Middle East Research Journal of Agriculture and Food Science
ISSN: **2789-7729 (Print & Open Access)**
Frequency: Bi-Monthly
DOI: 10.36348/merjafs.2021.v01i01.004

KUWAIT SCHOLARS PUBLISHER

Website: http://www.kspublisher.com/
Email: office.kspublisher@gmail.com

Evaluation and Participatory Selection of Newly Released Variety for Tef Growing Areas of Benishangul Gumuz Region

Tesfaye Mitiku[1*], Misgana Marga[2], Desta Bekele[3]

[1]Ethiopian Institute of Agricultural Research Holeta Agricultural Research Center
[2]Ethiopian Institute of Agricultural Research Ambo Plant Protection Research Center
[3]Ethiopian Institute of Agricultural Research Assosa Agricultural Research Center

ABSTRACT: Tef Eragrostis tef (Zucc.) r) is a panicle bearing C4 self-pollinated cereal that originated and diversified in Ethiopia. Urbanization displaces the major tef production belts of the country resulting a serious threat to this an income-generating preferred endemic grain and emerging global commodity. Tef should now expand its horizons to all suited agro-ecologies and poise the country to take advantage of the emerging global opportunities. So, the aim of the study was to evaluate the best performing improved tef variety/es and advances the outstanding and tef variety/ies via participatory variety selection to large scale demonstration by incorporating farmers' selection criteria. To strengthen the partnership of tef growers in order to enhance adoption levels and reduce limited technology outreaching. The trial was composed of 12 newly released tef variety including one standard check and one local check. As results of combined analysis of the two year data indicated that there was high ($p \leq 0.01$) significant difference among most of the varieties at variable traits. Accordingly; 50% heading, 95% maturity, Plant height, panicle length, grain yields exhibit significant difference indicates the presence of large genetic variation among the genotypes and further improvement through simple selection is possible; whereas lodging index and shoot biomass were non-significant indicating no genetic variability between genotypes in these two traits which insures further improvement of the varieties with this traits is limited success. Thus; DZ-Cr-429 (Neguse) 1335.9 (kg/ha), Areka-1 1257.1 (kg/ha), and Quncho 1071.3 (kg/ha) revealed the highest grain yield. Farmers' visual selection of the varieties based on grain yield, white seed color, panicle length, low loading index, and high shoot biomass and plant height was practiced. Thus; farmers' selected DZ-Cr-429 (Neguse) 65 total scores, Quncho 52 total scores and Areka-1 39 scores respectively with rank of one to third as overall preference of the farmers. The three varieties DZ-Cr-429 (Neguse), Quncho and Areka-1 were recommended in that DZ-Cr-429 (Neguse), and Areka-1 on the yield advantage of the varieties and Quncho for the honor of farmer's preference by common discation and similar consensus based on the results of field experiment and farmers preference.

Keywords: Tef, participatory, improved variety and preference.

RESEARCH PAPER

***Corresponding Author:**
Tesfaye Mitiku
Ethiopian Institute of Agricultural Research Holeta Agricultural Research Center

How to cite this paper:
Tesfaye Mitiku *et al;* "Evaluation and Participatory Selection of Newly Released Variety for Tef Growing Areas of Benishangul Gumuz Region". Middle East Res J. Agri Food Sci., 2021 Nov-Dec 1(1): 25-31.

Article History:
| Submit: 25.10.2021 |
| Accepted: 27.11.2021 |
| Published: 28.12.2021 |

INTRODUCTION

Tef, *Eragrostis tef* (Zucc.) r) is an annual grass species and a member of the grass family Poaceae and genus Eragrostis (Costanza S. H. *et al.*, 1979). It is a panicle bearing C4 self-pollinated cereal that originated and diversified in Ethiopia (Kebede, *et al*., 1989). Ecologically, tef is a resilient crop adapted to diverse agro-ecologies with relatively tolerant to both low (especially terminal drought) and high (waterlogging) moisture stresses (Seyfu K., 1997). Tef therefore, is considered as a low-risk crop to farmers. For better performance, it requires an altitude of 1800-2100 masl, annual rainfall of 750-850 mm and a temperature range of 10-27^{o} C (Adera, 2016). It has been considered as food insurance in highlands and mid-altitude areas for Ethiopian farming families since its domestication, during the stress and credited as food security crop.

Tef is produced for different purposes including food and feed, cash and foreign currency earnings. Tef has been a supper-staple food for over 50 million people of Ethiopia and preferred endemic grain crop that is the known favorite national food relaxed in most Ethiopian main dishes. The food culture of tef in Ethiopia is both historical and part of Ethiopian antiquity and a significant part of the country's national identity. Tef straw *(chid)*, besides being the most appreciated feed for cattle, it is also used to reinforce mud and plaster the walls of house and local grain storage facility called gotera (Adera, 2016).

In Ethiopia, tef is the leading crop accounting for 29.71% of the total acreage and 20.12% of the gross grain production of all cereals grown in the country (CSA, 2015). Tef is grown over three million hectares of land in Ethiopia and the average production is estimated to 1.75 tons per hectare (CSA, 2018). In Benishangul Gumuz region it covers about 0.025 million hectares of land and 0.329 million tons of grain was produced during 2017/18 cropping season. Even if; the region is considered as non-traditional tef growing region; Matakel, Assosa and Mao Komo areas are major tef producing zones. Thus, the growing of tef and its food preference is becoming increased across the region as well as the use of tef as a cereal for humans is exceeding the boundaries of Ethiopia due to its being gluten-free health crop which gained popularity worldwide as an alternative grain for persons with gluten sensitivity and for patients of celiac disease (Saturni *et al*., 2010). It is considered as the "latest super food of the 21st century" such that its national and international popularity is rapidly growing (Collyns, 2013).

So, the breeding strategy of the country should focus on promoting the non-traditional growing areas and expanding tef production and productivity to substitute the tef belt that pushed from the dominant production area of the central part of the country.

Though; Oromia and Amhara regions produce about 85% of the national tef production volume and 84% of area cultivated during 2010/2011 cropping season; they cannot satisfy an overwhelming demand of tef in the country and out of the country. Additionally legal and illegal urbanization activities displace the major tef production belts of the central part of the country resulting a serious threat to this income-generating global commodity for Ethiopian producers and international preferred consumers. The Ethiopian governments, who have accorded attention to two regions for tef production that purely, satisfy domestic and foreign food insecurity reasons should diversify across the regions. Tef must now expand its horizons to all suited agro-ecologies and poise the country to take advantage of the emerging global opportunities. So far, some improved varieties of tef, such as *Quncho, Tseday* (Dz- Cr-37), *Boset* and *Simada* have been evaluated by AsARC based on the key traits inexpence of farmers' participation that may lag adoption intensity by stockholders.

Participatory variety selection is the research process by which farmers are routinely involved in selecting varieties that they prefer the most appropriate traits for their own uses among stable varieties that are being field tested. In participatory variety selection, farmers have involved in selecting the varieties based on their indigenous knowledge by setting a key criteria for their decision-making. Farmers' involvement in participatory variety selection can take many advantages, which includes defining breeding goals and priorities, selecting the best varieties, hosting trials on their land, selecting varieties for further crossing; discussing results with the scientists, planning for the following year's activities, suggesting methodological changes, and multiplying the seed of the selected varieties(Witcombe, 2005).

Participatory variety selection involves a mix of actors including scientists, breeders, farmers and other stakeholders in plant breeding stages (Probst, 2016). In conventional plant breeding (CPB) new varieties are released before knowing by the farmers and whether they like the varieties or not is non-sense and the process is typically supply-driven. However, participatory variety selection is turned upside down because the process is driven by the initial adoption by farmers at the end of a full cycle of selection and is therefore demand-driven (Nelson *et al*., 2015).

So, participatory research is now seen by many as a way to address the problems of most agricultural research programs, as participatory variety selection is expected to produce varieties that are targeted, relevant and appropriate (Bellon, 2006). Participatory variety selection is enhancing adoption of suitable improved varieties in order to address the needs of a broader range of users and to enhance farmer skills in variety selection and seed production efforts (Bhargava *et al*., 2014).

Therefore, the objectives of the study was to evaluate the best performing improved tef variety/es and advance the outstand and adapted tef variety/ies to large scale demonstration by identifying farmers' selection criteria. To strengthen the partnership and networking tef growers in order to generate information for future breeding program and reduce limited technology outreaching. To transfer tef from non-traditional to traditional growing environment by expanding its horizons to all suited agro-ecologies in the region.

METHODOLOGY

Description of the experimental area

The trial was conducted in Benishangul Gumuz Regional state north western Ethiopia, by Assosa Agricultural Research Center during 2019 and 2020 cropping seasons. The center is located at latitude of 100 02' N, longitude of 340 34' E and an altitude about 1553 m above sea level and about 662km from the Capital city of Ethiopia. The area receives a mean annual rainfall of 1275 mm. The rainy season extends from April to October and maximum rain is received in the months of June to August. It has a warm humid climate with mean maximum and minimum temperatures 32.00C and 17.00C, respectively.

Plant materials, experimental design and trial management

The trial was composed of 12 newly released tef variety including one standard check and one local check. The experiment was arranged in a completely randomized block design with three replications. The plot size was 2m x 2m ($4m^2$) and distance between blocks and plots are 1.5m and 1m respectively. Fertilizer rates 100 $kgha^{-1}$ DAP/NPS/ was applied at the time of planting whereas 120 $kgha^{-1}$ Urea was applied in the form of split application, half of which was applied together with DAP at sowing time and the remaining was top dressed at tillering stage. Hand weeding was also practiced due to it was important agronomic practice in tef especially at seedling stage due to it cannot compete with weeds.

DATA COLLECTION

Plant based data collection

Data were collected on plant and plot basis for different agronomic traits (IBPGR/ICRISAT, 1993). Important data such as, days to 50% heading, days to 95% maturity, plant height, panicle length, lodging index, Shoot Biomass, Seed color and grain yield and stand % were collected.

Plant height (cm)

The height of the plant from the bottom to the tip of the panicle at maturity on 5 randomly tagged plants.

Panicle length (cm)

The length of individual panicle measured from panicle base to tip of the panicle using randomly selected representative plant.

Plot based data collection

Days to flowering (DTF):- Number of days from sowing till 50% of the plants in a plot showed flowering halfway down the panicle

Days to maturity (DTM):- The number of days from sowing to the date when 95% of the plants matured physiologically.

Grain yield (GY): Grain yield obtained from total harvest of the plot and then converted to ton/ha.

Qualitative data collected

Seed color: 1 = White, 2 = Light white, 3 = Red, 4 = Gray.

STATISTICAL DATA ANALYSIS

The data were analyzed using proc ANOVA in SAS software version 9.4 (SAS, 2015) and means were separated using LSD (Least Significant Difference) at the 5 % level of significance. Farmers' preference data were analyzed using pair wise matrix preference ranking method. Pair wise comparison matrix is a good way of weighing up the relative importance of different courses of action. It is a tool that provides a framework for comparing each course of action against all others and helps to show the difference in importance between factors.

Participatory Varietal Selection Procedures

Farmers set and prioritized criteria for the participatory selection. The criteria for selection included plant height, panicle length, lodging index, Shoot Biomass, Seed color and grain yield. The genotypes were evaluated using farmers' selection criteria. A total of twenty four farmers of both sexes (male=17, female=7) participated in the study. Farmers were allowed to set their own selection criteria and then both male and female participants prioritized and jointly agreed on preferred characters. All of them were tabulated in a matrix scoring table and each selection criterion was compared with another in a pair wise fashion. The rank assignments were determined from the number of times each selection criterion was preferred by the group. A direct matrix table was prepared for the tef varieties. Scores were given to each variety based on the selection criteria (5 = very good, 4 = good, 3 = average, 2 = poor, and 1 = very poor). During direct matrix ranking farmers have given rating of importance (a relative weight) of a selection criterion ranked from 1 to 3 (3 = very important, 2 = important and 1 = less important) and rating of performance of a variety for each traits of interest (selection criteria) was given based on their level of importance on the basis of common agreement of evaluators'. The score of each variety was multiplied by the relative weight of a given character to get the final result and then added with the results of other characters to determine the total score of a given variety. Scoring and ranking were done on consensus, and differences were resolved by discussion as indicated by de Boef and Thijssen (2006).

Pair-wise matrix ranking and direct matrix ranking were used to identify the prioritization order of the farmers' selection criteria (Table 1, 2 and 3). Several farmers were participated and selected different improved tef varieties based on their preference characteristics and agronomic performance. Accordingly, the preferred improved tef variety should have high grain yield, white seed color, panicle length, low loading index, and high shoot biomass and plant height. Farmers gave the highest weight to grain yield followed by seed color, panicle length, high shoot biomass and low lodging index.

RESULT AND DISCATION

The result of combined analysis of the two year data indicated that there was high ($p \leq 0.01$) significant difference observed among most of evaluated varieties for most traits. Thus, 50% heading, 95% maturity, Plant height, panicle length, grain yields exhibit significant difference. However; lodging index

and shoot biomass were non-significant indicating no genetic variability between genotypes in these two traits which insures further improvement of the varieties with this trait is limited success. The former phrase indicates the presence of large genetic variation among the genotypes and further improvement through simple selection was possible Similar results were reported by Abiy and Firew (2016); Kinde *et al*. (2016) on sorghum. Accordingly; DZ-Cr-429 (Neguse) 1335.9 (kg/ha), Areka-1 1257.1 (kg/ha), and Quncho 1071.3 (kg/ha) revealed the highest grain yield. The yield performance of local check was 725.5kg/ha. The yield performances of most of the varieties were relatively better when compared to local check and about 10 varieties were identified as the superior germplasm over a local check. In other words, farmers' visual selection of the varieties based on grain yield, white seed color, panicle length, low loading index, and high shoot biomass and plant height was practiced. Thus; Based on these traits farmers' selected DZ-Cr-429 (Neguse) 65 total scores, Quncho 52 total scores and Areka-1 39 scores respectively with rank of one to third as the best varieties depend on the cumulative of overall preference of the farmers selected criteria's such as, yield, marketable seed color, shoot biomass and panicle length. However, according to the breeder data based selection DZ-Cr-429 (Neguse) and Areka-1 were the two top score in grain yield following each other, whereas Quncho was ranked first in farmers preference with the yield penalty of 185.8 kg/ha. Quncho was very attractive to farmers due to its appealing grain color and size. As Joshi *et al*., (1996) reported in addition to grain yield farmers also consider other parameters like growing period, plant height, thresh ability, milling recovery, taste and other characters of cooked rice.

Generally, it was concluded that increasing these amounts of grain yield through improvement is challenging and it takes long time in tef. Therefore; the three varieties DZ-Cr-429 (Neguse), Quncho and Areka-1 were recommended in that DZ-Cr-429 (Neguse), and Areka-1 on the yield advantage of the varieties and Quncho for the honor of farmers preference by common discation and reaching on similar consensus based on the results of field experiment and farmers' morphological evaluation and negotiate common understand and agreement due to grain yield is the primary trait of interest as crop breeding is concerned.

Table-1: Pair-wise ranking of farmers selection criteria of tef PVS at Assosa condition in 2020.

4. o.	**4. ntry**	**4. PH**	**4. PL**	**4. LI**	**4. SBM**	**4. SC**	**4. GY**	**4. T. Score**	**4. Rank**		
4.	4.								4. Farmers	4. Researchers	4. Mean
4.	4. elative weight	4. 1	4. 2	4. 2	4. 2	4. 3	4. 3	4.			
4.	4. DZ-Cr-438(RIL No. 41) (Dagiem)	4.	4.	4.	4.	4.	4.	4.	4.	4. .9522 t/ha[5]	4.
4.	4. DZ-Cr-429 (Neguse)	4.	4. 0	4. 0	4. 0	4. 5	4. 5	4. 5	**4.**	4. .3359 t/ha[1]	**4.**
4.	4. DZ-Cr-457 (Tesfa)	4.	4.	4.	4.	4.	4.	4.	4.	4. .7689 t/ha[10]	4. 1
4.	4. DZ-Cr-442 (Felagot)	4.	4.	4.	4.	4.	4.	4.	4. 2	4. .7731 t/ha[9]	4. 0
4.	4. DZ-Cr-419 (Hiberande)	4.	4.	4.	4.	4.	4.	4.	4.	4. .0378 t/ha[4]	4.
4.	4. DZ-Cr-438(RIL 7)	4.	4.	4.	4.	4.	4.	4. 3	**4.**	4. .6539 t/ha[12]	**4.**

	(Abola)										
4.	4. Areka-1	4.	4.	4.	4.	4.	4.	4.9	**4.**	4.2571 t/ha[2]	**4.**
4.	4. DZ-Cr-458(RIL-18) (Ebba)	4.	4.	4.	4.	4.	4.	4.	4.	4.8717 t/ha[8]	4.
4.	4. DZ-Cr-453(RIL - 120B) (…...)	4.	4.	4.	4.	4.	4.	4.	4.0	4.9467 t/ha[6]	4.
4.0	4. Quncho	4.	4.	4.	4.	4.2	4.2	4.2	**4.**	4.0713 t/ha[3]	4.
4.1	4. New released variety 2019 from Bako	4.	4.	4.	4.	4.	4.	4.6	**4.**	4.9139 t/ha[7]	**4.**
4.2	4. Local	4.	4.	4.	4.	4.	4.	4.	4.1	4.7255 t/ha[11]	4.2

NB. PH Plant height, PL panicle length, LI lodging index, SBM shoot biomass, SC seed color, GY grain yield

Table-2: Direct matrix ranking of PVS of tef varieties by a group of farmers' at Assosa condition in 2020

4. arieties	**4. agiem**	**4. eguse**	**4. esfa**	**4. elagot**	**4. iberande**	**4. bola**	**4. reka-1**	**4. bba**	**4. Z-Cr-453**	**4. uncho**	**4. ako**	**4. eguse**	**4. esfa**
4. agiem	4.	4.	4.	4.	4.	4.	4.	4.	4.	4.	4.	4.	4.
4. eguse	4. eguse	4.	4.	4.	4.	4.	4.	4.	4.	4.	4.	4.0	4.
4. esfa	4. agiem	4. eguse	4.	4.	4.	4.	4.	4.	4.	4.	4.	4.	4.0
4. elagot	4. agiem	4. eguse	4.	4.	4.	4.	4.	4.	4.	4.	4.	4.	4.0
4. iberande	4. iberand	4. eguse	4. iberand	4. iberand	4.	4.	4.	4.	4.	4.	4.	4.	4.

4. bola	4. bola	4. [illegible]	4. bola	4. bola	4. bola	4.	4.	4.	4.	4.	4.	4.	4.
4. reka-1	4. reka-1	4. [illegible]	4. reka-1	4. reka-1	4. reka-1	4. reka-1	4.	4.	4.	4.	4.	4.	4.
4. bba	4. agiem	4. [illegible]	4. bba	4. bba	4. iberande	4. bola	4. reka-1	4.	4.	4.	4.	4.	4.
4. Z-Cr-453	4. Z-Cr-453	4. [illegible]	4. Z-Cr-453	4. Z-Cr-453	4. iberande	4. bola	4. reka-1	4. Z-Cr-453	4.	4.	4.	4.	4.
4. uncho	4. uncho	4. [illegible]	4. uncho	4. uncho	4. uncho	4. uncho	4. uncho	4. uncho	4. uncho	4.	4.	4.	4.
4. ako	4. ako	4. [illegible]	4. ako	4. ako	4. ako	4. ako	4. reka-1	4. ako	4. ako	4. uncho	4.	4.	4.

Table-3: Farmers' pair-wise ranking of tef varieties at non- traditional growing areas of BGRS in 2019 and 2020

No.	Selection criteria	PH	PL	LI	SBM	SC	GY	T. Score	rank
1	PH	*	PL	LI	SBM	SC	GY	1	6
2	PL		*	PL	SBM	SC	GY	2	3
3	LI			*	LI	SC	GY	2	3
4	SBM				*	SC	GY	2	3
5	SC					*	GY	4	2
6	GY						*	5	1

Table-4: Mean performance evaluation of agronomic characters of Participatory variety selection and adaptation of newly released tef variety at Assosa condition

4. No.	4. Entry	4. DH	4. DM	4. GFP	4. PH	4. PL	4. LI	4. SBM t/ha	4. GY kg/ha
4. 1	4. DZ-Cr-438(RIL No. 41) (Dagiem)	4. 37.67	4. 78.50	4. 40.83	4. 95.93	4. 35.40	4. 58.00	4. 5.88	4. 952.2
4. 2	4. DZ-Cr-429 (Neguse)	4. 34.17	4. 76.33	4. 42.17	4. 94.67	4. 37.00	4. 57.00	4. 5.58	4. 1335.9
4. 3	4. DZ-Cr-457 (Tesfa)	4. 36.17	4. 77.33	4. 41.17	4. 96.20	4. 35.57	4. 59.33	4. 5.42	4. 768.9
4. 4	4. DZ-Cr-442 (Felagot)	4. 33.50	4. 72.83	4. 39.33	4. 88.17	4. 33.00	4. 69.00	4. 5.29	4. 773.1
4. 5	4. DZ-Cr-419 (Hiberande)	4. 39.50	4. 83.50	4. 44.00	4. 106.05	4. 43.77	4. 53.00	4. 6.08	4. 1037.8
4. 6	4. DZ-Cr-438(RIL 7) (Abola)	4. 39.17	4. 77.00	4. 37.83	4. 106.34	4. 45.17	4. 55.33	4. 5.71	4. 653.9
4. 7	4. Areka-1	4. 31.17	4. 78.83	4. 47.67	4. 90.23	4. 34.73	4. 53.33	4. 5.79	4. 1257.1
4. 8	4. DZ-Cr-458(RIL-18) (Ebba)	4. 34.50	4. 78.67	4. 44.17	4. 95.42	4. 39.03	4. 55.67	4. 5.67	4. 871.7
4. 9	4. DZ-Cr-453(RIL - 120B) (……)	4. 35.67	4. 78.50	4. 42.83	4. 110.83	4. 46.65	4. 62.00	4. 5.96	4. 946.7
4. 10	4. Quncho	4. 40.17	4. 82.67	4. 42.50	4. 102.97	4. 41.90	4. 55.67	4. 6.00	4. 1071.3
4. 11	4. New released variety 2019 from	4. 39.33	4. 82.83	4. 43.50	4. 119.47	4. 48.00	4. 62.67	4. 6.83	4. 913.9

4. No.	4. Entry	4. DH	4. DM	4. GFP	4. PH	4. PL	4. LI	4. SBM t/ha	4. GY kg/ha
	Bako								
4. 12	4. Local	4. 37.83	4. 80.00	4. 42.17	4. 96.80	4. 36.78	4. 66.00	4. 5.25	4. 725.5
4.	4. Mean	4. 36.57	4. 78.92	4. 42.35	4. 100.26	4. 39.75	4. 58.92	4. 5.79	4. 942.33
4.	4. Cv	4. 4.46	4. 5.96	4. 11.35	4. 7.64	4. 10.199	4. 15.63	4. 16.39	4. 23.30
4.	4. Lsd	4. 1.88	4. 5.43	4. 5.56	4. 8.85	4. 4.69	4. 10.65	4. 1.09	4. 253.87
4.	**4. P-value**	**4. ****	**4. ****	**4. ns**	**4. ****	**4. ****	**4. ns**	**4. ns**	**4. ****

REFERENCES

- Abraham, R. (2015). Achieving Food Security in Ethiopia by Promoting Productivity of Future World Food Tef: A Review. *Adv Plants Agric Res, 2*; 00045.
- Seyfu, K. (1997). Tef, Eragrostis tef (Zucc.) Trotter: Promoting the conservation and use of underutilized and neglected crops. International Plant Genetic Resources Institute, Rome, Italy.
- CSA. (2018). Agricultural Sample Survey Statistical Bulletin I. Report on area and production of major crops. Addis Ababa, Ethiopia: Central Statistical Agency, 53.
- CSA. (2015). Agricultural Sample Survey Statistical Bulletin I. Report on area and production of major crops. Addis Ababa, Ethiopia: Central Statistical Agency, 53.
- Costanza, S. H., Dewet, J.M., & Harlan, J.R. (1979). Literature review and numerical taxonomy of Eragrostis tef (T'ef) . *Economic botany, 33*; 413-424.
- Kebede, H., Johnson, R., & Ferries, D. (1989). Photosynthetic response of Eragrostis tef to temperature, Physiology Plant, 77, 262-266
- Adera, S. (2016). Response of Tef (Eragrostis tef) to Different Blended Fertilizer Rates on Vertisols in Jama District, Northeastern Ethiopia. M. Sc Thesis Summited Haramaya University, Haramaya.
- Collyns, D. (2013). Quinoa brings riches to the Andes. Retrieved from http://www.theguardian.com/world/2013/jan/14/quinoa-andes-bolivia-peru-crop
- Saturni, L., Ferretti, G., & Bacchetti, T. (2010). The gluten-free diet: safety and nutritional quality. Nutri, 2; 16-34.
- SAS. (2015). SAS Institute Inc. SAS/STAT 9.4 Users' Guide; SAS Institute: Cary, NC, USA.
- Collyns, D. (2013). Quinoa brings riches to the Andes. The Guardian. January14.
- Joshi, A., & Witcombe, J. R. (1996). Farmer participatory crop improvement. II. Participatory varietal selection: A case study in India. Journal of Experimental
- Lamessa, K., Gudeta, G. C. A. T. D., Haile, S., Usmael, A., & Mechara, E. (2016). Evaluation of sorghum (Sorghum bicolor (L) Moench) varieties and environments for yield performance and stability. *Evaluation*, *6*(21).
- Kinde, L., Gebeyehu, C., Abubeker, T., Dadi, G., Shanene, H., Abdela, U. (2016). Evaluation of Sorghum (Sorghum bicolor (L) Moench) Varieties and Environments for Yield Performance and Stability, Journal of Biology, *Agriculture and Healthcare*, *6*(21).
- De Boef, W.S., & Thijssen, M.H. (2007). Participatory tools working with crops, varieties and seeds. A guide for professionals applying participatory approaches in agrobiodiversity management, crop improvement and seed sector development. Wageningen UR Centre for Development Innovation.