Black Sea Journal of Agriculture
doi: 10.47115/bsagriculture.639422

Open Access Journal
e-ISSN: 2618 – 6578

Research Article
Volume 4 - Issue 2: 79-87 / April 2021

GENETIC GAIN IN YIELD AND YIELD ATTRIBUTING TRAITS OF RICE UNDER UPLAND ECOSYSTEM OF FOGERA, NORTHWEST ETHIOPIA

Bantalem ZELEKE[1]*, Tiegist DEJENE[2], Fisseha WOREDE[3]

[1]Amhara Regional Agricultural Research Institute, Adet Agricultural Research Center, Bahir Dar, Ethiopia
[2]Bahir Dar University, College of Agriculture and Environmental Sciences, Bahir Dar, Ethiopia
[3]Ethiopian Institute of Agricultural Research, Fogera Rice Research and Training Center, Bahir Dar, Ethiopia

Abstract: Evaluation of varieties from different years in a common environment is one of the most direct methods used to estimate breeding progress. Twenty upland rice varieties released in Ethiopia from 1998 to 2016 were evaluated at Fogera National Rice Research and Training Center in 2017 cropping season to estimate the amount of genetic gain over the years. The varieties were laid out in a randomized complete block design with three replications. Analysis of variance revealed significant differences among varieties for all traits. Grain yield was increased from 2.76 t ha^{-1} to 4.86 t ha^{-1} over the past 18 years. The average rate of increase in grain yield of upland rice per year, estimated from the linear regression on year of variety release, was 0.044 t ha^{-1} with a relative genetic gain of 1.59% year^{-1}, although non-significant. The study showed significant improvements in grain-filling period, panicles length and number of filled-grains panicle^{-1}. Significant reduction was also observed in days to heading and thousand-seed weight. No marked changes were observed in grain yield per plant and biological yield, number of fertile tillers, plant height and days to maturity over the 18-year period.

Keywords: Genetic gain, Grain yield, Regression, Rice, Yield attributes

***Corresponding author:** Amhara Regional Agricultural Research Institute, Adet Agricultural Research Center, Bahir Dar, Ethiopia
E mail: bantalem2006@gmail.com (B. ZELEKE)
Bantalem ZELEKE https://orcid.org/0000-0001-8551-4390
Tiegist DEJENE https://orcid.org/0000-0002-2911-1666
Fisseha WOREDE https://orcid.org/0000-0001-8828-5028
Received: October 29, 2019
Accepted: March 14, 2021
Published: April 01, 2021
Cite as: Zeleke B, Dejene T, Worede F. 2021. Genetic gain in yield and yield attributing traits of rice under upland ecosystem of Fogera, Northwest Ethiopia. BSJ Agri, 4(2): 79-87.

1. Introduction

The global production area and yield of rice has been estimated to be 167 million hectares and 769.6 million tons, respectively. About 692 million tons of paddies are produced from 145 million hectares of land in Asian continent. Asia produces about 90% of the world's rice production (FAOSTAT, 2017) which shows its importance in food security for Asians. Africa harvested 36.5 million tons of rice from 14.9 million ha of cultivated land, with productivity of 2.4 t ha^{-1}. In Ethiopia, 48484 ha of land was covered, and 140335 tons of paddy rice was produced in 2017 resulting with a national average productivity of 2.89 ton ha^{-1} (FAOSTAT, 2017). Nonetheless, a yield as high as 6 ton ha^{-1} has been recorded on research fields under upland ecosystem (Dessie et al., 2018).

Rice introduced to Ethiopia in 1970s but formal research was started in 1985/6 with the establishment of Pawe and Abobo agricultural research centers during the resettlement program. Since then, a number of rice germplasm have been introduced from different international institutions for different agro-ecosystems and objectives, and evaluated on multi-locations and years. Consequently, the first rice variety was released in 1998 by Pawe agricultural research center. Up to now, 35 varieties have been released and registered for different agro-ecosystems (MoANR, 2016).

Evaluation of breeding progress allows quantification of genetic change that has been achieved over time. Different traits influencing yield should be analyzed periodically to evaluate breeding progress and to determine traits with greatest contribution to yield (Green et al., 2012). Assessment of the contribution of plant breeding on yield improvement of a certain crop and appraisal of the past gains are useful for identifying potential areas for future breeding endeavors (Waddington et al., 1986). As stated by Evans (1993) knowledge of changes resulted by crop breeding on grain yield and its components is important to evaluate the efficiency of previous works. In measuring progress in genetic yield potential, complications can arise as a result of interactions between cultivar and growing condition (Evans and Fischer, 1999). Nonetheless, evaluation of improved varieties released in different years in a common environment has been a direct method used to estimate the progress in yield improvement made in a given crop (Perry and D'Antuono, 1989). Breseghello et al. (1998) proposed the method used to calculate grain yield growth rate for a region, a state, or the entire area of interest in a breeding program. The gain for sub regions within the same program may show whether the new lines are adapted to specific environmental conditions.

In Ethiopia, works pertaining to genetic gain have been documented on bread wheat (Tarekegn et al., 1995), tef (Teklu and Tefera, 2005; Dargo et al., 2016), barley (Fekadu et al., 2011), maize (Worku and Zelleke, 2007), lowland sorghum (Woldesemayat et al., 2015), haricot bean (Bezaweletaw et al., 2006), groundnut (Hagos et al. 2012), lentil (Bogale et al., 2015), faba bean (Tolessa et al., 2015) and chick pea (Belete et al., 2017). However, no work has been reported on rice in Ethiopia. The objectives of the present investigation are to know the level of genetic gain on yield and yield related characters of released upland rice varieties based on their time of release and to determine changes produced by genetic improvement on yield and yield related traits.

2. Material and Methods

2.1. Description of the Study Area

The study was undertaken at Fogera national rice research and training center, Ethiopia. Average altitude of Fogera ranges from 1,750 to 2,500 meters above sea level (m.a.s.l.) with an average rain fall of 1284 millimeter and temperature ranging from 11.5°C to 27.9°C. The experimental site is located at 11°58' N latitude, 37° 41'E longitude and at an elevation of 1810 m.a.s.l. Based on ten years' average meteorological data, the annual rainfall is 1300 mm and mean annual minimum and maximum temperatures are, 11.5° C and 27.9°C, respectively. The soil type is Vertisol with pH of 5.90.

2.2. Experimental Materials

Experimental materials were 20 upland rice varieties released by different research centers in different years. Eight of the varieties were NERICA (New Rice for Africa) types initially developed for upland ecosystem by Africa Rice. NERICA varieties were developed by interspecific hybridization of *Oryza glaberrima* and *Oryza sativa* (Samado et al., 2008). The description of the varieties is as shown in Table 1.

2.3. Experimental Design and Management

A field experiment was conducted using 20 released upland rice varieties at Fogera national rice research and training center during 2017 main cropping season. Randomized complete block design with three replications in 14m x 39.5m total area was used. Each experimental plot had a total area of 6m^2 (1.5m x 4m) and six rows at 0.25m interval while the distance between plots and between blocks were 0.5m and 1m, respectively. Seeds have been sown in rows with manual drilling at a rate of 60kg ha^{-1}. Fertilizer application was at a rate of 60.5 kg NPS and 125 kg urea per hectare. All NPS have been applied during planting while urea application was in three splits at planting, tillering and at panicle initiation stages.

Table 1. List of upland rice varieties used for the study

No	Variety	Pedigree	Year of release
1	Pawe-1	M-55	1998
2	Kokit	IRAT-209	2000
3	Suprica-1	WAB 450	2006
4	NERICA3	WAB 450-IB-P-2B-HB	2006
5	NERICA4	WAB 450-IB-P-9/1	2006
6	NERICA2	WAB 450-1-1-P31-1-HB	2007
7	Getachew	AD-01	2007
8	Andassa	AD-012	2007
9	Tana	AD-048	2007
10	NERICA14	WAB 880-1-32-1-2-P1-HB	2010
11	Kallafo-1	FOFIFA-3737	2010
12	NERICA6	WAB 450-IBP-160-HB	2011
13	NERICA15	WAB 881-10-37-18-3-P1-HB	2011
14	Hidasse	WAB 515-B-16A1-2	2012
15	Chewaqa	YIN lu 20	2013
16	NERICA10	WAB 450-11-1-1-P41-HB	2013
17	NERICA12	WAB 880-1-38-20-17-P1-HB	2013
18	Adet	WAB 450-1-B-P-462-HB	2014
19	NERICA13	WAB 880-1-38-20-28-P1-HB	2014
20	Fogera-1	ART15-7-16-30-2-B-B	2016

Source: MoANR (2016)

2.4. Data Collection

Observation and data recording for the traits under study were based on the standard evaluation system for rice (IRRI, 2013). The data were collected from ten randomly selected plants of each plot for traits treated on plant-basis like plant height (cm), panicle length (cm), number of panicles per plant, number of total grains per panicle, number of filled-grains per panicle, number of fertile tillers per plant, yield per plant (gm). However, days to heading, days to maturity, grain-filling period, thousand-seed weight (gm), biological yield (t ha^{-1}) and grain yield (t ha^{-1}) were taken on plot-basis; the four central rows were considered. Grain yield was adjusted at 14% moisture level.

2.5. Statistical Analysis

2.5.1. Analysis of variance

Analysis of variance (ANOVA) was done using Statistical Analysis System (SAS) version 9.4 Computer software program following SAS statement for randomized complete block design (SAS, 2012). Mean separation was done by comparing every pair of means by Least Significance Difference (LSD) test.

2.5.2. Genetic gain

Linear regression analysis was used to calculate the genetic gain for each trait considered in the study. The breeding effect was estimated as a genetic gain for grain yield and associated traits in upland rice by regressing mean of each character for each variety against the year of release of that variety using PROC REG procedure of SAS. The coefficient of linear regression gives the estimate of genetic gain in ton ha^{-1} year^{-1} or in % per year (Evans and Fisher, 1999). The relative annual gain achieved over the years was determined as a ratio of genetic gain to the corresponding mean value of oldest variety and expressed as percentage.

Annual rate of gain (b) $= \frac{\text{covxy}}{v(x)}$

where X= the year of variety release, Y= the mean value of each character for each variety, Cov= Covariance, and V= Variance

The functional form of linear relationship between a dependent variable Y and independent variable X is represented by the equation:

$$Y = \alpha + \beta x$$

where Y= the value of the dependent variable, X= the independent variable, α= the intercept of the line and β= the regression coefficient (slope of the line), or the changes in Y per unit change in X.

3. Results and Discussion

3.1. Analysis of Variance and Performance of Varieties

The result of the analysis of variance for the different morphological and agronomic traits is presented in Table 2. There were significant differences ($P<0.01$) among varieties for all characters studied, indicating the existence of genetic variability within the varieties. The present investigation is in confirmation with early findings (Veasey et al., 2008; Worede et al., 2014; Fentie et al., 2014).

Mean of days to heading of all varieties in the trial was 94.71 days. The variety NERICA10 was significantly ($P\leq0.05$) earliest in heading than the other varieties whereas Pawe-1 was very late in heading than the other varieties. Likewise, mean days to maturity of all varieties were 142.87. The variety NERICA14 had significantly ($P\leq0.01$) earliest maturity. However, Pawe-1 had highly significant ($P\leq0.01$) late days to maturity from all the other varieties. The mean of grain-filling period of varieties was 48.15 days. The variety Kokit had the shortest (33.3) grain-filling period, although it was not significantly ($P\leq0.01$) different from variety NERICA14. The variety NERICA10 had significantly longest grain-filling period than the other varieties (Table 3).

The mean plant height was 85.38cm which ranged from 70.7cm (NERICA10) to 107.6cm (Getachew). Getachew was the tallest (107.6cm) followed by Andassa (104cm), Tana (101.8cm) and Chewaqa (101.4cm); however, Pawe-1 was the shortest (71.4cm). Panicle length of the varieties ranged from 12.1 cm to 20.9 cm with a mean of 18.39cm. The variety NERICA2 showed the longest panicle length (20.9 cm) which was significantly ($P\leq0.01$) different from all the other varieties in the study except NERICA13, NERICA12 and Getachew. In contrast, the variety Pawe-1 had the smallest panicle (12.1 cm) of all the varieties (Table 3).

Number of fertile-tillers ranged from 6 to 9.7. The variety NERICA4 scored the highest number of fertile-tillers per plant followed by Andassa (9.4) and Tana (8.8). While that of variety NERICA15 was significantly lower than the rest of the varieties. The mean number of panicles per plant was 10.02 and it ranged from 8.4 (Kokit) to 13.5 (Hidasse). Hidasse, followed by NERICA6 (11.7) and NERICA12 (11.1) had higher number of panicles per plant. The oldest improved variety, Pawe-1, had 9.7 panicles.

The total number of grains per panicle ranged from 57.5 (NERICA14) to 105.8 (NERICA4). NERICA4 followed by Fogera-1 (105.1), NERICA6 (104) and Superica-1 (102.7) were varieties with higher total number of grains per panicle. Likewise, number of filled-grains panicle^{-1} of varieties ranged from 53.5 to 98.5 with the mean of 75.09 filled-grains panicle^{-1}. The variety NERICA4 produced highest number of filled-grains panicle^{-1} than the others. The varieties such as NERICA15, NERICA14, Kokit, Pawe-1 and NERICA10 produced lower number of filled-grains panicle^{-1} than the other varieties in the study (Table 3).

Table 2. Analysis of variance for 13 traits of 20 upland rice varieties at Fogera in 2017

Traits	Variety (df=19)	Error (df=38)	R^2 (%)
Days to heading	303.413**	2.439	0.984
Days to maturity	259.137**	4.997	0.963
Grain-filling period	256.894**	5.578	0.958
Plant height (cm)	382.638**	11.694	0.943
Panicle length (cm)	10.882**	0.689	0.89
Number of panicles per plant	3.911**	0.744	0.78
Number of total grains per panicle	753.097**	3.256	0.991
Number of filled-grains per panicle	650.801**	3.386	0.989
Number of fertile tillers per plant	3.070**	0.354	0.815
Thousand-seed weight (gm)	26.124**	0.950	0.932
Yield per plant (gm)	47.803**	0.621	0.975
Biological yield (t ha^{-1})	10.465**	0.379	0.933
Grain yield (t ha^{-1})	1.874**	0.113	0.893

*,**= Significant at $P \leq 0.05$ and 0.01, respectively, df= degree of freedom R^2= coefficient of determination.

Mean yield per plant of upland rice varieties was 13.02 g, and it ranged from 5.2 g for NERICA15 to 20.7 g for NERICA12. Besides NERICA12, NERICA4, NERICA3, Suprica-1 and Tana also had higher yield per plant. However, varieties such as NERICA15, Kokit, Chewaqa and NERICA14 had relatively lower yield per plant than the other varieties in the study (Table 3).

Table 3. Mean of yield and yield related traits of the 20 upland rice varieties

Varieties	DH	DM	GFP	PH	PL	NPP	NTGP	NFGP	NFTP	TSW	YP	BY	GY
Adet	89.3^{hi}	144.3^{cdef}	55.0^{cd}	79.1^{f}	18.0^{ef}	9.5^{defgh}	86.4^{e}	82.1^{g}	7.0^{ghi}	28.6^{cde}	13.7^{fgh}	8.8^{defg}	4.5^{bcd}
Andassa	103.3^{d}	146.0^{bcde}	42.7^{g}	104.0^{ab}	19.1^{cde}	9.7^{cdefgh}	83.6^{ef}	73.8^{j}	9.4^{ab}	27.9^{def}	14.7^{defg}	9.8^{cd}	5.1^{a}
Chewaqa	107.3^{b}	148.0^{bc}	40.7^{gh}	101.4^{b}	19.1^{cde}	9.7^{cdefgh}	74.4^{g}	62.1^{l}	6.7^{hij}	25.3^{ij}	8.4^{j}	7.7^{hi}	3.8^{fghi}
Kallafo-1	85.0k	142.0^{f}	57.0^{bc}	83.2^{ef}	16.9^{fg}	9.7^{cdefgh}	75.6^{g}	69.2^{k}	7.7^{defg}	29.8^{c}	13.4^{ghi}	8.1^{ghi}	4.2^{def}
Fogera-1	92.3^{fg}	142.3^{ef}	50.0^{ef}	80.9^{ef}	17.7^{fg}	10.7^{bcd}	105.1^{ab}	95.3^{b}	8.5^{bcd}	25.1^{ij}	14.2^{efg}	9.3^{cde}	4.9^{abc}
Getachew	106.3^{bc}	146.0^{bcde}	39.7^{gh}	107.6^{a}	20.3^{abc}	10.5^{bcde}	85.7^{e}	76.0^{ij}	6.2^{ij}	28.3^{cde}	12.6^{hi}	12.4^{a}	4.4^{cde}
Hidasse	90.7^{gh}	142.7^{def}	52.0^{de}	81.3^{ef}	19.2^{bcde}	13.5^{a}	96.1^{c}	87.5^{de}	7.5^{defgh}	26.5^{fghi}	14.9^{def}	7.8^{ghi}	4.1^{defg}
Kokit	90.3^{gh}	123.7^{gh}	33.3^{j}	73.4^{gh}	17.6^{fg}	8.4^{h}	59.0^{i}	54.0^{no}	7.1^{fghi}	27.6^{defg}	8.0^{j}	5.8^{kl}	3.5^{hi}
NERICA10	79.7^{l}	146.0^{bcde}	66.3^{a}	70.7^{h}	18.2^{def}	9.1^{efgh}	80.8^{f}	58.1^{m}	8.1^{cde}	26.0^{hij}	9.0^{j}	6.6^{jk}	3.3^{ij}
NERICA12	97.7^{e}	149.3^{b}	51.7^{de}	93.9^{c}	19.5^{abcd}	11.1^{bc}	96.6^{c}	90.5^{cd}	8.2^{cde}	32.6^{b}	20.7^{a}	9.1^{cdef}	4.9^{ab}
NERICA13	90.7^{gh}	145.7^{bcdef}	55.0^{cd}	85.1^{de}	20.5^{ab}	9.8^{cdefgh}	75.3^{g}	70.3^{k}	6.9^{ghij}	32.6^{b}	12.4^{i}	8.7^{efgh}	4.7^{abcd}
NERICA14	86.3^{jk}	120.7^{h}	34.3^{ij}	72.4^{h}	19.2^{bcde}	8.6^{gh}	57.5^{i}	53.7^{o}	6.7^{hij}	26.3^{ghi}	8.7^{j}	5.4^{l}	3.7^{fghi}
NERICA15	87.7^{ij}	125.0^{g}	37.3^{hi}	85.2^{de}	18.2^{def}	10.1^{cdef}	57.7^{i}	53.5^{o}	6.0^{j}	27.1^{efgh}	5.2^{k}	6.1^{kl}	2.3^{k}
NERICA2	85.3^{jk}	145.7^{bcdef}	60.3^{b}	78.8^{fg}	20.9^{a}	9.9^{cdefg}	92.0^{d}	80.5^{gh}	8.4^{bcd}	25.6^{hij}	12.2^{i}	**7.2^{ij}**	3.6^{ghi}
NERICA3	91.0^{gh}	146.0^{bcde}	55.0^{cd}	78.2^{fg}	17.2^{fg}	9.9^{cdefg}	85.0^{e}	79.0^{hi}	8.1^{cdef}	27.6^{defg}	16.8^{c}	8.3^{fgh}	4.8^{abc}
NERICA4	90.7^{gh}	145.0^{cdef}	54.3^{cd}	79.1^{ef}	18.0^{ef}	10.3^{cdef}	105.8^{a}	98.5^{a}	9.7^{a}	27.0^{efgh}	19.2^{b}	9.4^{cde}	5.0^{ab}
NERICA6	99.0^{e}	146.3^{bcd}	47.3^{f}	90.6^{cd}	19.9^{abc}	11.7^{b}	104.0^{ab}	85.5^{ef}	6.7^{hij}	24.4^{j}	15.5^{cd}	5.8^{kl}	3.9^{efgh}
Pawe-1	122.7^{a}	160.0^{a}	37.3^{hi}	71.4^{h}	12.1^{h}	9.7^{cdefgh}	62.7^{h}	57.0^{mn}	7.4^{efgh}	35.8^{a}	9.0^{j}	10.0^{c}	2.8^{jk}
Superica-1	94.3^{f}	146.3^{bcd}	52.0^{de}	89.7^{cd}	16.6^{g}	9.3^{defgh}	102.7^{b}	92.4^{bc}	8.2^{cde}	31.5^{b}	16.5^{c}	6.7^{jk}	3.7^{fghi}
Tana	104.7^{cd}	146.3^{bcd}	41.7^{g}	101.8^{b}	19.5^{bcd}	8.9^{fgh}	86.3^{e}	82.7^{fg}	8.8^{abc}	28.8^{cd}	15.2^{de}	11.1^{b}	5.0^{ab}
Mean	94.71	142.87	48.15	85.39	18.39	10.02	83.61	75.1	7.656	28.23	13.015	8.19	4.12
LSD (5%)	2.582	3.695	3.904	5.652	1.372	1.425	2.983	3.042	0.983	1.611	1.303	1.018	0.555
C.V (%)	1.649	1.565	4.905	4.005	4.516	8.609	2.158	2.451	7.771	3.453	6.055	7.521	8.155

Means with in a column followed by the same letter are not significantly different at P≤0.05. DH= Days to heading, DM= Days to maturity, GFP= Grain-filling period, PH= Plant height, PL= Panicle length, NFTP= Number of fertile tillers per plant, NPP= Number of panicles per plant, NTGP= Number of total grains per panicle, NFGP= Number of filled-grain per panicle, TSW= Thousand-seed weight, YP= Yield per plant, BY= Biological yield and GY= Grain yield.

Thousand-seed weight ranged from 24.4gm (NERICA6) to 35.8gm (Pawe-1) with a mean of 28.23gm. Pawe-1 followed by NERICA12 and NERICA13 (both 32.6gm) and Superica-1 (31.5gm) were large seeded varieties.

The mean biological yield of the upland rice varieties was 8.19 t ha^{-1}, and it ranged from 5.4 t ha^{-1} for NERICA14 released in 2010 to 12.4 t ha^{-1} for Getachew released in 2007 (Table 3). Varieties such as Tana (11.1 t ha^{-1}) and Pawe-1 (10 t ha^{-1}) also had higher biological yield. The varieties released in 1998, 2007 and 2016 had relatively higher biological yield than the others (Table 4).

Table 4. Trend of genetic progress for grain-yield and biological-yield in upland rice varieties released from 1998-2016 over the oldest variety (Pawe-1)

Varieties	Year of release	Mean grain yield (t ha^{-1})	Increment over the oldest variety		Mean biological yield (t ha^{-1})	Increment over the oldest variety	
			t ha^{-1}	%		t ha^{-1}	%
Pawe-1	1998	2.760	-	-	10.00	-	-
Kokit	2000	3.490	0.730	26.449	5.78	-4.22	-42.20
NERICA3	2006						
NERICA4	2006	4.522	1.762	63.849	8.10	-1.90	-18.98
Superica-1	2006						
Andassa	2007						
Getachew	2007	4.523	1.763	63.889	10.11	0.11	1.11
NERICA2	2007						
Tana	2007						
Kallafo-1	2010	3.980	1.220	44.203	6.73	-2.27	-32.73
NERICA14	2010						
NERICA15	2011	3.122	0.362	13.104	5.91	-4.10	-40.92
NERICA6	2011						
Hidasse	2012	4.130	1.370	49.638	7.83	-2.17	-21.70
NERICA10	2013						
Chewaqa	2013	4.001	1.241	44.968	7.81	-2.19	-21.91
NERICA12	2013						
Adet	2014	4.598	1.838	66.606	8.74	-1.26	-12.62
NERICA13	2014						
Fogera-1	2016	4.860	2.100	76.087	9.28	-0.72	-7.20

The mean grain yield of upland rice varieties was 4.12 t ha^{-1}, which ranged from 2.31 t ha^{-1} for the variety NERICA15 to 5.13 t ha^{-1} for the variety Andassa. Andassa had significantly ($P \le 0.05$) highest yield than the others (Table 3). The highest yielder variety, Andassa represents 63.8 % increment over the older variety (Pawe-1). More or less, similar trends of genetic progress were reported in wheat in Ethiopia (Tarekegn et al., 1995). The recently released upland rice variety, Fogera-1, showed significantly ($P \le 0.05$) higher grain yield than most of the varieties tested in the study except Andassa, NERICA4, Tana and NERICA12. It exceeded the oldest variety (Pawe-1) by 76.08%. In the same way, Tarekegn et al. (1995) reported 89% and 71% grain yield improvement of the recent bread wheat variety at Holetta and Kulumsa, respectively. In winter wheat, 27.6% greater seed yield of newly released cultivar than the older cultivars was reported in UK (Shearman et al., 2005). Mean grain yields of varieties released in 2006, 2007, 2014 and 2016 exceeded that of the older variety released in 1998 by 1.76 (63.85%), 1.76 (63.89%), 1.84 (66.61%) and 2.10 (76.10%) t ha^{-1}, respectively (Table 4).

3.2. Genetic Improvement of Yield and Yield Attributing Traits

The linear regression analysis of days to heading and days to maturity on year of variety release showed negative regression coefficient, which was significantly different from zero for days to heading (Table 5). In agreement with this study, Donmez et al. (2001) in winter wheat reported that modern cultivars were significantly earlier than the oldest ones for days to flowering. Breseghello et al. (2011) also reported reduction of 0.25 days yr^{-1} in days to flowering in upland rice.

As evidenced from the regression of variety means against year of release, plant height showed 0.353 cm $year^{-1}$ increment although it was not significant (Table 6). In agreement to this finding, Teklu and Tefera (2005) reported low (0.4285 cm $year^{-1}$) and non-significant genetic gain of plant height over 35 years of tef improvement. Contrary to this, Ortiz et al. (2002) reported that yield improvement was achieved by reducing plant height in two row barley (0.2 cm $year^{-1}$) and six row barley (0.16 cm, $year^{-1}$) varieties. Breseghello et al. (2011) also reported reduction of 0.52 cm yr^{-1} in plant height in upland rice.

The analysis showed that the regression coefficient for panicle length for the period studied was 0.216, which is significantly (P≤0.05) different from zero (Table 6). This result indicated panicle length was steadily modified with the year of release of a variety.

Number of fertile tillers per plant of upland rice varieties showed a slight but not significant (P≤0.05) decreasing trend over the 18 years period (Table 5). The annual relative genetic gain of number of fertile tiller per plant for the periods 1998-2016 was -0.45% (Table 6). This implies that there was a decreasing trend in number of fertile tiller per plant across the years of release.

Number of filled-grains per panicle revealed significant (P≤0.05) trend of increase over the period studied (Table 5). Accordingly, it increased by 0.76 grains $year^{-1}$, indicating that rice improvement program has significantly enhanced number of filled-grain $panicle^{-1}$. This implies that improved grain yield in the modern varieties appears to be associated more with the production of a higher number of filled-grain $panicle^{-1}$. The annual relative genetic gain for number of filled grain $panicle^{-1}$ was estimated to be 1.33 % for the period 1998-2016 (Table 6).

Table 5. Mean values, regression coefficient (b), intercept and coefficient of determination (R^2) for various traits of 20 upland rice varieties released from 1998-2016

Traits	Mean	b	Intercept	R^2
Days to heading	94.72	-0.931*	1965.74	0.185
Days to maturity	142.87	-0.104	352.46	0.003
Grain-filling period	48.15	0.827*	-1613.34	0.173
Plant height (cm)	85.39	0.353	-624.26	0.0212
Panicle length (cm)	18.39	0.216*	-414.69	0.277
Number of panicles per plant	10.02	0.082	-154.98	0.112
Number of total grain per panicle	83.61	1.013	-1951.34	0.088
Number of filled-grains per panicle	75.09	0.76*	-1450.87	0.058
Number of fertile tillers per plant	7.66	-0.033	73.15	0.022
Thousand-seed weight (gm)	28.23	-0.232*	493.44	0.133
Yield per plant (gm)	13.02	0.094	-175.67	0.012
Biological yield (t ha^{-1})	8.19	-0.044	93.13	0.011
Grain yield (t ha^{-1})	4.12	0.044	-84.10	0.067

*= Significant at P≤0.05.

Table 6. Mean annual relative genetic gain (RGG) of different traits over the18 years of upland rice improvement in Ethiopia

Traits	Mean of the oldest variety	Increment/decrement	RGG (% $year^{-1}$)
Days to heading	122.7	-0.931	-0.76
Days to maturity	160.0	-0.104	-0.07
Grain-filling period	37.30	0.827	2.22
Plant height (cm)	71.43	0.353	0.50
Panicle length (cm)	12.13	0.216	1.78
Number of panicles per plant	9.77	0.082	0.84
Number of total grain per panicle	62.70	1.013	1.62
Number of filled-grains per panicle	57.00	0.760	1.33
Number of fertile tillers per plant	7.40	-0.033	-0.45
Thousand-seed weight (gm)	35.83	-0.232	-0.65
Yield per plant (gm)	9.02	0.094	1.04
Biological yield (t ha^{-1})	10.00	-0.044	-0.44
Grain yield (t ha^{-1})	2.76	0.044	1.59

The linear regression analysis for thousand-seed weight depicted significant (P≤0.05) negative linear relationship with cultivar age (Table 5). The relative annual genetic gain of thousand-seed weight of varieties mean over year of variety release was -0.65% (Table 6).

The average rate of increase in grain yield of upland rice varieties was 0.044 t ha^{-1} year^{-1}, although non-significant (Table 5 and Figure 1). Notwithstanding yield potential increment with the deployment of dwarfing genes in wheat and rice, it is generally considered that yield is under multi genic control and the yield potential progress is mostly gradual (Evans and Fischer, 1999). Similar trends have been reported by dos Reis et al. (2015) who reported 13.99 kg ha^{-1} improvement in irrigated rice per year. Under irrigation, Peng et al. (2000) reported 75 and 81 kg ha^{-1} grain yield increment per year in rice in 1996 and 1998, respectively. Tabien et al. (2008) found 42.2 and 26.3 kg ha^{-1} yield improvement per year for irrigated rice under high and low N conditions, respectively. Breseghello et al. (2011) also found 19.1 kg ha^{-1}, corresponding to 0.67% per year, gain for yield in upland rice. Zhu et al. (2016) reported 61.9 and 75.3 kg ha^{-1} annual gains of rice grain yield in 2013 and 2014, respectively. Teklu and Tefera (2005) also reported genetic gains of 27.16 kg ha^{-1} per year of release in tef.

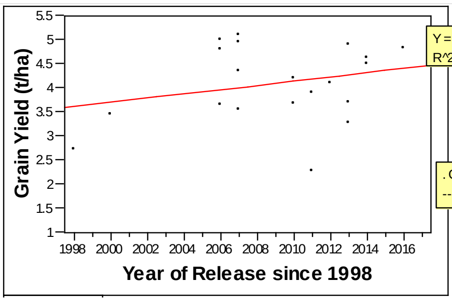

Figure 1. Relationship between mean grain yield of 20 upland rice varieties and the year of release.

Grain yield showed a general increase from old to new varieties during the last two decades of upland rice breeding in Ethiopia (Figure 1). This is in agreement with the findings of Teklu and Tefera (2005) in tef, Tarekegn et al. (1995) in wheat, Wych and Stuthman (1983) in oat.

The relative annual genetic yield gain in the 20 varieties of upland rice released between 1998 and 2016 was 1.59% year^{-1} (Table 6). Similar to the present study, an annual increase of 0.8% in oats (Wych and Stuthman, 1983), 0.9% in malt barley (Wych and Rasmusson, 1983), 1% in irrigated rice (Peng et al., 2000), 0.79% in tef (Teklu and Tefera, 2005) and 0.86% in wheat (Miri, 2009) were reported. This indicates that grain yield of rice has not yet attained a ceiling in Ethiopia, signifying the opportunity to further improve upland rice yield. In line with the present findings, Teklu and Tefera (2005) in tef in Ethiopia, and Khodarahmi et al. (2010) in wheat in Iran found no indication of yield potential plateau.

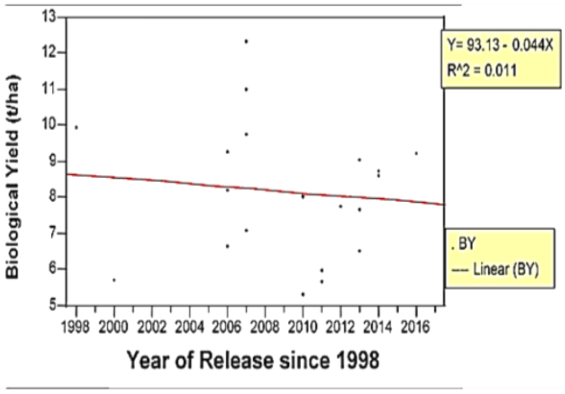

Figure 2. Relationship between mean biological yield of 20 upland rice varieties and the year of release.

The average rate of increase in biological yield of upland rice varieties was -0.044 t ha^{-1} per annum, though not-significant (Table 5 and Figure 1). The annual relative genetic gain for biological yield of the upland rice varieties was estimated to be -0.44% for the period 1998-2016 (Table 6). In contrast, Zhu et al. (2016) reported 0.097 and 0.11 t ha^{-1} annual gains of biological yield for rice in 2013 and 2014, respectively. Teklu and Tefera (2005) also reported a significant biological yield improvement in tef. Similarly, Donmez et al. (2001) pointed out that the gain in grain yield in wheat genotypes was accompanied by an increase in total biomass yield (0.16%). The study revealed that upland rice improvement program has not significantly enhanced the biological yield of the modern varieties.

3.3. Phenotypic Correlations of Grain Yield and Other Traits

The result of the phenotypic correlation analysis is depicted in Table 7. Days to maturity showed significant positive association with grain yield (r_p=0.30*). The result is in agreement with Fentie et al. (2014). The correlation between plant height and grain yield was positive and significant (r_p=0.39**) which indicates that an increase in plant height leads to an increase grain yield. Similar results have been reported by Fentie et al. (2014) and Ratna et al. (2015).

The correlation between number of productive tillers per plant and grain yield was positive and significant (r_p=0.50**) which is in agreement with the report of Madhavilatha et al. (2005) and Ratna et al. (2015). Number of filled-grains per panicle had positive and highly significant association with grain yield (r_p=0.64**). The result is substantiated with those of Elsadig and Abdalla (2013), Ratna et al. (2015) and Somchit et al. (2017).

Yield per plant had highly significant positive correlation (r_p=0.77**) with grain yield. Biological yield was in positive and significant relationship with grain yield (r_p=0.57**). This result is supported by the findings of Rangare et al. (2012), Fentie et al. (2014) and Rathor et al. (2014).

Table 7. Phenotypic correlation coefficient (r_p) of 13 traits of 20 released upland rice varieties

Variable	DM	GFP	PH	PL	NPP	NTGP	NFGP	NFTP	TSW	YP	BY	GY
DH	0.54**	-0.53**	0.47**	-0.32*	0.07	-0.05	-0.02	-0.05	0.42**	0.03	0.54**	0.01
DM		0.43**	0.27*	-0.2	0.2	0.49**	0.42**	0.33*	0.40**	0.47**	0.57**	0.30*
GFP			-0.23	0.14	0.13	0.54**	0.44**	0.38**	-0.05	0.44**	-0.01	0.28*
PH				0.43**	0.18	0.26*	0.26*	0.01	0	0.28*	0.50**	0.39**
PL					0.23	0.24	0.2	-0.06	-0.41**	0.16	0.02	0.37**
NPP						0.45**	0.43**	0	-0.08	0.34**	0.15	0.17
NTGP							0.95**	0.48**	-0.18	0.81**	0.25*	0.55**
NFGP								0.49**	-0.05	0.88**	0.34**	0.64**
NFTP									0.05	0.56**	0.29*	0.50**
TSW										0.16	0.39**	0.04
YP											0.39**	0.77**
BY												0.57**

*, ** at 5 % and 1% probability level respectively, DH= Days to heading, DM= Days to maturity, GFP= Grain-filling period, PH= Plant height, PL= Panicle length, NFTP= Number of fertile tillers per plant, NPP= Number of panicles per plant, NTGP= Number of total grains per panicle, NFGP= Number of filled grains per panicle, TSW= Thousand-seed weight, YP= Yield per plant, BY= Biological yield and GY= Grain yield.

The study of correlation revealed that plant height, number of productive tillers per plant, yield per plant and biological yield were characters which possessed significant positive association with grain yield. The positive and significant correlation of these traits with grain yield suggests that yield have increased with increase of those characters.

4. Conclusion and Recommendation

Information on the genetic progress achieved over time from a breeding program is useful to develop effective and efficient breeding strategies for further improvement. The present study showed increment in grain yield of upland rice varieties with 0.044 t ha^{-1} (1.59% $year^{-1}$) average rate of increase per year and decrement in biological yield with -0.044 t ha^{-1} (-0.44% $year^{-1}$), although non-significant. The result demonstrated significant reduction in days to heading and thousand-seed weight, and significant increment in panicle length, grain-filling period and number of filled-grains $panicle^{-1}$. On the looming climate change, there might have been occurrences of new biotic and abiotic stress factors, and the latest varieties may be better adapted to these factors in addition to the significant changes.

The positive and significant correlation of plant height, number of productive tillers per plant, yield per plant and biological yield with grain yield suggests that yield have increased with the increase of those characters. However, this study needs subsequent testing of varieties at different locations to come up with sound recommendation.

Author Contributions

BZ; initiated the research idea, developed, organized, analyzed and interpreted the data and wrote the manuscript. TD: suggested the research methods, structured the paper and organized the manuscript FW; supervised the research, suggested the research methods, structured the paper and edited the manuscript.

Conflict of Interest

The authors declare that there is no conflict of interest.

References

Belete T, Mekbib F, Eshete M. 2017. Assessment of genetic improvement in grain yield potential and related traits of Kabuli type chickpea (Cicer arietinum L.) varieties in Ethiopia (1974-2009). Adv. Crop Sci Tech, 5: 284.

Bezaweletaw K, Belete K, Sripichitt P. 2006. Genetic gain in grain yield potential and associated agronomic traits in haricot bean (Phaseolus vulgaris L.). Kasetsart J (Natural Sci), 40: 835-847.

Bogale DA, Mekbib F, Fikre A. 2015. Genetic improvement of lentil [Lens culinaris Medikus] between 1980 and 2010 in Ethiopia. Malays J Med Biol Res, 2(3): 284-292.

Breseghello F, de Morais OP, Rangel PHN. 1998. A new method to estimate genetic gain in annual crops. Genetics and Mol Biol, 21(4). DOI: 10.1590/S1415-47571998000400024.

Breseghello F, de Morais OP, Pinheiro PV, Silva ACS, da Maia de Castro E, Guimarães ÉP, de Castro AP, Pereira JA, de Matos Lopes A, Utumi MM, de Oliveira JP. 2011. Results of 25 years of upland rice breeding in Brazil. Crop Sci, 51: 914-923.

Dargo F, Mekbib F, Assefa K. 2016. Genetic gain in grain yield potential and associated traits of tef [Eragrostis tef (Zucc.) Trotter] in Ethiopia. Global J Sci Frontier Res, D16(6): 1-17.

Dessie A, Zewdu Z, Worede F, Bitew M. 2018. Yield stability and agronomic performance of rain fed upland rice genotypes by using GGE bi-plot and AMMI in North West Ethiopia. Int J Res Rev, 5(9): 123-129.

Donmez E, Sears RG, Shroyer JP, Paulsen GM. 2001. Genetic gain in yield attributes of winter wheat in the Great Plains. Crop Sci, 41: 1412-1419.

dos Reis GG, Fritsche-Neto R, Soares PC, de Oliveira Cornélio

VM, de Sousa Reis M, de Morais OP, da Silva Marques T. 2015. Accuracy and genetic progress of agronomic traits in irrigated rice program in Brazil. Afr J Agric Res, 10(43): 4032-4038.

Elsadig AI, Abdalla KM. 2013. Estimation of genetic variability and correlation for grain yield components in rice (Oryza sativa L.). Glob J Plant Ecophysiol, 3: 1-6.

Evans LT. 1993. Crop evolution, adaptation and yield. Cambridge University Press, New York, USA.

Evans LT, Fischer RA. 1999. Yield potential: Its definition, measurement and significance. Crop Sci, 39: 1544-1551.

FAOSTAT. 2017. URL: http://www.fao.org/faostat/en/#data/QC. (access date: 10.09.2019).

Fekadu W, Zeleke H, Ayana A. 2011. Genetic improvement in grain yield potential and associated traits of food barley (Hordeum vulgare L.) in Ethiopia. Ethiop J Appl Sci Technol, 2(2): 43-60.

Fentie D, Alemayehu G, Siddalingaiah M, Tadesse T. 2014. Genetic variability, heritability and correlation coefficient analysis for yield and yield component traits in upland rice (Oryza sativa L.). East African J Sci, 8(2): 147-154.

Green AJ, Berger G, Griffey CA, Pitman R, Thomason W, Balota M, Ahmed A. 2012. Genetic yield improvement in soft red winter wheat in the Eastern United States from 1919 to 2009. Crop Sci, 52: 2097–2108.

Hagos F, Zeleke H, Woyessa B. 2012. Genetic gain in yield and yield related traits of groundnut (Arachis hypogea L.) in central rift valley of Ethiopia. East African J Sci, 6(2): 125-136.

IRRI. 2013. Standard evaluation system for rice. 5th (ed.). International Rice Research Institute, 55p, Manila. Philippines.

Khodarahmi M, Nabipour A, Zargari K. 2010. Genetic improvement of agronomic and quality traits of wheat cultivars introduced to temperate regions of Iran during 1942-2007. Afr J Agric Res, 5(9): 947-954.

Madhavilatha L, Sekhar MR, Suneetha Y, Srinivas T. 2005. Genetic variability, correlation and path analysis for yield and quality traits in rice (Oryza sativa L.). Res on Crops, 6(3): 527-534.

Miri H. 2009. Grain yield and morpho-physiological changes from 60 years of genetic improvement of wheat in Iran. Experimental Agri, 45: 149-163.

MoANR. 2016. Crop variety register. Issue No. 19. Plant variety release, protection and seed quality control directorate. Addis Ababa, Ethiopia.

Ortiz R, Nurminiemi M, Madsen S, Rognli OA, Bjørnstad Å. 2002. Genetic gains in Nordic spring barley breeding over sixty years. Euphytica, 126(2): 283-289.

Peng S, Laza RC, Visperas RM, Sanico AL, Cassman KG, Khush GS. 2000. Grain yield of rice cultivars and lines developed in the Philippines since 1966. Crop Sci, 40: 307-314.

Perry MW, D'Antuono MF. 1989. Yield improvement and associated characteristics of some Australian spring wheat cultivars introduced between 1960 and 1982. Aust J Agr Res, 50: 457-472.

Rangare NR, Krupakar A, Ravichandra K, Shukla AK, Mishra AK. 2012. Estimation of characters' association and direct and indirect effects of yield contributing traits on grain yield in exotic and Indian rice (Oryza sativa L.) germplasm. Intl J Agric Sci, 2(1): 54-61.

Rathor AP, Singh A, Suresh BG, Lavanya GR, Yadav Y. 2014. Diversity analysis of local land races and improved germplasm of rice (Oryza sativa L.) under Allahabad agro-climatic conditions. Indian J Applied Res, 4(8): 38-42.

Ratna M, Begum S, Husna A, Dey SR, Hossain MS. 2015. Correlation and path coefficients analyses in basmati rice. Bangladesh J Agri Res, 40: 153-161.

Samado EA, Guei RG, Nguyen N. 2008. NERICA: Origin, nomenclature and identification characteristics, pp. 10-19. In E.A. Somado, R.G. Guei and S.O. Keya, (eds.). NERICA®: The New Rice for Africa – a Compendium. Africa Rice Center, Cotonou, Benin.

SAS. 2008. Statistical Analysis System. Version 9.2, SAS Institute Inc., Cary, NC., USA.

Shearman VJ, Sylvester-Bradley R, Scott RK, Foulkes MJ. 2005. Physiological processes associated with wheat yield progress in the UK. Crop Sci, 45: 175-185.

Somchit P, Sreewongchai T, Sripichitt P, Matthayatthaworn W, Uckarach S, Keawsaard Y, Worede F. 2017. Genetic relationships of rice yield and yield components in RILs population derived from a cross between KDML105 and CH1 rice varieties. Walailak J Sci Tech, 14(12): 997-1004.

Tabien RE, Samonte SOPB, McClung AM. 2008. Forty-eight years of rice improvement in Texas since the release of cultivar Bluebonnet in 1944. Crop Sci, 48: 2097-2106.

Tarekegn A, Tanner DG, Gebeyehu G. 1995. Improvement in yield of bread wheat cultivars released in Ethiopia from 1949 to 1987. African Crop Sci J, 3(1): 41-49.

Teklu Y., Tefera H. 2005. Genetic improvement in grain yield potential and associated agronomic traits of tef (Eragrostis tef). Euphytica, 141: 247-254.

Tolessa T, Keneni G, Mohammad H. 2015. Genetic progresses from over three decades of faba bean (Vicia faba L.) breeding in Ethiopia. Australian J Crop Sci, 9: 41-48.

Veasey EA, da Silva EF, Schammass EA, Oliveira GCX, Ando A. 2008. Morphoagronomic genetic diversity in American wild rice species. Braz Arch Biol Tech, 51: 95-104.

Waddington S, Ransom S, Osamanzi M, Sounders D. 1986. Improvement in the yield potential of bread wheat adapted to North West Mexico. Crop Sci, 26: 699-703.

Woldesemayat MY, Mekbib F, Gebeyehu S. 2015. Genetic gain in lowland sorghum [Sorghum Bicolor (L.) Moench] varieties in Ethiopia. Int J Hortic Plant Breed Sci, 2(1): 1 -13.

Worede F, Sreewongchai T, Phumichai C, Sripichitt P. 2014. Multivariate analysis of genetic diversity among some rice genotypes using morpho-agronomic traits. J Plant Sci, 9: 14-24.

Worku M, Zelleke H. 2007. Advances in improving harvest index and grain yield of maize in Ethiopia. East African J Sci, 1: 112-119.

Wych RD, Rasmusson DC. 1983. Genetic improvement in malting barley cultivars since 1920. Crop Sci, 23: 1037-1040.

Wych RD, Stuthman DD. 1983. Genetic improvement in Minnesota-adapted oat cultivars released since 1923. Crop Sci, 23: 879-881.

Zhu G, Peng S, Huang J, Cui K, Nie L, Wang F. 2016. Genetic improvements in rice yield and concomitant increases in radiation- and nitrogen-use efficiency in middle reaches of Yangtze River. Sci Rep, 6, 21049. DOI: 10.1038/srep21049.