.51	15.73	4.61	0.09^{ns}	0.25^{ns}	0.25^{ns}
BY	10807.00	9383.30	15.17	1.22	27.24	9466.66	114.04*	–	0.88***
GY	2397.00	1996.40	20.07	1.55	40.00	2034.11	30.88**	0.88***	–
HI	22.28	21.29	4.65	0.33	7.75	21.51	0.07^{ns}	–0.39**	0.08^{ns}
BPR	66.59	59.62	11.69	1.17	21.48	58.42	0.70*	0.96***	0.87***
SGR	39.67	35.41	12.03	1.07	19.66	35.15	0.38*	0.85***	0.89***
HB	15.65	19.63	–20.28	–0.71	0.38	17.28	–0.14^{ns}	–0.10^{ns}	–0.05^{ns}

Note: *** = *Very highly significant at P ≤ 0.001;* ** = *Highly significant at P ≤ 0.01;* * = *Significant at P ≤ 0.05; and ns = Non-significant.* RGG = *Relative genetic gain (%); r(GY) = Correlation coefficient of grain yield; r(BY) = Correlation coefficient of biomass yield; DH = Days to 50% heading; DM = Days to 50% maturity; GFP = Grain filling period; PH = Plant height (cm); FL = Finger length (cm); TPP = Tillers plant^{-1}; EPP = Ears plant^{-1}; FPE = Fingers ear^{-1}; BY = Biomass yield (kg ha^{-1}); GY = Grain yield (kg ha^{-1}); HI = Harvest index (%); BPR = Biomass production rate (kg ha^{-1} day^{-1}); SGR = Seed growth rate (kg ha^{-1} day^{-1}); and HB = Head blast severity (%).* R^2 = *Coefficient of determination (%).*

Table 5. Estimates of relative genetic gain and regression coefficient of all traits with year of variety release at Finoteselam.

Trait	Overall mean	Mean of old varieties	Total RGG (%)	RGG (% year^{-1})	R^2 (%)	Intercept	Regression coefficient(b)	Correlation coefficient	
								r(BY)	r(GY)
DH	99.13	99.34	–0.21	–0.29	5.29	102.41	–0.29^{ns}	–0.30*	–0.39**
DM	155.92	148.17	5.23	0.07	0.78	154.72	0.10^{ns}	–0.21^{ns}	–0.36**
GFP	56.78	48.84	16.26	0.78	21.10	52.31	0.38*	0.13^{ns}	0.08^{ns}
PH	80.90	83.53	–3.15	–0.31	3.68	84.00	–0.26^{ns}	0.04^{ns}	0.19^{ns}
FL	7.79	4.59	69.72	1.96	6.64	6.78	0.09^{ns}	0.25*	0.10^{ns}
TPP	3.34	2.27	47.14	3.96	49.44	2.29	0.09**	0.56***	0.54***
EPP	4.34	3.27	32.72	2.75	49.15	3.28	0.09**	0.56***	0.54***
FPE	5.84	4.60	26.96	1.09	10.19	5.26	0.05^{ns}	0.23^{ns}	0.16^{ns}
BY	9955.00	8428.15	18.12	1.15	24.43	8813.89	97.15*	–	0.79***
GY	2386.00	2033.80	17.32	1.20	28.82	2099.06	24.39*	0.79***	–
HI	24.13	24.21	–0.33	0.04	0.06	24.05	0.01^{ns}	–0.53***	0.09^{ns}
BPR	64.05	56.89	12.59	1.05	17.73	56.96	0.60^{ns}	0.97***	0.82***
SGR	42.29	41.70	1.41	0.41	3.23	40.31	0.17^{ns}	0.62***	0.82***
HB	26.71	28.33	–5.72	–0.64	0.55	28.85	–0.18^{ns}	–0.04^{ns}	–0.13^{ns}

Note: *** = *Very highly significant at P ≤ 0.001;* ** = *Highly significant at P ≤ 0.01;* * = *Significant at P ≤ 0.05; and ns = Non-significant.* RGG = *Relative genetic gain (%); r(GY) = Correlation coefficient of grain yield; r(BY) = Correlation coefficient of biomass yield; DH = Days to 50% heading; DM = Days to 50% maturity; GFP = Grain filling period; PH = Plant height (cm); FL = Finger length (cm); TPP = Tillers plant^{-1}; EPP = Ears plant^{-1}; FPE = Fingers ear^{-1}; BY = Biomass yield (kg ha^{-1}); GY = Grain yield (kg ha^{-1}); HI = Harvest index (%); BPR = Biomass production rate (kg ha^{-1} day^{-1}); SGR = Seed growth rate (kg ha^{-1} day^{-1}); and HB = Head blast severity (%).* R^2 = *Coefficient of determination (%).*

3.2.4. Progress on biomass production rate and seed growth rate

The analysis of variance for biomass production rate and seed growth rate depicted highly significant differences ($P \leq 0.001$) among the tested varieties (Table 1). Most of the recently released varieties provide a higher biomass production rate and seed growth rate than the older varieties at both locations (Tables 4 and 5). At Adet, both biomass production rate and seed growth rate increased significantly ($P \leq 0.05$) with the year of variety release with annual genetic gain of 0.7 kg ha^{-1} day^{-1} year^{-1} and 0.38 kg ha^{-1} day^{-1} year^{-1}, respectively. Moreover, the relative annual gains were 1.17% year^{-1} for biomass production and 1.07% year^{-1} for seed growth (Table 4). At Finoteselam, all of the productivity traits showed positive but non-significant increment with the year of variety release with annual change of 0.6 kg ha^{-1} day^{-1} year^{-1} (1.05% year^{-1}) and 0.17 kg ha^{-1} day^{-1} year^{-1} (0.41% year^{-1}) for biomass production rate and seed growth rate, respectively (Table 5). Similarly, Fano Dargo *et al.* (2016) reported a significant increase ($P \leq 0.01$) in biomass production rate on the tested teff varieties. This result implies that substantial improvement was apparent but was not as such ample, suggesting further breeding efforts as productivity traits are indications of efficiency of giving high biomass and grain growth within a short growing period.

3.2.5. Progress on phenological traits

The analysis of variance revealed that, both days to heading, days to maturity and grain filling period had significant differences ($P \leq 0.01$) among locations and varieties (Table 1). Moreover, regression analysis at both locations revealed that, days to heading showed a negative trend over 20 years, meaning that the varieties being released currently are somewhat early in heading. The annual rate of change in days to heading was estimated to be –0.2 days year^{-1} (–0.2% year^{-1}) and –0.29 days year^{-1} (–0.29% year^{-1}) at Adet and Finoteselam, respectively. However, the annual rate of change in days to maturity was positive and near to zero, 0.04 days year^{-1} (0.03% year^{-1}) and 0.01 days year^{-1} (0.07% year^{-1}) at Adet and Finoteselam, respectively. Grain filling period also showed a bit increment. Thus, rate of change was estimated to be 0.24 days year^{-1} (0.42% year^{-1}) and 0.38 days year^{-1} (0.78% year^{-1}) at Adet and Finoteselam, in that order (Tables 4 and 5). Likewise, Wondimu Fekadu *et al.* (2013) reported that phenological traits showed a non-significant decreasing trend in food barely.

Despite small progress made on days to heading ($r_{year} = -0.2^{ns}$ at Adet and $r_{year} = -0.29^{ns}$ at Finoteselam), the change was not significant in grain filling period and days to maturity (Tables 4 and 5). Therefore, changes are still required because the changes obtained were non-significant. As a result, the varieties to be released in the future should be early maturing by comparing the standard checks since earliness is a major concern for finger millet. This is because finger millet is a late maturing crop as compared to other cereals, and sometimes it is exposed to terminal moisture and cannot leave the farming area for the next cropping season.

3.2.6. Progress on blast disease reaction

The analysis of variance for head blast susceptibility depicted significant ($P \leq 0.001$) differences among the varieties and locations. The susceptibility of the varieties was higher at Finoteselam, which might be due to the more prevalence of blast disease in the area since it has higher temperature and humidity. Among the tested varieties, a small change was observed from the oldest to the newest varieties. Regression analysis showed a positive relationship in variety release and disease susceptibility, implying reductions in percentage of head blast susceptibility even though the change was not significant. Thus, the annual rate of change and relative genetic gain was –0.14% year^{-1} and –0.71% year^{-1} at Adet, and –0.18% year^{-1} and –0.64% year^{-1} at Finoteselam (Tables 4 and 5), indicating some sort of reduction in percentage of blast infection (increasing in disease resistance of the released varieties with respective of year of release). Similarly, Tamene Temesgen *et al.* (2015) reported that, annual rate of reduction in chocolate spot severity was –0.27% year^{-1}; and relative genetic gain was –0.65% year^{-1}.

Despite the progress made, the change obtained was not significant at both locations (Tables 4 and 5). In spite of its importance, the current rate of yield increment in finger millet is inadequate in Ethiopia. Although a number of biotic and abiotic factors contributed to the lower grain yield increment, blast is considered as one of the major biotic factors impeding finger millet productivity in Ethiopia. In line with this postulation, Dagnachew Lule *et al.* (2013) reported, an average of 42% of finger millet grain yield was lost due to blast disease in Ethiopia. Similarly, finger millet yield loss because of blast disease was 41.8% (Gashaw Getachew *et al.*, 2014). Therefore, this limitation can be reduced by developing finger millet genotypes which are more resistant or tolerant to blast. Thus, finger millet breeders should give due attention to develop blast resistant/tolerant varieties as this disease is a serious cause of loss of yield.

3.3. Traits Correlated with Yield Improvement

At Adet, grain yield had a significant genetic correlation with biomass yield, biomass production rate, seed growth rate, number of tiller per plant, but had a non-significant positive correlation with grain filling period, plant height, finger length, number of ears per plant, number fingers per ear, and harvest index. However, grain yield had a non-significant negative correlation with days to heading, days to maturity and head blast susceptibility (Table 6). At Finoteselam, grain yield also had positive significant correlation with biomass yield, biomass production rate, seed growth rate, number of tiller per plant, number of ears per plant; but had a non-significant positive correlation with grain filling period, plant height, finger length, number fingers per ear, and harvest index. However, grain yield had significant negative correlation with days to heading; and non-significant correlation with days to maturity and head blast susceptibility (Table 6).

Likewise, Molla Fentie (2012) found a significant correlation of grain yield with biomass yield. Devaliya *et al.* (2017) also reported a highly significant genotypic correlation of grain yield with number of productive tillers per plant and negative correlation with phenological traits. Similarly, negative and significant correlation between grain yield and days to maturity was reported by Kebere Bezaweletaw *et al.* (2006) in finger millet. Likewise, positive correlations were reported between grain yield and productive tillers and between plant height and finger length (Chemeda Daba and Gemechu Keneni, 2010). In contrast to the present result, a significant and positive correlation was observed for grain yield with days to maturity (Chemeda Daba and Gemechu Keneni, 2010). Tazeen *et al.* (2009) also reported that, grain yield was positively correlated with biomass and harvest index. Moreover, these results are in accordance with the findings of Ganapathy *et al.* (2011), Anuradha *et al.* (2013), Abhinav *et al.* (2016) and Chavan *et al.* (2020) on finger millet. This suggests selecting for the trait with high positive correlation would improve the grain yield of respective crop.

In addition, Nandini *et al.* (2010) found correlation of grain yield with plant height and tiller number on finger millet, which is in agreement with the preset result. This can be due to the increase in finger length that increases with plant height. Moreover, plant height was negatively correlated with phenological traits; meaning that, it is not always true that plant height increased as the number of days to mature increased. Among the tested varieties, most of the shortest varieties were late maturing because these varieties were released for mid-lowland areas and the current site was somewhat highland. In line with this, Andualem Wolie and Tadesse Dessalegn (2011) reported a negative genotypic correlation of plant height with days to maturity.

Generally, the present study at both locations revealed that, the type and number of yield related traits correlated with grain yield was almost the same except the magnitude of correlation. The strongest positive correlation with grain yield was observed by biomass yield, biomass production rate, seed growth rate, number of tillers per plant and number of ears per plant. The existence of strong correlation is the indications of those traits which are conditioned by linked gene, be it in the positive or negative direction. Consequently, selection for one trait can indirectly introduce changes in the other trait in positive or negative direction due to either genetic linkage or presence of pleiotropic gene effect or both (Falconer, 1989).

Therefore, the overall increment of grain yield over 20 years was associated with improvements with these significantly correlated traits. As a result, these traits will serve as a selection criterion as they are correlated and improved with grain yield. However, the strongest negative correlation was observed for days to maturity and days to heading, implying an opportunity to develop relatively early maturing varieties with better yield potential. Most of the varieties tested were late in maturity, which required an average of 160 days to mature (Table 1). Even though the present experiment was conducted in the areas where moisture stress was not much prevalent, the growing period for finger millet varieties should not be so long. This is because early maturity is advantageous to escape terminal moisture stress as well as to leave the farm for the next cropping.

Table 6. Genotypic correlation coefficients of traits of the tested finger millet varieties at Adet (above diagonal) and Finoteselam (below diagonal).

Trait	DH	DM	GFP	PH	FL	TPP	EPP	FPE	BY	HI	BPR	SGR	HB	GY
DH	–	0.86***	–0.11^{ns}	–0.36^{ns}	0.01^{ns}	–0.12^{ns}	–0.13^{ns}	0.33^{ns}	–0.16^{ns}	–0.37^{ns}	–0.40^{ns}	–0.25^{ns}	–0.33^{ns}	–0.32^{ns}
DM	0.76***	–	0.42^{ns}	–0.37^{ns}	0.14^{ns}	0.10^{ns}	0.09^{ns}	0.39^{ns}	–0.18^{ns}	–0.14^{ns}	–0.47*	–0.43^{ns}	–0.34^{ns}	–0.24^{ns}
GFP	–0.41^{ns}	0.29^{ns}	–	–0.09^{ns}	0.24^{ns}	0.40^{ns}	0.41^{ns}	0.16^{ns}	–0.06^{ns}	0.38^{ns}	–0.21^{ns}	–0.39^{ns}	–0.08^{ns}	0.11^{ns}
PH	–0.38^{ns}	–0.65**	–0.34^{ns}	–	0.49*	0.00^{ns}	–0.02^{ns}	0.02^{ns}	0.35^{ns}	–0.15^{ns}	0.41^{ns}	0.29^{ns}	0.37^{ns}	0.27^{ns}
FL	0.11^{ns}	0.42^{ns}	0.42^{ns}	–0.22^{ns}	–	0.23^{ns}	0.25^{ns}	0.72*	0.07^{ns}	–0.09^{ns}	0.02^{ns}	–0.09^{ns}	0.68**	0.01^{ns}
TPP	–0.36^{ns}	–0.07^{ns}	0.44^{ns}	–0.15^{ns}	0.28^{ns}	–	0.99**	0.43^{ns}	0.37^{ns}	0.30^{ns}	0.30^{ns}	0.30^{ns}	–0.12^{ns}	0.51*
EPP	–0.36^{ns}	–0.07^{ns}	0.44^{ns}	–0.16^{ns}	0.28^{ns}	0.99***	–	0.41^{ns}	0.30^{ns}	0.30^{ns}	0.25^{ns}	0.23^{ns}	–0.11^{ns}	0.44^{ns}
FPE	0.32^{ns}	0.50*	0.23^{ns}	–0.33^{ns}	0.77*	0.22^{ns}	0.22^{ns}	–	0.12^{ns}	0.06^{ns}	0.00^{ns}	0.07^{ns}	0.46*	0.14^{ns}
BY	–0.37^{ns}	–0.26^{ns}	0.18^{ns}	0.30^{ns}	0.20^{ns}	0.58**	0.58**	0.10^{ns}	–	–0.19^{ns}	0.95***	0.86***	–0.12^{ns}	0.89***
HI	–0.09^{ns}	–0.20^{ns}	–0.15^{ns}	0.18^{ns}	–0.24^{ns}	–0.12^{ns}	–0.12^{ns}	–0.08^{ns}	–0.38^{ns}	–	–0.14^{ns}	0.06^{ns}	0.13^{ns}	0.27^{ns}
BPR	–0.53*	–0.52*	0.05^{ns}	0.45*	0.05^{ns}	0.53*	0.53*	–0.05^{ns}	0.96***	–0.27^{ns}	–	0.91***	0.00^{ns}	0.87***
SGR	–0.13^{ns}	–0.53*	–0.55*	0.58**	–0.23^{ns}	0.17^{ns}	0.16^{ns}	–0.09^{ns}	0.54*	0.32^{ns}	0.65**	–	–0.02^{ns}	0.87***
HB	–0.41^{ns}	–0.17^{ns}	0.35^{ns}	0.04^{ns}	0.58**	0.07^{ns}	0.07^{ns}	0.38^{ns}	–0.04^{ns}	–0.12^{ns}	0.00^{ns}	–0.32^{ns}	–	–0.08^{ns}
GY	–0.45*	–0.41^{ns}	0.09^{ns}	0.43^{ns}	0.03^{ns}	0.51*	0.51*	0.05^{ns}	0.77***	0.30^{ns}	0.80***	0.78***	–0.13^{ns}	–

Note: *** = *Very highly significant at* $P \leq 0.001$; ** = *Highly significant at* $P \leq 0.01$; * = *Significant at* $P \leq 0.05$ *and ns = Non-significant. DH = Days to 50% heading; DM = Days to 50% maturity; GFP = Grain filling period; PH = Plant height (cm); FL = Finger length (cm); TPP = Tillers plant*$^{-1}$; *EPP = Ears plant*$^{-1}$; *FPE = Fingers ear*$^{-1}$; *BY = Biomass yield (kg ha*$^{-1}$*); HI = Harvest index (%); BPR = Biomass production rate (kg ha*$^{-1}$*day*$^{-1}$*); SGR = Seed growth rate (kg ha*$^{-1}$*day*$^{-1}$*); HB = Head blast severity (%); and GY = Grain yield (kg ha*$^{-1}$*).*

Stepwise regression analysis using grain yield as dependent variable indicated that, biomass yield and harvest index were the most important traits which greatly contributed most of the variation on grain yield, 99.74% at Adet and 99.42% at Finoteselam (Table 7). Therefore, it can be considered that changes obtained had probably contributed to the changes in grain yield during the last 20 years of finger millet breeding. Similarly, Wondimu Fekadu *et al.* (2013) reported that, harvest index, biomass yield and biomass production rate were traits contributed to gain in grain yield of food barley varieties. In general, grain yield in the latest varieties appears to be associated more with the production of a higher biomass, indicated biomass yield may serve as an index for identifying and improving finger millet varieties. Hence, it is of vital importance to give due attention to biomass yield and other significantly correlated traits while selecting finger millet lines for future improvement.

Table 7. Stepwise regression analysis of grain yield on selected yield components.

Adet				
Independent variable	Intercept	Regression coefficient (B)	Partial R^2 (%)	R^2 (%)
Biomass yield		0.22***	79.36	79.36
Harvest index	–2105.05	95.91***	20.38	99.74
Finoteselam				
Biomass yield		0.24***	58.79	58.79
Harvest index	–2478.11	103.22***	40.63	99.74

Note: *** = *Very highly significant at P ≤ 0.001. R^2 = Coefficient of determination (%).*

4. Conclusion and Recommendation

The results of this study have demonstrated a substantial progress in the plant breeding work executed for improving the productivity of finger millet in the last 20 years. Stepwise regression analysis revealed that biomass and harvest index accounted for 99.74% of the variation on grain yield at Adet and 99.42% at Finoteselam. The results indicated that the yield gain was largely obtained through increased biomass and harvest index. These traits can be considered as the selection criteria for the improvement of finger millet grain yield since they exhibited a strong positive correlation. Even though changes have been made on grain yield, biomass yield and some important traits, the changes made on most of the traits were non-significant. Therefore, to bring drastic changes in most important traits like head blast resistance, earliness, finger length, number of fingers per ear and number of ears per plant, appropriate breeding strategies should be devised for future research works to come up with effective yield gains. Thus, this result should be used to revise the past breeding approaches and define future research directions.

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6. References

Abeledo L.G., Calderini, D.F. and Slafer, G.A. 2003. Genetic improvement of barley yield potential and its physiological determinants in Argentina (1944–1998). *Euphytica*, 130: 325–334.

Abhinav, S., Preeti, S., Prafull, K. and Praveen, P. 2016. Genetic analysis for estimation of yield determinants in finger millet [*Eleusine coracana* (L.) Gaertn.]. *Advances in Life Sciences*, 5(16): 5951–5956.

Andualem Wolie and Tadesse Dessalegn. 2011. Correlation and path coefficient analyses of some yield related traits in finger millet [*Eleusine coracana* (L.) Gaertn.] germplasms in northwest Ethiopia. *African Journal of Agricultural Research*, 6(22): 5099–5105.

Anuradha, N., Udayabhanu, K., Patro, T.S.S.K. and Sharma, N.D.R.K. 2013. Character association and path analysis in finger milet [*Eleusine coracana* (L.) Gaertn]. *International Journal of Food, Agriculture and Veterinary Sciences*, 3(3): 113–115.

Ashok, S., Patro, T.S.S.K., Anuradha, N. and Divya, M. 2018. Studies on genetic variability for yield and yield attributing traits in finger millet [*Eluesine coracana* (L) Gaertn]. *International Journal of Current Microbiology and Applied Sciences*, 7: 90–95.

Chavan, B.R., Jawale, L.N. and Shinde, A.V. 2020. Correlation and path analysis studies in finger millet for yield and yield contributing traits [*Eleusine coracana* (L.) Gaertn]. *International Journal of Chemical Studies*, 8(1): 2911–2914.

Chemeda Daba and Gemechu Keneni, 2010. Morpho-agronomic classification of some native and exotic finger millet (*Eleusine coracana* L.) germplasm accessions in Ethiopia. *East African Journal of Sciences,* 4(1): 20–26.

CSA (Central Statistics Agency). 2021. Agricultural sample survey 2020/21. Report on area and production of major crops. Statistical Bulletin, 590. Addis Ababa, Ethiopia. Pp. 19-34.

Dagnachew Lule, Kassahun Tesfaye, Masresha Fetene and De Villiers, S. 2013. Evaluation of Ethiopian finger millet (*Eleusine coracana*) germplasm against *Magnaporthe grisea*, the cause of finger millet blast disease. In: Paper presented on the first Bio-innovate Regional Scientific Conference, United Nation Conference Center, 25–27 February 2013, Addis Ababa, Ethiopia.

Devaliya, S.D., Manju, S. and Visat, M.L. 2017. Character association and path analysis in finger millet (*Eleusine coracana* (L.) Gaertn.). *Trends in Biosciences*, 10(31): 6690–6694.

Endashaw Girma, Wosene Gebreselassie and Berhane Lakew. 2019. Genetic gain in grain yield and associated traits of Ethiopian bread wheat (*Tritium aestivium* L.) varieties. *International Journal of Agriculture and Biosciences*, 8(1): 12–19.

Erenso Degu, Asfaw Adugna, Taye Tadesse and Tesfaye Tesso. 2009. Genetic resources, breeding and production of millets in Ethiopia. Pp. 43–56. *In*: Zerihun Tadele (ed.). *Proceedings of an International Conference*, 19-21 September 2007, Bern, Switzerland.

Falconer, D.S. 1989. *Introduction to Quantitative Genetics*. 3rd edition. Longman, London. Pp. 26–34.

Fano Dargo, Firew Mekibeb and Kebebew Assefa. 2016. Genetic gain in grain yield potential and associated traits of teff (*Eragrostis tef* (Zucc.) Trotter) in Ethiopia. *Global Journal of Science Frontier Research*, 16(6): 1–17.

Ganapathy, S., Nirmalakumari, A. and Muthiah, A.R. 2011. Genetic variability and inter-relationship analyses for economic traits in finger millet germplasm. *World Journal of Agricultural Sciences*, 7(2): 185–188.

Gashaw Getachew, Tesfaye Alemu and Kassahun Tesfaye. 2014. Evaluation of disease incidence and severity and yield loss of finger millet varieties and mycelia growth inhibition of *Pyricularia grisea* isolates using biological antagonists and fungicides in vitro condition. *Journal of Applied Biosciences*, 73: 5883–5901.

Gomez, K.A. and Gomez, A.A. 1984. *Statistical procedures for agricultural research*. 2nd edition. John Wiley and Sons, New York.

Goron, T.L. and Raizada, M.N. 2015. Genetic diversity and genomic resources available for the small millet crops to accelerate a new green revolution. *Frontiers in Plant Science*, 6: 157–168.

Hailegebrial Kinfe, Yiergalem Tsehay, Alem Reda., Redae Welegebriel, Desalegn Yalew, et al. 2017. Yield performance and adaptability of finger millet landrace in North Western Tigray, Ethiopia. *World News of Natural Sciences*, 15: 98–111.

Heisey, P.W., Lantican, M.A. and Dubin, H.J. 2002. Impacts of International Wheat Breeding Research in Developing Countries, 1966–97. Mexico, D.F. CIMMYT.

Hilu, K.W., Dewet, J.M.J. and Harlan, J.R. 1979. Archaeobotanical studies of *Elueusine coracana* ssp. *coracana* (finger millet). *American Journal of Botany*, 669(3): 330–333.

Kashiani, P. and Saleh, G. 2010. Estimation of genetic correlations on sweet corn inbred lines using SAS mixed model. *American Journal of Agricultural and Biological Sciences*, 5(3): 309–314.

Kebede Dessalegn, Dagnachew Lule, Megersa Debela, Chemeda Birhanu, Girma Mengistu et al. 2019. Genotype by environment interaction and grain yield stability of Ethiopian black seeded finger millet genotypes. *African Crop Science Journal*, 27(2): 281–294.

Kebere Bezaweletaw, Sripichit, P., Wongyai, W. and Hongtrakul, V. 2006. Genetic variation, heritability and path-analysis in Ethiopian finger millet [*Eleusine coracana* (L.) Gaertn] landraces. *Kasetsart Journal of Natural Sciences*, 40: 322–334.

Manoj, K., Narayan, B.D. and Jiban, S. 2019. Phenotypic diversity of finger millet [*Eleusine coracana* (L.) Gaertn.] genotypes. *Malaysian Journal of Sustainable Agriculture*, 3(2): 20–26.

Mekuria Temtme. 2017. Genetic improvement in quality, grain yield and yield associated traits of durum wheat *(Triticum turgidum* var. *durum* L.*)* in Ethiopia. MSc Thesis, Hawassa University, Ethiopia. Pp. 58.

Michael Kebede. 2016. Genetic gain of maize *(Zea Mays* L.*)* varieties in Ethiopia. MSc Thesis, Haramaya University, Ethiopia. Pp. 110.

MoA (Ministry of Agriculture). 2020. Crop variety register, Issue No. 23. Plant variety release, protection and seed quality control directorate. Addis Ababa, Ethiopia.

Molla Fentie. 2012. Participatory evaluation and selection of improved finger millet varieties in North Western Ethiopia. *International Research Journal of Plant Sciences*, 3(7): 141–146.

Nandini, B., Ravishankar, C.R., Mahesha, B., Shailaja, H. and Kalyana, M.K.N. 2010. Study of correlation and path analysis in F_2 population of finger millet. *International Journal of Plant Sciences*, 5(2): 602–605.

Obilana, A.B. 2003. Overview: importance of millets in Africa. Pp. 18. *In*: Belton, P.S. and Taylor, J.P.N. (eds.). *Workshop on the proteins of sorghum and millets: Enhancing nutritional and functional properties for Africa*. Pretoria, South Africa.

Reddy, C.V.C.M. and Reddy, Y.R. 2011. Genetic parameters for yield and quality traits in desi cotton (*Gossypium arboretum* L.). *Journal of Cotton Research and Development*, 25(2): 168–170.

Rutkoski, J.E. 2019. Estimation of realized rates of genetic gain and indicators for breeding program assessment. *Crop Science*, 59: 981–993.

Tamene Temesegen, Gemechu Kefeni and Hussein Mohammad. 2015. Genetic progresses from over three decades of faba bean (*Vicia faba* L.) breeding in Ethiopia. *Australian Journal of Crop Science*, 9(1): 41–48.

Tazeen, M., Nadia, K. and Farzana, N.N. 2009. Heritability, phenotypic correlation and path coefficient studies for some agronomic characters in synthetic elite lines of wheat. *Journal of Food, Agriculture and Environment*, 7(3&4): 278–282.

Upadhyaya, H.D., Gowda, C.L.L. and Reddy, G. 2007. Morphological diversity in finger millet germplasm from Southern and Eastern Africa. *Journal of SAT Agricultural. Research*, 3(1): 1–3.

Wondimu Fekadu, Amsalu Ayana and Habtamu Zelekle. 2013. Improvement in grain yield and malting quality of barley (*Hordeum vulgare* L.) in Ethiopia. *Ethiopian Journal of Applied Science Technology*, 4(2): 37–62.

Yaregal Damtie, Firezer Girma, Alemu Terfessa and Habtamu Demelash. 2019. Genetic diversity and heritability estimates among Ethiopian finger millet [*Eleusine coracana* (L.) Gaertn] genotypes for yield and its contributing traits at Assosa, Western Ethiopia. *Asian Journal of Plant Science and Research*, 9(2): 6–15.

Zigale Semahegn, Temesgen Teressa and Tamirat Bejiga. 2021. Finger Millet [*Eleusine coracana* (L.) Gaertn] breeding in Ethiopia: A review article. *International Journal of Research Studies in Agricultural Sciences*, 7(3): 38–42.