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Food-fodder performance of food and malt barley cultivars in Ethiopian highlands

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In Ethiopia, barley selection has focused on grain yield traits. Limited information is available on straw yield and its nutritive value. The aim of this study was to screen cultivars for grain and straw yield and nutritive value using forty cultivars of food and malt barley types at two locations in Ethiopia (Bekoji and Kofele) in 2018. Food-fodder quality traits investigated were crude protein (CP), neutral detergent fibre (NDF) and metabolizable energy (ME) of grain and straw. Location, cultivar and their interaction affected the performance in malt as well as food barley types. Wide cultivars differences were observed within food and malt types respectively: Grain CP: 10.2-12.2% and 11.4.1-13.3%, grain NDF: 40-2-52.7% and 38-42.9%, grain ME: 9.9-12.3 MJ/kg and 12.1-14.5 MJ/kg, straw CP: 4.1-5.7% and 4.9-6.2%, straw NDF: 73.5-76.7% and 72.9-76.1%, straw ME: 5-5.6 MJ/kg and 5.3-5.8 MJ/kg. Across locations, IBON174/03 produced most grain (6.95 t/ha), traveller produced most straw (9.1t/ha) and HB1963 was relatively high in both straw 8.4 t/ha and grain yield 6.4 t/ha, making it an interesting food-feed cultivar. Therefore IBON174/03, traveller and HB1963 are promising barley cultivars for the study area.

Key words: Food-feed, cultivar, barley, straw.

INTRODUCTION

Barley (*Hordeum vulgare* L.) is the fourth most important cereal crop in terms of worldwide grain production (FAOSTAT, 2017). The developing countries contribute to more than half of land area planted with barley crops. Moreover, barley is a multiple-purpose crop with high economic and social importance. It is grown to produce grain for human and straw for livestock consumption and malt for brewing (Kaso and Guben, 2015). However, growing barley is associated with a production of large quantities of straw which is used extensively as ruminant feed specially in developing countries during dry seasons.

According to the report of Jaleta et al. (2015) cereal straws (barley teff and wheat) appears to be preferred as

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Table 1. Altitude, soil types and climatic variables of the study sites for barley cultivar evaluation.

Site	Altitude (m)	Ecology	Soil type	Rainfall (mm)	Temperature (°C)	
					Minimum	Maximum
Bekoji	2780	Highland	Clay (nitosols)	1020	7.9	18.6
Kofele	2620	Highland	Eutric vertisols	1036	7.5	19.6

livestock feed by the farmers and share about 77-88% of animal feed in mixed crop livestock system, from cereals barley is higher than teff and wheat for livestock feed (Seyoum et al., 2020). It has been reported that crop residue biomass and nutritive value are key determinants in varietal selection by farmers in mixed crop-livestock systems (Jaleta et al., 2015; Schiere et al., 2004). Consequently, livestock researchers and crop breeders have launched research themes to upgrade straw yield and nutrient composition alongside grain yield using plant breeding approaches in pulses (Alkhtib et al., 2017; Blümmel et al., 2010; Jane Wamatu et al., 2017) and cereals (Addisu, 2018; Ertiro et al., 2013; Jensen et al., 2011).

Exploiting differences in feed traits of barley types could provide novel breeding targets for new barley varieties with potentially higher food and livestock feed value that would be particularly useful in a range of diverse environments in mixed crop-livestock systems. Thus, the current study aimed to identify superior cultivars in terms of grain yield, straw yield and food-feed potential (dual-purpose use) for mixed farming systems in Ethiopian highlands.

MATERIALS AND METHODS

Experimental sites and design

The study was conducted at Kulumsa Agricultural Research Center, Bekoji and Kofele experimental sites. The agro- ecological description of the experimental sites is presented in Table 1. The experiment comprised of twenty food and twenty malt improved cultivars drawn from National Variety traits (NVT) of the Ethiopian Barley improvement program. The cultivars were planted using randomized complete block design with three replications during the main cropping season (June to November) under rain-fed condition, with a plot size of 2.5 m × 1.2 m. Spacing between plots and blocks was 0.5 m and 1 m, respectively. All plots were equally managed as per recommended agronomic practices for barley growing in Ethiopia, Fertilizer was applied at a rate of 50/100 kg/ha urea /DAP respectively.

Data collection and sampling

At physiological maturity (maturity date varied from 121 days early matured to 154 days late matured) all above ground biomass of each plot was harvested and air-dried for two weeks to constant moisture. Plots were manually harvested over 4 middle rows of each plot and the total biomass yield was taken, then threshed. Straw yield of each plot was calculated by subtracting grain yield from total biomass yield. Representative samples from each plot were taken and ground to pass through a 1 mm sieve, then stored for feed nutritional analysis.

Laboratory evaluation

All grain and straw samples were analysed for crude protein (CP), neutral detergent fibre (NDF), metabolizable energy (ME) and *in vitro* organic matter digestibility (IVOMD) using a combination of wet chemistry analyses and Near Infrared Reflectance Spectroscopy (NIRS); Instrument FOSS 5000 Forage Analyzer with WINISI II software package in the 1108-2492 nm spectra range). A good-of-fitness barley NIRS equation (Wamatu et al., 2019) was used for the prediction of dry matter (DM), nitrogen, neutral detergent fiber (NDF) and *in vitro* digestibility (IVOMD). Validation of the NIRS equation was undertaken by analyzing 20% of representative samples using conventional wet chemistry. Crude protein was determined according to AOAC (1990). The neutral detergent fiber (NDF) was determined according to Van Soest and Robertson (1985), IVOMD was determined according to Tilley and Terry (1963) and the metabolizable energy (ME) was estimated from digestible energy and IVOMD using regression and summation equations developed by NRS (2001).

The standard error of calibration (and prediction) for barley straw was 0.37% (0.508%) for CP, 2.26% (2.38%) for NDF and 1% (1.2%) for ME, 0.5% (0.7%) for IVOMD respectively. The standard error of calibration (and prediction) for barley grain was 0.403 (0.982) for CP, 1.63 (0.944) for NDF and 0.045 (0.8832) for ME. All chemical analyses were performed at the International Livestock Research Institute (ILRI) Animal Nutrition Laboratory in Addis Ababa, Ethiopia.

Calculations and statistical analysis

A general linear model was used to test the effect of cultivar on grain yield, straw yield and potential utility index (PUI). PUI, which estimates the proportion of utilizable portion of total barley biomass for food and feed was calculated according to the following equations.

$$PUI= \frac{GY + 0.01 \times IVOMD \times SY}{GY+SY}$$

PUI, potential utility index (W/W), Grain yield (GY) (t/ha), Straw yield (SY) (t/ha), IVOMD, *in vitro* organic matter digestibility was analysed by NIRS and expressed as %. HI, which estimates the proportion of grain yield (GY) to total barley biomass (GY+SY).

$$HI = \frac{GY}{GY+SY}$$

HI, Harvest Index (W/W), Grain yield (GY) (t/ha), Straw yield (SY) (t/ha). Data of the study was subjected to the analysis of variance according to the following model:

Table 2. Grain yield, straw yield, potential utility index, harvest index and rank of twenty malt barley cultivars grown in the highlands of Ethiopia in the 2018 cropping season.

Cultivar	Grain yield t/ha	Straw yield t/ha	PUI t/t	HI	Rank
IBON-HI14/15-104	5.9	5.9	0.696	0.504	4
NDICARDAMB-190	6.2	7.5	0.683	0.458	12
NDICARDAMB-320	5.8	7.0	0.682	0.462	15
HB1963	6.4	8.0	0.704	0.431	2
USDF5-27	6.5	7.0	0.692	0.483	5
IBON-HI14/15-144	5.3	6.7	0.683	0.444	13
IBON-HI13/14-129	6.1	7.0	0.683	0.470	14
MBHIBYT-22	5.2	6.8	0.672	0.433	20
Traveller	6.1	9.1	0.697	0.401	3
IBON-HI13/14 -49	6.5	7.9	0.692	0.449	6
NDICARDAMB-185	5.8	7.1	0.679	0.453	17
IBON-HI14/15-148	4.6	5.6	0.692	0.465	7
MBBELGIUM-30	5.4	7.2	0.674	0.433	19
IBON-HI13/14-128	6.5	7.4	0.691	0.466	8
IBON174/03	6.9	8.0	0.723	0.465	1
IBON-HI14/15-153	5.5	6.5	0.690	0.467	9
ICARDA GP-75	5.6	7.1	0.687	0.446	11
ICARDA GP-67	5.7	7.2	0.677	0.442	18
IBON-HI14/15-126	5.2	6.6	0.681	0.443	16
USDF5-11	6.1	7.3	0.689	0.458	10
Mean	5.9	7.2	0.688	0.454	
SEM	0.6	0.9	0.016	0.024	
LSD(0.05)	1.7	2.6	0.050	0.071	

PUI: Potential utility index ; HI : Harvest Index ; Cultivars are ranked according to PUI value, LSD, least significant difference. Averages combining both growing locations (Bekoji and Kofele).

$Y_{ijk} = M + G_i + Lo_j + B_k(L_i) + (G \times Lo)_{ij} + E_{ijk}$

Where Y_{ijk} is the response variable, M is the mean, G_i is the effect of barley cultivar i, L_j is the effect of the location j, $B_k(L_i)$ is the effect of the block k within k location i, $(G \times L)_{ij}$ is the interaction between the cultivar and the location and E_{ijk} is the random error.

RESULTS

Grain yield (GY), straw yield (SY) and potential utility index (PUI) across locations

The grain yield performance of malt barley ranged from 5.2 to 6.9 t/ha. The highest grain yield was recorded for cultivars IBON174/03 (6.9 t/ha), USDF5-27 (6.5 t/ha) and IBON-HI13/14-49 (6.4 t/ha), and the lowest yield was recorded for cultivar IBON-HI14/15-126 (5.2 t/ha) (Table 2). The straw yield performance of malt barley ranged from 5.5 to 9.1 t/ha. Traveller (9.1 t/ha), HB1963 (8.4 t/ha) and IBON174/03 (8.0 t/ha) showed the highest grain yield whereas IBON-HI14/15-148 performed least (5.6 t/ha) (Table 2). The potential utility index of malt barley ranged from MBHIBYT-22 (0.69) to IBON174/03 (0.72) (Table 2).

The grain yield performance of food barley ranged from 4.0 to 5.8 t/ha. The highest grain yield was recorded for cultivars, EH1493 (5.8 t/ha), ICARDA GP P# 44 (5.4 t/ha) and IBON-HI 13/14-P# 113 (5.2 t/ha) whereas the lowest yield was obtained for IBON-HI 13/14-P# 31 (4.0 t/ha) (Table 3). The straw yield of food barley ranged from 4.0 t/ha to 6.9 t/ha. Cultivars EH1493 (6.9 t/ha), IBON-HI14/15 P#155 (6.5 t/ha) and HB1966 (6.4 t/ha) produced most straw. The lowest straw yield was recorded for IBON-HI 13/14-P#31 (4.5 t/ha) (Table 3). The potential utility index of food barley ranged from 0.67-0.70. Based on the PUI, IBON-HI 13/14-P# 85 (0.70), ICARDA GP P# 44 (0.70) and IBON-HI 14/15-P# 165 (0.70) were the three best cultivars (Table 3).

Grain and straw nutritive quality

A wide range in grain nutrient and energy concentration was observed across the cultivars for food and malt

Table 3. Grain yield, straw yield, potential utility index, harvest index and rank of twenty food barley cultivars grown in the highlands of Ethiopia in the 2018 cropping season.

Cultivar	Grain yield t/ha	Straw yield t/ha	PUI t/t	HI	Rank
ICARDA GP P# 44	5.4	6.0	0.701	0.521	2
IBON HI 13/14-P# 53	4.4	5.6	0.669	0.569	19
IBON HI 13/14-P# 74	4.7	5.6	0.688	0.541	9
HB1966	5.2	6.4	0.677	0.552	17
MBF4 P#+2015	4.6	5.7	0.680	0.559	15
ICARDA GP P# 127	4.4	5.3	0.690	0.537	7
IBON HI 13/14-P# 85	5.1	5.6	0.703	0.516	1
IBON HI 14/15-P# 155	5.1	6.5	0.676	0.560	18
IBON HI 13/14-P# 91	4.9	5.5	0.688	0.535	10
IBON HI 13/14-P# 113	5.2	6.4	0.678	0.550	16
EH1493	5.8	6.9	0.683	0.551	13
HB1307	5.2	6.2	0.686	0.538	11
IBON HI 13/14-P# 23	4.7	5.6	0.694	0.544	6
IBON HI 13/14-P# 109	4.4	5.3	0.696	0.537	5
MBF4 +2015 P# 1	4.5	5.9	0.668	0.565	20
IBON HI 14/15-P# 165	4.4	5.0	0.700	0.522	3
IBON HI 14/15-P# 116	4.2	4.9	0.689	0.539	8
IBON HI 13/14-P# 81	4.5	5.4	0.683	0.548	14
IBON HI 14/15-P# 143	4.9	5.9	0.684	0.540	12
IBON HI 13/14-P# 31	4.0	4.5	0.699	0.524	4
Mean	4.8	5.7	0.687	0.542	
SEM	0.6	0.8	0.018	0.026	
LSD(0.05)	1.7	1.1	0.050	0.036	

PUI: Potential utility index ; HI : Harvest Index ; Cultivars are ranked according to PUI value, LSD, least significant difference. Averages combining both growing locations (Bekoji and Kofele).

barley cultivar: Wi: grain CP: 10.2-12.2% and 11.4.1-13.3%, grain NDF: 40-2-52.7% and 38-42.9%, grain ME: 9.9-12.3 MJ/kg and 12.1-14.5 MJ/kg, (Table 4 for malt type barley and Table 5 for food type barley).

Also for straw, large variation in nutritive value was found across cultivars for food and malt barley cultivar: straw CP: 4.1-5.7% and 4.9-6.2%, straw NDF: 73.5-76.7% and 72.9-76.1%, straw ME: 5-5.6 MJ/kg and 5.3-5.8 MJ/kg (Table 4 for malt type barley and Table 5 for food type barley). Multiple differences were found between cultivars, but with a significant cultivar-location interaction, meaning that the growing location had an impact on the performance of the cultivars and their concomitant PUI ranking. The overall grain quality in Kofele was superior to that in Bekoji. The difference between low and high yielding cultivars was presented in Table 6 (Food barley) and Table 7 (Malt barley).

Food-fodder correlation

Table 8 presents the relationship between straw yield and nutritive value as well as grain yield and nutritive value across food and malt barley cultivars. The correlation between grain yield and straw yield was positive for both food and malt barley cultivars regardless of the location ($r > 0.7$). Grain yield was correlated weakly to moderately ($r < 0.39$) with straw nutritive value parameters for both food and malt barley in both locations.

Generally, the linear correlations between nutrient composition of grain (grain CP, grain NDF and grain ME) and nutrient composition of straw (straw CP, straw NDF and straw ME) were weak to moderate ($r < 0.44$) for food and malt barley in Bekoji and Kofele.

DISCUSSION

Exploiting differences in feed traits of barley types could provide novel breeding targets for new barley varieties with potentially higher food and livestock feed value that would be particularly useful in a range of diverse environments in mixed crop-livestock systems. These genotypes would promote sustainable use of resources in

Table 4. Nutritive value of grain and straw of malt barley cultivars grown in the highlands of Ethiopia in the 2018 cropping season.

Cultivar	Grain			Straw		
	CP %	NDF %	ME MJ/kg	CP %	NDF %	ME MJ/kg
IBON-HI14/15-104	11.8	42.5	13.8	5.5	75.0	5.7
NDICARDAMB-190	12.2	39.5	14.0	6.2	73.4	5.7
NDICARDAMB-320	12.7	38.0	13.3	6.1	72.9	5.8
HB1963	12.2	38.7	14.3	5.4	76.1	5.4
USDF5-27	11.4	41.2	13.5	5.8	74.1	5.6
IBON-HI14/15-144	12.3	40.2	13.2	6.0	75.4	5.4
IBON-HI13/14-129	12.1	41.8	13.0	4.9	73.6	5.9
MBHIBYT-22	12.2	41.3	12.1	6.1	73.9	5.8
Traveller	11.7	40.2	13.7	5.3	75.2	5.6
IBON-HI13/14 -49	11.9	42.8	13.5	5.2	74.3	5.7
NDICARDAMB-185	12.7	41.4	14.5	6.0	74.0	5.6
IBON-HI14/15-148	11.7	41.7	13.0	6.1	73.8	5.5
MBBELGIUM-30	12.1	41.4	13.5	4.9	74.8	5.7
IBON-HI13/14-128	12.0	41.3	13.5	5.6	74.3	5.3
IBON174/03	12.2	40.4	13.2	5.4	73.9	5.7
IBON-HI14/15-153	12.2	41.9	13.3	5.4	73.9	5.4
ICARDA GP-75	12.9	39.8	13.6	5.6	75.9	5.8
ICARDA GP-67	13.3	43.1	13.6	5.8	74.1	5.7
IBON-HI14/15-126	11.5	42.9	14.6	5.4	75.2	5.8
USDF5-11	12.6	40.4	13.8	6.6	73.0	5.8
Mean	12.2	41.0	13.5	5.6	74.3	5.6
SEM	0.5	1.9	0.85	0.6	1.3	0.21
LSD(0.05)	1.4	5.2	2.18	1.7	3.5	0.57

CP, crude protein, NDF, neutral detergent fibre, ME, metabolizable energy, LSD, least significant difference. Averages combining both growing locations (Bekoji and Kofele).

the farming systems by increasing biomass production for human and livestock production.

Cultivar improvement of straw traits along with grain traits requires information on the cultivar-environment interactions between grain and straw traits and the relationship between these traits across different environments. The current study showed that cultivar variation in yield and quality traits depends on location. That means that the selection of an optimal barley cultivar should be based on location. Further research is therefore warranted to identify the parameters (e.g., soil type, precipitation and slope) that could predict the location effect on barley performance.

Cultivar performance depended on growing location as shown previously in for instance chickpea (Alkhtib et al., 2018; Wosene et al., 2015) and maize (Ertiro et al., 2013). It implies that other cultivars may be selected when tested at another location.

Genotype-environment interaction is known to account for the variation in nutritive value of cereal straw (Seyoum et al., 2020) (Birhanu et al., 2020) also identified IBON 174/03 as a high grain yielder although only grain quality and not straw quality was evaluated in that study. Our study evaluated both grain and straw quality and added HB1963 and Traveller in addition to IBON 174/03. Large variation in food and malt barley cultivars has been demonstrated in several studies (Pearce et al., 1988; Reed and Yilma, 1986; Wamatu et al., 2019). Our study walks the same trail but also adds the insight that not only grain quality but also straw quality showed an interesting range for selection. A factor that complicates easy selection of superior cultivars is the impact of growing location observed in both barley types. Tsige et al. (2020) already identified this effect but our study clarifies that some traits are more sensitive to changes in growing conditions than others. For instance, there was a huge difference between locations in ME compared to other traits. The ME at the Kofole site was higher than the ME in Bekoji which may originate from the high rainfall in Kofele compared to Bekoji. High rainfall was correlated to

Table 5. Nutritive value of grain and straw of food barley cultivars grown in the highlands of Ethiopia in the 2018 cropping season.

Cultivar	Grain			Straw		
	CP (%)	NDF (%)	ME (MJ/kg)	CP (%)	NDF (%)	ME (MJ/kg)
ICARDA GP P# 44	11.1	44.2	11.2	4.1	**76.7**	5.1
IBON HI 13/14-P# 53	12.0	44.3	11.3	5.0	76.0	5.1
IBON HI 13/14-P# 74	10.8	51.0	10.6	4.8	75.7	5.3
HB1966	10.2	52.7	10.0	4.6	75.7	5.0
MBF4 P#+2015	11.0	47.1	11.1	5.7	74.8	5.4
ICARDA GP P# 127	11.0	46.3	11.1	5.2	75.0	5.6
IBON HI 13/14-P# 85	11.5	44.8	11.2	4.7	74.7	5.4
IBON HI 14/15-P# 155	12.2	42.3	11.1	4.7	75.3	5.2
IBON HI 13/14-P# 91	10.6	51.8	9.9	4.8	75.9	5.2
IBON HI 13/14-P# 113	11.0	42.7	10.4	4.8	75.7	5.1
EH1493	11.9	44.1	12.3	4.9	74.2	5.2
HB1307	11.8	41.9	11.2	5.1	74.3	5.4
IBON HI 13/14-P# 23	11.2	43.9	11.2	5.4	73.5	5.4
IBON HI 13/14-P# 109	11.0	42.1	11.0	4.8	75.2	5.1
MBF4 +2015 P# 1	12.2	40.2	12.1	4.8	76.0	5.3
IBON HI 14/15-P# 165	11.6	44.5	10.9	4.8	75.0	5.3
IBON HI 14/15-P# 116	11.2	42.0	11.0	4.7	76.1	5.5
IBON HI 13/14-P# 81	11.0	44.0	11.7	4.8	75.4	5.3
IBON HI 14/15-P# 143	11.1	44.5	11.8	4.5	76.1	5.1
IBON HI 13/14-P# 31	11.7	41.9	11.2	5.0	75.7	5.5
Mean	11.3	44.8	11.1	4.9	75.0	5.3
SEM	0.8	4.5	0.76	0.5	1.9	0.2
LSD(0.05)	2.2	12.5	2.1	0.7	2.7	0.6

CP, crude protein, NDF, neutral detergent fibre, ME, metabolizable energy, LSD, least significant difference. Averages combining both growing locations (Bekoji and Kofele).

Table 6. Yield and nutritive value of grain from food and malt barley cultivars grown at two locations (Bekoji and Kofele) in the Ethiopian highlands.

Site	Food type				Malt type			
	Yield t/ha	CP (%)	NDF (%)	ME (MJ/kg)	Yield t/ha	CP (%)	NDF (%)	ME (MJ/kg)
Bekoji								
Mean	3.9	9.2	39	9	5.6	12.0	39	9
Min	2.9	7.2	30	6.7	4.4	10.9	33	6.7
Max	5.2	10.7	54	11	6.9	13.3	44	10.9
Kofele								
Mean	5.7	13.4	5	11.1	6.2	12.4	43	13.5
Min	4.8	11.3	45	9.8	5.1	11.6	41	11.7
Max	6.7	14.4	52	13.7	7.3	13.2	46	15.6

Crude protein (CP) and neutral detergent fibre (NDF) are in % of dry matter while metabolizable energy (ME) is in MJ/kg dry matter.

high ME in straw (Acone and Wootton, 1999). It was not the purpose to compare malt barley with food barley, but malt barley outperformed food barley in both yield and nutritive value. This difference was expected because of

Table 7. Yield and nutritive value of straw from food and malt barley cultivars grown at two locations (Bekoji and Kofele) in the Ethiopian highland.

Site	Food				Malt			
	Yield t/ha	CP (%)	NDF (%)	ME (MJ/kg)	Yield t/ha	CP (%)	NDF (%)	ME (MJ/kg)
Bekoji								
Mean	4.7	3.2	73	5.4	6.8	5	73.5	5.7
Min	3.0	2.7	71	5.2	4.9	4.2	72	4.7
Max	6.6	3.9	75	5.7	8.6	6.1	77	5.9
Kofele								
Mean	6.7	6.5	77	5.1	7.5	6.3	75.2	5.6
Min	5.2	4.9	71	4.8	4.9	5.1	72.6	5.1
Max	8.0	7.6	80	5.5	9.6	7.8	77	5.9

Crude protein (CP) and neutral detergent fibre (NDF) are in % of dry matter while metabolizable energy (ME) is in MJ/kg dry matter.

Table 8. Relationship between grain and straw traits in food and malt barley cultivars grown in Ethiopian highlands.

Site	Grain traits	Straw traits			
		Yield	CP (%)	NDF (%)	ME (MJ/kg)
			Food type		
Bekoji	Yield	0.22	ns	-0.50	0.39
	CP	Ns	0.29	-0.27	0.26
	NDF	Ns	0.39	ns	ns
	ME	Ns	ns	-0.43	ns
Kofele	Yield	0.22	-0.27	ns	ns
	CP	Ns	ns	ns	ns
	NDF	Ns	ns	ns	ns
	ME	Ns	ns	ns	ns
			Malt type		
Bekoji	Yield	0.32	ns	ns	ns
	CP	Ns	ns	ns	ns
	NDF	Ns	ns	ns	ns
	ME	Ns	ns	ns	ns
Kofele	Yield	0.25	ns	ns	ns
	CP	Ns	ns	ns	ns
	NDF	Ns	ns	0.32	-0.33
	ME	Ns	ns	ns	ns

ns, $p>0.05$ otherwise $p\leq 0.05$; CP, crude protein, NDF, neutral detergent fibre, ME, metabolizable energy.

the basic difference between malt and food barley types. The higher grain and straw yield observed in malt barley type might be related to the high germination rate as a criterion for malt barley (Macleod, 2013). At least, our study points the necessity to consider the impact of location when selecting parental varieties (or potential food-fodder genotypes) of food and malt barley for breeding programs. This is especially the case for food-feed use of barley, since features of grains and straw were clearly affected by location with different effect sizes, meaning that the overall value of food-feed barley may vary more widely than just grain yield.

Conclusions

The wide cultivar variation in straw yield and nutritive value combined with the poor association between yield and nutritive value for grain as well as straw allows for upgrading of straw yield and its nutritive value without decreasing grain yield and its nutritive value. This improvement could be achieved by employing appropriate breeding approaches.

Considering the environmental impact on the cultivar performance, three superior varieties were identified, that is, IBON174/03 (as grain yielder), HB1963 (as grain and straw yielder) and Traveller (as straw yielder). To evaluate how well the straw of these cultivars suits animal nutrition, a trial with regional livestock is required to evaluate the digestive and metabolic responses to the identified promising barley cultivars.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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