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Potential of Oats (*Avena sativa*) for Food Grain Production with its Special Feature of Soil Acidity Tolerance and Nutritional Quality in Central Highlands of Ethiopia

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Abstract

Oats remain an important crop in marginal ecologies, for grain as well as for feed. They are well adapted to a wide range of soil types and can perform better than other small-grain cereals on acid soils. Low soil pH and associated soil infertility problems are considered to be amongst the major challenges to acid sensitive crops production. This study demonstrated that grain type white seeded food oat variety 79 Ab 382 (Tx) 80 SA 94 is superior in grain yield performance on acidic soil in the multilocation trials across the testing environments. It has better agronomic performance and has showed a comparative yield advantage of 5.53% over the mean. Hence, it has been approved for release by the National Variety Release Committee. Therefore, cultivation of the new variety is recommended in highland acid prone areas of the country having similar climatic conditions with the testing sites. The oat variety 79Ab 382 (Tx) 80SA94 contain a high percentage of protein (16.0), fat (8.4) and ash (3.6) which have proved it highly nutritive in comparison to other cereals. Its high lipid content (8.4%) makes it different from other cereals. The mineral content of 79Ab 382 (Tx) 80 SA 94 oat variety was better than other cereals and its calcium content was (156.35 mg l^{-1}). In preparation of injera; mixing ratio of 75% teff and 25% oat (treatment 4) showed an excellent over all acceptance with all injera quality parameters (i.e., texture, colour, odour, taste and eye distribution) at equal level with injera made from teff which is the stable food in the country. Since this underutilized food oat has a better nutritional value than those conventional small seeded cereal crops, it gave an insight to feed the ever-increasing population of the country and solve the demand of raw material for up-coming agro industries.

Keywords: Food grain production; Agro-ecological zones; Nutritious cereals

Introduction

Most cultivated lands of the Ethiopian highlands are prone to soil acidity due to removal of sample amount of nutrients by leaching, crop mining and runoff as compared with grazing and forest lands. A recent study also showed that soil acidity increased on cultivated land as compared to forest and grazing lands in western part of Ethiopia [1].

According to current ATA report, about 43% of the Ethiopian total land is affected by soil acidity. Production loss and sustainability are of major problems to these areas.

Several research outputs conducted in Ethiopia and elsewhere demonstrated that surface soil acidity can be easily corrected by liming [2]. As liming alone is expensive, and in some situations sub-soil acidity restricts the benefit of lime, then plants with better tolerance to acidity are alternative integral measures in-terms of cost efficiency and sustainability.

Among the different forage crops recommended for various agro-ecological zones of Ethiopia, common oats (*Avena sativa*) is abundantly grown in the central highlands especially at Selale in North Shewa and some parts of West Shewa like Meta-Robi and Galessa area of Dendi wereda. It is also grown to a considerable scale in other parts of the country like Arsi, Bale and Gojam [3]. Production of Oats by small holder farmers in different parts of the country dates back at least three decades as conventional research on the species was initiated in the early 1970's following introductions of about 9,054 lines of oats collected from over 55 countries of the world [4]. About 40 additional dual-purpose (forage and/or grain) type oats varieties were also introduced from CIMMYT in the mid 1980's.

Even though the initial aim of oats introduction to the smallholders was for feed production, it has been realized that it is also being extensively grown as a food grain. However, it has been perceived that farmers have awareness on the existence of different oats varieties with different merits and consequently they grow the single variety they own for multipurpose uses [5].

Although oats is chiefly used as livestock feed, the white colored grain type can also be processed for human food. Oats as a food grain has rapidly gained increasing popularity in recent years, as a result of its serum cholesterol lowering properties thereby preventing heart related problems [6,7].

Oats are one of the most nutritious cereals, high in protein and fiber. The protein of rolled oats is generally greater than that of other cereals. Oats bran can be sprinkled on salads, soups and other foods to add fiber. Oats grain is also rich in carbohydrates and is a good source of minerals (Ca, P, Fe) and vitamins (thiamine, riboflavin, Vit E). To improve the quality of oats for human consumption, an understanding of the influence of genetic and environmental factors on grain quality is essential [8].

Biologically the most important metabolically active proteins of oat are the enzymes. The oat grout, similar to other cereal grains, contains

numerous enzymes such as proteases, maltase, α-amylase, lichenase, phenoxyacetylase and hydroxylase, phosphatase, tyrosinase and lipase as summarized by Caldwell and Pomeranz [9]. The percentage of fat varies from 3.1 to 10.9% but in some oat variety it may be high oil as 15% [10,11].

Calcium is an essential nutrient that plays a vital role in neuromuscular function, blood clotting, as well as providing rigidity to the skeleton by virtue of its phosphate salts. Its non-structural roles require the strict maintenance of ionized calcium concentration in tissue fluids at the expense of the skeleton if necessary and it is therefore the skeleton which is at risk if the supply of calcium falls short of the requirement. Calcium deficiency and negative calcium balance must sooner or later lead to osteoporosis [12].

While oats is widely growing in central highlands both for feed and grain purpose, no/less emphasis was given to develop food oat varieties as compared to other small seeded cereal crops like wheat and barley which are considered as major nutritious food crops.

Therefore, this study is anticipated to fill this gap with the following objectives:

- To identify acid tolerant high yielding and promising food oat (*Avena sativa*) variety.
- To evaluate its competitive nutritional advantages.
- To determine the best mixing ratio of oat with other small seeded cereals to prepare quality injera and to verify the existing farmers practice blending ratio.
- To assess the overall acceptability of injera produced from oat at different mixing ratios with conventional crops through analysis of its sensory properties.

Materials and Methods

Six varieties, namely SRCP × 80 Ab 2252, SRCP × 80 Ab 2291, SRCP × 80 Ab 2806, 79 Ab 382 (Tx) 80 SA 94, 79 Ab 3825 80 SA 95, 79 CP 84 80 SA 130 were brought from the Animal Feeds and Nutrition national program coordinating centre (Holeta) and were promoted to National Variety Trial (NVT) in 2014/15 and 2015/16 cropping seasons on soil acidity-prone areas. The experiment was done at seven soil-acidity prone locations (Holetta over years, Emdibir, Dufa, Rebugebeya over years and Telecho; having an exchangeable acidity ranging from 0.7 upto 2.0 Meq/100 g soil).

Ultimately good variety with better agronomic performance across all testing sites was identified. The identified variety was entered into the Variety Verification Trial (VVT) for release in 2016. The candidate variety 79 Ab 382 (Tx) 80 SA 94 with its standard check were evaluated by National Variety Release committee (NVRC) under field condition, and it was selected and has got letter of conformation for release from NVRC.

Nutritional content analysis

Protein, fat, ash and minerals were analyzed using the official methods of analysis according to the AOAC method [13].

Protein content

Total protein of oat-kjeldhal method: One-gram ground sample of oat measured and transferred into completely dry kjeldhal flask. Ten-gram of kjeldhal tablet was added to the sample inside the flask. Twenty millilitre of 98% concentrated sulphuric acid was mixed with the sample. The sample digestion was started by connecting the kjeldhal flasks with the digestion rock (2000 Food ALYT SBS). And the digestion was completed when the brown color of the sample was completely disappeared. After the digested sample was cooled, 250 ml of distilled water and 70 ml of sodium hydroxide (32%) were added and distilled into 25 ml of excess boric acid containing 0.5 ml of screened indicator. The distillate was titrated with 0.1 N hydrochloric acid to the red end point.

Total nitrogen (N%)=(T-B*14)/W(100-MC)

Where, W is weight of the sample taken for analysis, T is volume of HCl used for titration, B is blank used as control.

Crude protein (CP%)=N*6.25.

Ash content: 3 g of ground sample were weighed out into the crucible, after the crucible has been heated and weighed and was placed in a temperature-controlled furnace at 500°C for about 5 hours for proper ashing. The crucible was then cooled in desiccators and immediately weighed.

% Ash=[(Weight before ash-Weight after ash)/Weight of Sample] × 100

Crude fat: 3 g of dry sample was weighed to within milligrams in an extraction thimble, it was placed in the extraction unit. The flask was connected to hexane containing at 2/3 of total volume to the extractor until 6 hours. When finished, the hexane was evaporated by distillation or in a rota evaporator. The flasks were cooled in a dryer and weighed.

% Oil=[(Weight of Sample)-(Weight of residue after extraction)/Weight of Sample] × 100

Mineral (Fe, Ca, Zn, Na and K) analysis: The content of metal ions in solutions were determined by Agilent atomic absorption spectrometry with a flame atomization technique using an automatic dispensing sample system, Gas flow was an air acetylene mixture of acetylene and air. Calcium, Iron, sodium, potassium and Zinc concentrations were determined by reference to an appropriate metal solution made of 1000 ppm standards. The samples were homogenized by shaking before used. The samples were filtered through dry free filter paper and the first 4 ml filtrate was discarded before collecting. Successively pipette in a test tube 2.0 ml sample, 8.0 ml 0.01 mol/l HCl was mixed well.

For calcium 2 ml $LaCl_3$ was added. The atomic absorption spectrophotometer was used to determine calcium, iron, sodium, potassium and zinc.

Injera quality: The released variety has good nutritional value and gives quality injera when blended with other small seeded cereals. Plant Materials used to make injera blended with the selected white seeded grain type food oat were seeds of barley (HB1307), teff (kuncho), bread wheat (danda'a).

Before making injera a group discussion was made with Wetebecha-minjaro and Rebugebya men and women farmers separately about their preference and experience how to prepare injera from oat flour for human consumption. They responded that mixing with other small seeded cereals it is best for injera, porridge or hard, beer (tela), genfo and also added to other dishes as a thickening. Oat-flour is not suitable for bread making and totally not used for kolo (fried cereal).

Oat injera is made by mixing its flour with small seeded cereals (barley, teff and wheat) at different ratios, and with water to make dough. The preference of Wetebecha-minjaro and Rebugebya women's

is the same i.e., they prefer barely (typically the white type called Gelane i.e., HB1307 variety, then teff to use with oat to made injera. They showed similar reflection on blend type (barley, oat and bread wheat), but very little difference on how to blend. Rebugebya women's group experienced 50% barley blend with 30% oat blend with 20% bread wheat, whereas Wetebecha–Minjaro women's practiced equal amount of barley and oat with less amount of germinated bread wheat (Bikil in Amharic).

Eleven blends (treatments) were made with different ratios and the blend type practiced by Wetebecha-minjaro and Rebugebya women's were included in the treatment (Table 1).

S No	Blend Types
1	100% Oat
2	100% Barley
3	100% Teff
4	75% Teff:25% Oat
5	50% Teff:50% Oat
6	60% Teff:40% Oat
7	50% Barley:50% Oat
8	50% Barley:30% Oat:20% Wheat
9	40% Barley:40% Oat:20% Wheat
10	40% Teff:40% Oat:20% Wheat
11	25% Teff:25% Barley:25% Oat:25% wheat

Table 1: Blend types used for baking injera at Holeta Agricultural Research Center (HARC) Barley Research Nutrition Laboratory.

The injera was made following the conventional procedure. In order to determine consumer acceptability of injera prepared from barley, oat, teff and wheat at different mixing ratios a sensory evaluation was conducted. A panel, consisting of 10 panelists (men and woman) who regularly consume injera as their staple food, was selected following the criterion described by Stone and Sidel [14].

Data analysis

Analysis of variance (ANOVA) for agronomic data was done using SAS statistical package [15] and that of nutritional quality parameters was done with SPSS software (SPSS Version 23).

Results and Discussion

The best performing variety with better agronomic performance across all testing sites was 79 Ab 382 (Tx) (80 SA 94); it showed clear superiority ($P \leq 0.05$) over the other varieties and standard check for plant height, biomass weight and grain yield morphological characteristics (Table 2) and entered into the variety verification trial for release in 2016/17. Moreover, the variety was also visually rated top scorer by National Variety Release Committee. Accordingly, 79 Ab 382 (Tx) 80 SA 94 was released in 2016/17.

	Morpho-Agronomic Traits						
	PLHT (cm)	Pln (cm)	BM (kg/ha)	HLW	TSW	MD	GYLD (kg/ha)
Variety							
SRCP × 80 Ab 2252	121.82	25.17	11241	46.19	35.24	151	2959.6
SRCP × 80 Ab 2291	120.23	28.37	12111.4	50.11	32.46	147	3111.3
SRCP × 80 Ab 2806	125.01	25.23	11409.5	49.72	34.62	148	2784
79Ab382 (Tx) 80 SA 94	96.95	19.45	10655.2	48.63	27.87	143	3228.1
79Ab3825 (Tx) 80 SA 95	128.51	25.07	12742.9	48.32	32.17	146	3065.6
79 CP 84 80 SA 130	129.18	26.25	12091.4	48.52	38.31	148	3214.9
Mean	120.28	24.92	11708.57	48.57	33.44	147	3059.29
CV (%)	5.22	7.51	21.09	3.71	8.98	1.6	28.19
LSD	3.85	1.15	1519.6	1.2	1.85	4.3	535.44

Table 2: Mean value of morpho-agronomic traits of oat varieties combined over location and over years (2014-16). PLHT=Plant height, Pln=Panicle length, BM=Biomass, HLW=Hecto litre weight, TSW=Thousand seed weight, MD=Maturity date, GYLD=Grain yield.

Nutritional quality

The Oats variety 79Ab 382 (Tx) 80SA94 contain a high percentage of protein (16.0), fat (8.4) and ash (3.6). High lipid content of this variety (8.4%) makes it different when compared to other cereals, such as white seeded teff (Kuncho), red seeded teff called Holeta-red (DZ253) and food barley (HB-1307) which the community named it 'Galane' (Table 3). This fact was suggested by Brand and Merwe [16], Petkov et al. [17].

The mineral content of 79Ab 382 (Tx) 80SA94 oat variety compared to the white seeded teff (Kuncho), red seeded teff (DZ253), food barley (HB-1307) is high in Calcium content (156.35 mg/L) (Table 3).

Nutritional Value	Sample Type			
	kuncho	DZ 2053	80 SA94	HB-1307
Ash	2.69 ± 0.0b	3.39 ± 0.1c	3.6 ± 0.01d	1.97 ± 0.7a
Protein	14.49 ± 0.13a	15.6 ± 1.01a	16.5 ± 0.0b	13.7 ± 0.14a
Fat	5.49 ± 07c	5.09 ± 0.01b	8.4 ± 0.00d	3.15 ± 0.07a
Fe	6.98 ± 00c	9.7 ± 0.01d	6.8 ± 0.02a	6.85 ± 0.07b
Ca	95.30 ± 0.14d	65.0 ± 0.00c	156.35+0.00b	38.00 ± 0.00a
Na	84.75+0.07a	156.35 ± 0.00d	96.69 ± 0.01b	122.75 ± 0.07c
Zn	7.79 ± 0.1c	3.80 ± 0.00a	3.7 ± 0.00a	6.2 ± 0.14b
K	208.19 ± 0.01c	67.7 ± 0.14b	2.31 ± 0.01a	2.3 ± 0.00a

Table 3: Nutritional parameters of the food oat (79Ab 382 (Tx) 80SA 94) variety compared with teff and barley as done in Holeta Agricultural Research Centre, Barley Nutrition Laboratory. Ash, protein and Fat=%, Fe, Ca, Na, Zn and K=mg L^{-1}.

To made injera the mixing ratio of 75% teff and 25% oat (treatment 4) showed an excellent over all acceptance with all injera quality parameters (i.e., texture, colour, odour, taste and eye distribution) at equal level with injera made from teff. On the other hand, 50% teff with 50% oat (treatment 5), 60% teff with 40% oat (treatment 6), 50% barley blend with 30% oat blend with 20% wheat (treatment 8) and 40% teff with 40% oat and 20% wheat (treatment 10) showed better overall acceptance. All these treatments have showed a good colour appearance as well (Table 4).

Injera Quality Parameters	Mean Values of Hedonic Scales for Each Treatment (Combination Rates)										
	1	2	3	4	5	6	7	8	9	10	11
Texture	3	4	5	5	4	4	4	4	3	4	4
Colour	5	4	4	4	5	5	4	5	5	5	5
Odour	3	4	5	5	4	4	4	4	3	4	4
Taste	4	4	5	5	4	4	3	3	2	4	4
Eye distn	2	2	5	5	3	4	3	4	3	4	4
Over-all acceptability	3	4	5	5	4	4	3	4	3	4	3

Table 4: Sensory test result of combination rate of the product. Hedonic scale: Like very much=5, Like slightly=4, Neither like nor dislike=3, Dislike moderately=2, Dislike very much=1.

Therefore, it is pertinent to conclude that 75%, 60% and 50% teff combined with 25%, 40% and 50% oat respectively gave best quality injera. Similarly, it was confirmed that injera prepared from 50% barley blend with 30% oat and blend with 20% wheat is the promising one (Table 4). Concerning shelf life, it was observed that as the mixing ratio of oat increases mould formation or development decreases (Figure 1).

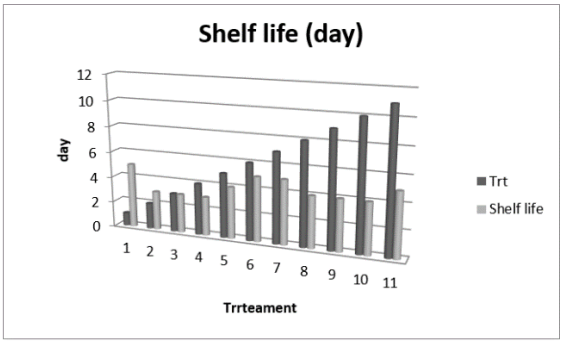

Figure 1: Shelf life (days) of injera made from different blend types. 1. 100% oat, 2. 100% barley, 3. 100% teff, 4. 75% teff+25% oat, 5.50% teff+50% oat, 6.60% teff +40% oat, 7.50% barley+50% oat, 8. 50% barley+30% oat+20% wheat, 9. 40% barley+40% oat+20% wheat, 10. 40% teff+40% oat+20% wheat, 11. 25% teff+25% barley +25% oat+25% wheat.

Conclusion

This study demonstrated that white seeded grain type food oat variety named as 79 Ab 382 (Tx) 80 SA 94 is superior in agronomic performance (especially grain yield), soil acidity tolerance and shortest and manageable plant height/less logging.

The Oats variety 79Ab 382 (Tx) 80SA94 contain a high percentage of protein (16.0%), fat (8.4%), ash (3.6%) and calcium content (156.35 mg l^{-1}) which has proved it highly nutritive in comparison to other cereals.

In preparation of injera, mixing ratio of 75% teff and 25% oat (treatment 4) showed an excellent over all acceptance with all injera quality parameters (i.e., texture, color, odour, taste and eye distribution) at equal level with injera prepared from teff. On the other hand, it was confirmed that injera prepared from 50% barley blend with 30% oat blend with 20% wheat is the better one. Concerning shelf

life, it was observed that an injera made from high proportion of oat compared to other mixed cereals can stay for long time without developing mould.

Hence, due to its all these positive features cultivation of the new variety is recommended in highland acid prone areas of the country having similar edaphic and climatic conditions with the testing sites.

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