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Tef (*Eragrostis tef* (Zucc.) Trotter) Variety 'Felagot'

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ጤፍ በኢትዮጵያ ከሚመረቱ የብርዕና አገዳ ሰብሎች ዋነኛው ሲሆን ከ65 በመቶ ለማያንስ ህዝብ ዋና የምግብ ሰብል በመሆን ያገለግላል። የጤፍ የዘር ቀለም ተለያይነት ያለው ሲሆን በአብዛኛው ነጭና ቡናማ/ቀይ አንዳንዴም ድብልቅ እና መካከለኛ የዘር ቀለም በየዓመቱ ከሶስት ሚሊዮን ማሳ በላይ በመሸፈን ይመረታል። ይሁን እንጂ ከሌሎች ሰብሎች ጋር ሲወዳደር ምርትና ምርታማነቱ ዝቅተኛ ነው። ለዚህም ዋና ዋና ምክንያት በመሆን የሚጠቀሰው የተሻሻሉ ዝርያዎች በበቂ ሁኔታ አለመኖር ነው። የዚህ ጥናት ዋና ዓላማ እየጨመረ የመጣውን የቡናማ/ቀይ ጤፍ ፍላጎት ለማሟላት በተለያየ የምርምር አሰራርና ሂደት የተገኘ የጤፍ ዝርያን በመፈተሽ የተሻለ ምርት የሚሰጥና በአርሶ አደሩና በተጠቃሚው ተመራጭ የሆነ ዝርያ ማፍለቅ ነበር። በጥናቱም አስራ ሁለት የተለያዩ የጤፍ ዓይነቶችን ጨምሮ አንድ በቅርቡ የተለቀቀ እና አንድ የአካባቢ ዝርያን በማነተት በስድስት ወካይ ጤፍ አብቃይ ቦታዎች ላይ ተፈትሸው ፍላጎት (ደዘ-ክሮስ-442) የተባለው ቡናማ/ቀይ ዘር ቀለም ያለው ዝርያ ከሌሎች ማወዳደሪያ ዝርያዎች የተሻለ ውጤት በማስመዝገቡ በብሄራዊ የዝርያ አፅዳቂ ኮሚቴ ተገምግሞ ለምርት እንዲውል ተወስኗል። በተጨማሪም ይህ ዝርያ ቡናማ/ቀይ ዘር ቀለም ያለው ዝርያ ከተለቀቀ ከአስራ አምስት አመታት በኃላ የተገኘና የወደፊት የውጭ ገበያ ፍላጎትን ለሚሟላ ከፍተኛ አስተዋፅኦ ሊያበረክት የሚችል ነው።

Abstract

*Tef [***Eragrostis tef** *(Zucc.) Trotter] is the major cultivated cereal crop in Ethiopia and serves as staple food grain for over 65% of the population. The area under tef cultivation is over three million hectares of land each year. Depending on the type of seed color, tef grains are categorized into white and brown, while some admixtures and intermediate seed colors also exist. However, the productivity of tef is very low as compared to other cereals due, among others, to lack of high yielding varieties. The objective of this study was to evaluate the performance of released brown seeded tef variety called Felagot and to provide unique morphological and agronomic descriptions of this new variety. Twelve genotypes resulting from two independent crosses and breed for at least seven generations plus local and standard check varieties were tested over two years (2014 and 2015 main season) at six tef growing locations namely: Debre Zeit light soil, Debre Zeit Black soil, Minjar, Adet, Bichena and Holetta using randomized complete block design with four replications. The study found that*

Felagot (DZ-Cr-442/ RIL-77C) which was obtained from a cross between Quncho (the popular variety) and Gea Lammie (local cultivar) exceled the other genotypes and it was approved for release by the Ethiopian National Variety Release Committee in March 2017. The main advantages of Felagot over the other tested lines were its higher grain yield together with high straw yield and brown seed color. In addition, it was released under the brown seed category after one and half decades. Furthermore, it is anticipated that because of the brown seed color Felagot will command high external market preferences and prices, and thereby contribute for future tef export market.

Introduction

Tef (*Eragrostis tef (*Zucc.) Trotter is a longstanding cereal crop. In Ethiopia, it is the leading crop in terms of area coverage which accounts for almost 30% of the total area under cereals and second (20%) to maize in terms of volume of cereal production (CSA, 2018). Nowadays, it is produced in different parts of the globe owing to the intrinsic gluten-free nature and makes preferred meal for gluten allergy people. Apart from its health benefits, tef is also known to be tolerant to extreme climatic and soil conditions. However, the production and productivity is low with the national average yield of 1.75 t ha^{-1} (CSA, 2018), while the attainable yield potential is about 6 t ha^{-1} (Seyfu, 1993). The main problem accredited to different production constraints include lodging, drought, water logging, weeds, seed shattering, poor pre- and post- harvest agronomic management practices and low genetic potential of the local varieties. To tackle these problems, methodical research and development have been started since the late 1950's to improve the genetic potential and agronomic aspects of the crop. Since then, the tef improvement work formerly started at the then Jimma Agricultural and Technical High School and later moved to Debre Zeit Agricultural Research Center (DZARC) under the Ethiopian Institute of Agricultural Research (EIAR) has been taking the mandate to coordinate the national tef improvement program. This research program has been supported by different foreign funding organizations, and different research activities have been conducted. Amongst the achievements the tef breeding program contributed, 49 improved varieties have been released until 2019 by the different federal and regional agricultural research centers of the country, and out of these 26 varieties were from Debre Zeit Agricultural Research Center (DZARC) (MoANR, 2019). These improved varieties play decisive roles through shifting the yield plateau from below 1 t ha^{-1} at the beginning of the second millennium to 1.75 t ha^{-1} in 2018 (Solomon *et al*., 2019)

Formerly, based on the consumer preferences, the prime objective of national tef breeding program was merely focused on white-seeded tef. However, due to the current consumers' outlook and market price the brown-seeded tef varieties have been given re-emphasis in the program. Likewise, the urban residents are becoming very interested in the brown seed type due to its nutritional benefits

especially high iron content (Melak-Hail, 1966) and its natural color which is used to garnish other food staffs. In addition, it is also usually consumed in the rural areas by the farming community as they perform better under less favorable conditions of fields and cultural practices than do the white-seeded types (Kebebew *et al.*, 2002). In view of this fact, the national breeding program has been undertaking different activities under the brown seed category and released only five brown seed improved tef varieties from the total of 49 released varieties. Of these, "Felagot" is recently released brown seeded tef variety after Dima which was released before 15 years ago and Key Tena before 18 years ago by Adet Agricultural Research Center and DZARC, respectively.

Therefore, this paper presents the performance of the recently released tef variety called *Felagot* comparing with other candidate genotypes and standard check. In addition, the paper describes morphological and agronomic properties of the new variety.

Materials and Methods

Plant materials

The experimental plant materials consisted of a total of 14 tef genotypes including the standard brown-seeded late maturing widely adapted check variety (Asgori) released in 1970 (Solomon *et al.*, 2019), a local (farmers' variety) check from each respective testing location, and 12 lines originating from two independent crosses and selected on the basis of their performance in the earlier preliminary variety trials. Of the latter 12 selected genotypes, eight of them were out-sourced from the cross between the popular variety Quncho (DZ-Cr-387/RIL355) (Kebebew *et al*., 2011) and Gea Lammie which was a local cultivar identified and described by Tadesse (1975). Quncho was selected as a female parent for its high yielding ability and wide adaptability, while cv. Gea Lammie as a pollen parent was selected for its brown seed color and early growth habit. The name "Gea Lamie" in Oromiffa entails the early maturity of the cultivar within two months. The remaining four selected test genotypes originated from the cross between the Gommadie (female parent) and Gea Lammie (pollen parent). The cultivar Gommadie which was one of the 35 cultivars established and described by Tadesse (1975) was selected because of its semi-compact panicle form that is similar to the panicle of rice, and hence presumed to be one of the panicle form ideotypes in terms of lodging resistance. The two simple crosses between the four parental lines indicated above were made in 2010. The purpose of the hybridization task was to develop stable, high yielding, brown seeded, and farmers- and consumer-preferred tef varieties for the high rainfall and optimum moisture (high potential) and terminal drought-prone areas. After a successful crossing, 400 F_2 populations were generated and substantially advanced till F7

using the single seed descent method. Eventually, the populations were reduced to few lines with best performance after seven generation of successive selection targeting on seed color, standing ability and grain yield. Hybridization and early generation testing i.e. observation nursery and preliminary variety trial were done at DZARC from where the national tef breeding program is coordinated. Subsequently, the national variety trial was done across locations and over two years.

Description of experimental sites and season

The field experiment was carried out at six locations namely Debre Zeit light soil, Debre Zeit black soil, Minjar, Adet, Bichena and Holetta during the 2014 and 2015 main cropping season. Geographical position, climatic and soil-type data of the six locations have been summarized and presented on Table 1.

Table 1. Geographical coordinates, weather data and soil type of the test locations

Parameter	Trail sites					
	Debre Zeit light soil	Debre Zeit Black soil	Minjar	Adet	Bichena	Holetta
Latitude (N)	8°45'	8°45'	8°45'	11°16'32"	10°26' 60"	9°06'33"
Longitude (E)	38°59'	38°59'	39°45'	37°29'30"	38°12'	38°49'02"
Altitude (m.a.s.l)	1860	1860	1781	2240	2556	2390
Rain fall (mm)	832	832	963	658.6	967	1144
Soil type	Vertisols	Andosol	Vertisols	Vertisols	Vertisols	Vertisols
Max. mean daily temperature (°C)	26.1	26.1	29	26.7	18.1°C	22
Min. mean daily temperature (°C)	8	8	10	11.2	14.7°C	6
Climate	Temperate	Temperate	Humid	Moist-cool	Cool-wet	Cool-wet

Experimental design and management

The field experiment was conducted using RCBD with four replications. Each plot (2 m x 2 m) consisted of ten rows of 2 m length with an inter-row spacing of 0.2 m. The distances were 1 m between plots and 1.5 m between blocks. As per the research recommendations of 15 kg/ha (1.5 g/plot) of seeds were hand broadcasted along the surface of each row. Fertilizers used were 40 kg N and 60 kg P_2O_5 per hectare for light soils and 60 kg N and 60 kg P_2O_5 per hectare for black soil. DAP was applied all at planting, while urea was applied in two splits half two weeks after sowing and the remaining half top dressed at tillering stage. Hand weeding was made three times during the crop growth stage. All other pre-and post-stand establishment agronomic practices were made as per the recommendations of the respective test locations.

Data collection

Qualitative date were taken on basal stalk color, panicle form, pigmentation of lemmas and anthers, and caryopsis color. In addition, data on plot basis were taken on phenology (days to heading and to maturity, and grain filling period as the number of days lapsed from heading till physiological maturity), lodging index

using the method of Caldicott and Nuttall (1979), grain yield, above ground biomass yield and harvest index. Furthermore, data on individual plant traits including plant height, culm length and panicle length were taken on five random samples of plants from the central parts of the middle rows of each plot.

Data analyses

For individual plant traits, averages of the data of the five random samples of plants per plot were used for data analyses. Agronomic and yield data were subjected to analyses of variance of data from individual environments and combined over five locations and two years with the general linear model (PROC GLM) procedure using SAS statistical package (SAS version 9.00, SAS Institute, 2002). F-max test of homogeneity of error variances was performed prior to making the combined analysis of variance over environments (years and locations). Mean performance were carried out in order to identify the best performing genotypes from the evaluated genotype and mean comparison for significant differences were made using Least Significant Difference (LSD). GEA-R version 2.0 used for the stability analysis.

Results and Discussion

Performance variations

Prior to executing analysis of variance, tests were made to confirm the homogeneity of error variances, except Bichena all of the test location over two years for the studied traits showed positive result. Consequently, the data of five locations (Debre Zeit light soil, Debre Zeit black soil, Minjar, Adet and Holetta) were pooled across locations and years and analyzed. Accordingly, the results of the combined analysis of variance across the five locations and years (ten environments) were presented on Table 2, grain yield was highly significantly ($P<0.001$) affected by year x location, location, location x genotype, genotypes, years and years x genotype which accounted for about 23.56%, 20.24% and 9.75 %, 3.86%, 2.94% and 2.54% of the total variance, respectively. The significant genotype x location interaction (GEI) effects demonstrated that genotypes responded differently to the variation in environmental conditions of locations. This is indicative of the necessity of testing tef genotypes at multiple locations. The large sum of squares for genotypes indicated that the genotypes were diverse, with large differences among genotypic means causing most of the variation in grain yield.

The mean agronomic performance of tef genotypes is presented in Table 3. The mean grain yield ranged from 2166 to 2542 $kgha^{-1}$ and Quncho X Gea Lammie RIL77C revealed the highest grain yield.

Table 2: Sums of squares, mean squares and proportion of variance explained by the different sources of variation in the combined analyses of variance of grain yield data of 14 tef genotypes tested at five locations during 2014 and 2015 (ten environments).

Source of variation	Degrees of freedom	Sum of squares	Mean squares	Proportion of total variance explained %)
Years	1	4826992.99	4826992.99**	2.94
Rep/year	3	206895.15	68965.05^{ns}	0.13
Locations	4	33243631.65	8310907.91**	20.24
Genotypes	13	6339691.40	487668.57**	3.86
Years x Locations	4	38696376.55	9674094.14**	23.56
Years x Genotypes	13	4166712.05	320516.31**	2.54
Locations x Genotypes	52	16017059.24	308020.37**	9.75
Years x Locations x Genotypes	52	7963731.27	153148.68^{ns}	4.85
Error	417	52777311.1	126564.3	32.13
Total	559	164238401.4		

*, **, Significant at $p \leq 0.05$ and $p \leq 0.01$ probability level respectively and ^{ns} non-significant.

Table 3. Mean agronomic performance of tef genotypes in the National variety Trial across five locations and two years (ten environments).

Genotypes	Days to heading (days)	Days to maturity (days)	Grain filling period (days)	Plant height (cm)	Panicle length (cm)	Lodging index	Biomass yield (kg/ha)	Grain yield (kg/ha)
Local check	45	97	52	94	35	88	10050	2329
DZ-01-99 (Asgori) Standard Check	47	96	49	95	40	87	11156	2448
Quncho X Gea Lammie RIL96	48	97	49	95	36	83	10781	2379
Quncho X Gea Lammie RIL185	47	96	50	95	36	82	11444	2512
Quncho X Gea Lammie RIL77C	**45**	**95**	**50**	**93**	**34**	**82**	**11294**	**2542**
Quncho X Gea Lammie RIL124A	48	95	47	95	36	88	10650	2206
Quncho X Gea Lammie RIL222B	47	96	49	98	36	83	10669	2319
Quncho X Gea Lammie RIL239	47	96	49	95	36	81	11250	2386
Quncho X Gea Lammie RIL129	49	95	46	99	38	85	11144	2394
Gommadie X Gea Lammie RIL94	47	96	49	99	35	80	10356	2307
Gommadie X Gea Lammie RIL96	47	97	50	96	28	74	10513	2166
Gommadie X Gea Lammie RIL100	45	98	54	93	29	79	10563	2214
Gommadie X Gea Lammie RIL102	47	95	48	87	30	84	10594	2404
Quncho X Gea Lammie RIL25B	46	97	51	97	36	83	11206	2406
Mean	46.6	96.0	49.4	95.0	34.6	82.6	10833.5	2358.0
R^2	0.98	0.98	0.96	0.83	0.75	0.78	0.76	0.67
CV (%)	2.65	2.38	5.12	6.34	11.03	8.78	15.7	15.08
LSD (0.05)	0.54	1.00	1.11	2.64	2.67	3.17	747.87	156.37
SEM (±)	0.38	0.73	0.51	0.54	0.28	0.58	128.79	22.91

Stability of the Variety "Felagot" and the tef genotypes tested in the NVT

Stability usually refers to a genotype's ability to perform consistently, whether at high or low yield levels, across a wide range of environments. The differences in yield were strongly influenced by genetic and environmental factors, it is necessary to choose superior lines with stable results. Tef yield were liable to a significant fluctuation with changes in the growing environments. Hence, the variety "*Felagot*" is the only line which showed both adaptive and stable character among the tested genotypes (Figure 1).

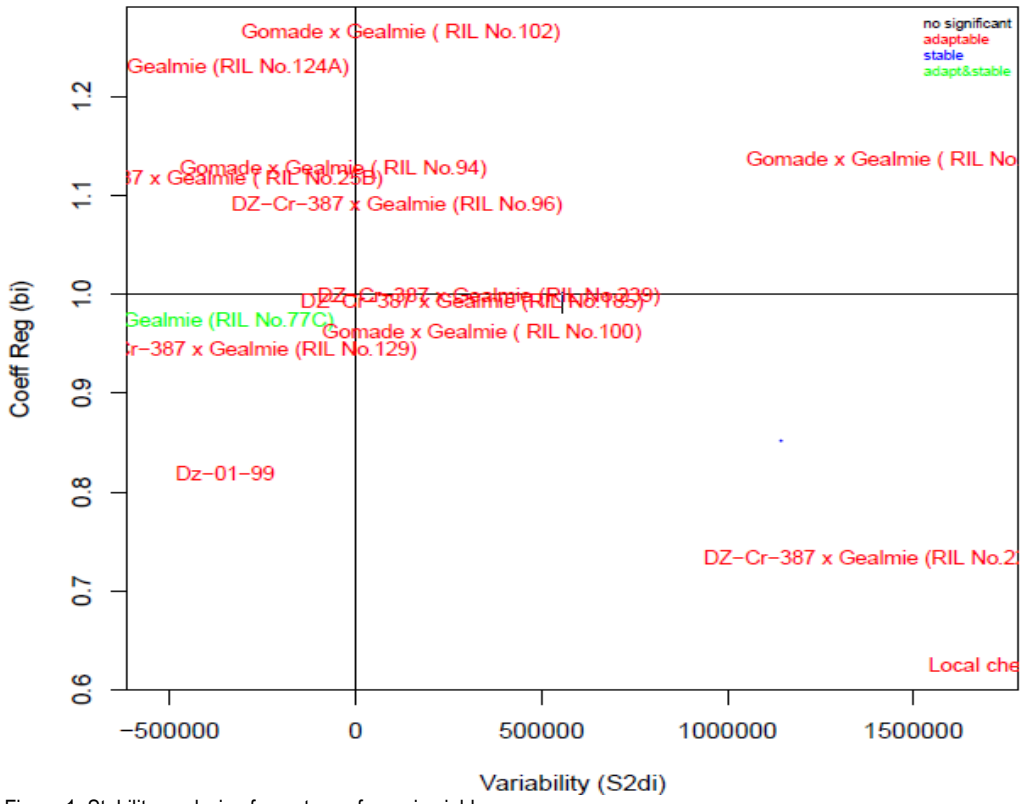

Figure 1: Stability analysis of genotypes for grain yield.

Meritorious features of the tef variety *"Felagot"*

Based on pooled analysis of the two-year multi-location trial, RIL77C was selected for its brown seed, high grain and biomass yield as well as additional traits. Hence, RIL 77C was given the name '*Felagot'* and applied for registration as a new improved tef variety. The word *'Felagot'* is an Amharic term meaning *'want/desire'* due to the high global market preference of the brown seed tef. Based on the application, the National Variety Release Committee in Ethiopia investigated the two-year performance of RIL 77C and visited several locations where the new variety was grown for evaluation. Consequently, the committee approved the release of RIL 77C as a new variety with the name '*Felagot*'.

Overall, *Felagot* tef variety showed grain yield advantage of 3.8% and 9.1% over the standard check and local check, respectively. It had also above average shoot biomass yield (Table 3). Moreover, *Felagot* variety has got an immense farmer's attention for its high yielding potential, brown seed color and good straw yield (straw yield is equally important as grain in tef) during participatory variety selection trials. Besides, it will play a significant role for future tef export market because of its brown seed color.

Description of the variety "Felagot"

The new tef variety named *Felagot* (DZ-Cr-442 / RIL-77C) is the product of a cross between a popular variety called Quncho and a local cultivar called Gea Lammie. *Felagot* variety showed distinct characters such as brown seed color, thousand kernel weights (0.29g), variegated (yellow and red) lemma color, purple anther color and medium size plant with loose panicle type. On the average, *Felagot* reaches the heading stage in 45 days and physiological maturity in 95 days after sowing. From the average plant height of 93 cm, the panicle of *Felagot* contributes to 36.5%. The combined mean performance analysis showed highly significant variations in shoot biomass and total grain yield among the tested tef genotypes. Likewise, the grain yield of *Felagot was* 2.5 t ha^{-1} at the research field (Table 4). Furthermore, utilization aspects of this variety are similar to most of the white seeded varieties already released so far. It is released for the optimum moisture and high rain fall areas or high potential tef producing areas. It performs well in areas having an altitude of 1700-2400 m.a.s.l and annual rainfall of 700-1200mm. It is also the only line which showed both adaptive and stable character among the tested genotypes (Figure 1). Breeder and foundation seeds of the variety are maintained by DZARC

Table 4. Distinguishing pheno-morphic and agronomic description of the tef variety "*Felagot*"

No.	Characteristics	Description		
I	**Qualitative traits**			
1	Basal stalk color	Purple		
2	Panicle form	Loose		
3	Lemma color	Variegated (Grey+Purple)		
4	Anther color	Purple		
5	Seed color	Brown		
II	**Quantitative traits**	**Minimum**	**Maximum**	**Mean ± SE**
1	Days to panicle emergence (days)	33	60	45±1.27
2	Days to maturity (days)	77	126	95±2.56
3	Grain filling period (days)	30	69	50±1.82
4	Plant height (cm)	70	119	93±1.88
5	Culm length (cm)	40	73	59±1.36
6	Panicle length (cm)	25	49	34±0.82
7	Biomass yield (t/ha)	7.000	18.750	11.294±453.90
8	Grain yield (t/ha)	1.8	3.6	2.5±75.62
9	Lodging index	54	99	82±1.96
10	Harvest index (%)	14	34	23±0.78

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