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SELECTING FOR FOOD-FEED TRAITS IN *desi* AND *kabuli* GENOTYPES OF CHICKPEA (*Cicer arietinum*)

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ABSTRACT

The study explored the genetic and environmental variability in chickpea for food-feed traits. Seventy nine genotypes of 17 early-maturing *desi* genotypes, 19 early-maturing *kabuli* genotypes and 43 late-maturing *kabuli* genotypes were evaluated for food-feed traits in 7 trials laid out in a randomized complete block *desi*gn in 3 locations in Ethiopia. All trials showed wide genotypic ranges in various traits related to grain yield, straw yield and straw quality. Analysis of variance for individual trials showed significant ($P<0.05$) effects of genotype, location and their interaction on grain and straw yields, CP, IVOMD and NDF in all populations. Correlation analysis exhibited either positive or insignificant correlations with straw yield in all trials. The correlation between IVOMD and grain yield was insignificant in all trials. Grain yield correlated significantly ($P<0.001$) and positively to NDF in early maturing *kabuli*, however, the correlation was moderate ($r= 0.396$). Grain yield correlated either weakly or insignificantly to CP and Ca in the trials. The correlation between P and grain yield was ignored as the straw content of P was very small in all genotypes (<1.78 g/kg). Weak or absence of correlations between grain yields with straw traits would enable chickpea breeders to manipulate grain yield and straw traits independently. This presents an opportunity to identify parental genotypes for improving grain yield and straw traits for individual locations.

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1 Introduction

Chickpea is one of the important pulse crops in the world. It ranks second in area and third in production among the pulses worldwide (Bampidisa & Christodoulou, 2011). It is mainly grown in South Asia, which accounts for more than 75% of the world chickpea area. India is by far the largest chickpea producing country. Other important chickpea producing countries are Pakistan, Turkey, Mexico, Canada, Australia and Ethiopia. Chickpea is classified into *desi* chickpea and *kabuli* chickpea (Bampidisa & Christodoulou, 2011). Grains of *desi* chickpea are small in size, light to dark brown in color, smooth or wrinkled and have a thick seed coat. Grains of *kabuli* chickpea are larger, whitish-cream colored and have a thin seed coat. The *desi* type is more prominent and accounts for close to 80% of global chickpea production. The grains are an important source of protein, minerals and vitamins for humans (Bampidisa & Christodoulou, 2011).Chickpea cultivation produces straw that is used as livestock feed. Generally, residues of pulses and cereals are important sources of feed for livestock raised by resource-poor smallholders in Southern Asia and sub-Saharan Africa. Chickpea straw contains an average of 65 g/kg of crude protein (CP), 694 g/kg of neutral detergent fiber (NDF), 516 g/kg of acid detergent fiber, 111g/kg of acid detergent lignin and 7.7 MJ/kg of metabolizable energy (Bampidisa & Christodoulou, 2011). Moreover, growing chickpea improves soil fertility, increases intensity of land use and provides households with cash (Kassie et al., 2009). Despite being a crop of temperate regions, advances in plant breeding from CGIAR (Consultative Group on International Agricultural Research) centers namely ICARDA (International Center for Agricultural Research in the Dry Areas), which holds the world mandate for *kabuli* chickpea, and ICRISAT (International Crops Research Institute for the Semi-Arid Tropics), has enabled chickpea cultivation to gradually spread to the sub-tropical and tropical regions of Africa, North America and Oceania. Chickpea germplasm developed by ICARDA is distributed and utilized in all these regions. Studies to simultaneously boost grain yield and nutritive traits of grain legume crop residueshave been reported in lentil (Wamatu et al. 2017; Alkhtib et al. 2017), faba bean (Alkhtib et al, 2016b) cowpea (Samireddypalle et al. 2017; Adeyanju et al. 2012). Previous studies on chickpea have reported wide genetic variation in grain yield, the number of secondary branches per plant, the number of pods per plant, biomass yield (Malik et al., 2009) and plant height (Aslamshad et al., 2009) which lead to an exploitable genetic variation in straw quality and yield. Furthermore, studies have reported an existence of positive and significant correlation between grain yield and the number of secondary branches per plant, plant height, number of pods per plant and biomass yield (Malik et al., 2009; Ali & Ahsan, 2012) which points to a possible positive correlation between grain yield with straw yield and nutritive quality. Therefore, the aim of this study was to determine varietal and environmental variations in straw traits in 79 genotypes across *desi* and *kabuli* types of chickpea and to evaluate their food-feed relationships. This is the preliminary stage in a series of steps to identify genotypes with food-feed traits. Evaluation of genotypic variation in yield and quality parameters of straw and food-feed relations would help chickpea breeders *des*ign appropriate approaches towards dual purpose food-feed (dual purpose) genotypes of chickpea to address needs for human food and livestock feed in mixed crop-livestock farming systems in developing countries.

2 Materials and Methods

2.1 Experimental layout and the chickpea cultivars

Seventy-nine (79) genotypes of chickpea were tested in 7 trials in 3 Ethiopian sites; Akaki (08°53’N 38°49’E), Minjar (08°44’N 38°58’E), and Chefe Donsa (08°57’N 39°06’E) located in the Central Highlands at altitudes of 2200, 1810 and 2450 m.a.s.l respectively and annual rainfall of 1025 mm, 867 mm and 843 mm respectively (Table 1). The Ethiopian Institute of Agricultural

Table 1 Experimental layout of the trails

Trail code	*Type*	*Location*	*Maturity type*	*Genotypes*	*N Blocks*	*Observations*
NVT − D − AK	*desi*	*Akaki*	*Early*	17 ∗	4	68
NVT − D − CD	*desi*	*ChefeDonsa*	*Early*	17 ∗	4	68
NVT − K − PE − AK	*kabuli*	*Akaki*	*Late*	18 †	4	72
NVT − K − PE − CD	*kabuli*	*ChefeDonsa*	*Late*	18 †	4	72
PVT − K − PE − AK	*kabuli*	*Akaki*	*Late*	25 ‡	3	75
PVT − K − PE − CD	*kabuli*	*ChefeDonsa*	*Late*	25 ‡	3	75
PVT − K − LMS − MN	*kabuli*	*Minjar*	*Early*	19	3	57

*, †and ‡ indicate to similar group of genotypes.

Research (EIAR) developed the genotypes, bred for high grain yield, using germplasm selected from ICARDA breeding lines. Elite genotypes were drawn from 2014 preliminary variety trials (PVT) and national variety trials (NVT) of the Ethiopian Chickpea Improvement Program selected based on their high grain yield and other agronomic traits in potential environments (PE) and low moisture stress environments (LMS). Seventeen genotypes of early-maturing *desi* (D) were grown in 2 locations viz. Akaki and ChefeDonsa. Nineteen early-maturing *kabuli*(K) genotypes were evaluated at one location (Minjar). Twenty-five late-maturing *kabuli* genotypes were evaluated in Akaki and ChefeDonsa. The 7 trials are identified by their codes (Table 1) which indicate which varietal trials the genotypes were drawn from (PVT, NVT), the chickpea type (D, K), the type based on physiological maturity (PE: late maturing, LMS: early maturing) and the locations they were planted (AK, CD, MN). In all trials, randomized complete block *desi*gn (RCBD) was used with three or four replications (Table 1). Fields were blocked based on slope. A unit plot measured 4 m×0.8 m. Spaces between rows were 20 cm while spaces between plants were 2 cm. Trials were hand planted in July 2015using recommended agronomic packages as optimized by EIAR for each site. At physiological maturity, plots were manually harvested from two 1.6 m^2 areas laid over two middle rows of each plot. The biomass was air-dried in the field, after which grain was removed and weighed. Straw yield was calculated by subtracting grain yield from total biomass yield. Sub-samples of 500g of representative straw were taken from each plot for chemical composition and digestibility analysis

2.2 Straw quality analysis

After oven-drying at 100^{O}C for 24 h, straw samples were ground to pass through a 1 mm sieve mesh. The samples were analyzed using Near Infrared Reflectance Spectroscopy (NIRS) and conventional wet chemistry. The NIRS instrument, Foss Forage Analyzer 5000 with the software package Win ISI II in the 1108-2492 nm spectra range was used to scan lentil straw samples and a good-of-fitness lentil NIRS equation 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 using conventional wet chemistry, whereby 20% representative samples were analyzed for DM and crude protein (CP) according to the methodology of AOAC (2000). Dry matter was determined by oven drying at 105 ˚C overnight (method 934.01). Ash was determined by burning in a muffle furnace at 500 ˚C overnight (method 942.05). Nitrogen content was determined by Kjeldahl method using Kjeldahl (protein/nitrogen) Model 1026 (Foss Technology Corp.), (method 954.01). A conversion factor of 6.25 was used to convert nitrogen to crude protein. Neutral detergent fiber, acid detergent fiber (ADF) and lignin were determined as described by Van Soest & Robertson (1985). Neutral detergent fiber was did not involve use of heat stable amylase and the result was expressed exclusive of residual ash. Acid detergent fiber was expressed without residual ash. Lignin was determined by solubilisation of cellulose with sulphuric acid. *In vitro* organic matter digestibility was measured in rumen microbial inoculum using *in vitro* gas production technique. The buffer solution was prepared according to the method described by Menke & Steingass (1988). Rumen fluid was collected prior to morning feeding using a vacuum pump from three ruminally cannulated cows fed a total mixed ration of grass hay (790 g/kg), wheat bran (203 g/kg), salt (3.2 g/kg) and a mineral and vitamin mixture (4.6 g/kg) on a DM basis. Use of cows was assessed and approved by the Environmental and Occupational Health and Safety Unit of ILRI. The rumen fluid from the cows was composited (1:1, v/v), filtered through four layers of cheese cloth, and added to the buffer solution (1:2, v/v), which was maintained in a water bath at 39^{o}C under continuous flushing with CO_2. The buffered rumen fluid (30 ml) was pipetted into 100 ml syringes containing 0.2 g of sample and immediately placed into a water bath at 39 °C. Gas production was recorded after 24 hours of incubation and used to calculate IVOMD according to Menke et al. (1979) equations suitable for legume hays as follows:

$$IVOMD(g/kg) = 14.88 + 0.889GP + 0.45CP + 0.0651XA$$

Where GP: 24 h net gas production (ml/200 mg); CP: Crude protein (g/kg DM); XA: Ash content (g/kg DM).

Ca and P were analyzed usingAtomic absorption spectroscopy (The Perkin-Elmer Corporation, 1996)

Laboratory analyses were undertaken at the Animal Nutrition Laboratories of the International Livestock Research Institute (ILRI) in Addis Ababa, Ethiopia and Patencheru, India.

2.3 Calculations and statistical analysis

A general linear model was used to test the effect of variety on grain yield, straw yield and nutritive value parameters of straw. Each trial was analyzed separately according to the following model:

$$Y_{ij} = \mu + B_i + G_j + E_{ij}$$

Where: Y_{ij}: grain/straw traits, µ: overall mean, B_i: effect of the block i, $G_{j:}$ effect of the genotype j, $E_{ij:}$ random error. To evaluate the effect of location and genotype-location interaction (GxL), data from all trials combined and analyzed according to the following model:

$$Y_{ijk} = \mu + G_i + L_j + GL_{ij} + B\left(L\right)_{ij} + E_{ijk}$$

Where: $Y_{ij:}$ grain/straw traits, µ: overall mean, G_i: effect of the genotype i, L_j: effect of location j, GL_{ij}: effect of interaction between the genotype and location, B(L)ij: effect of block i within location j, $E_{ijk:}$ random error.

Relationships between grain and straw traits were calculated separately for each trial using Pearson's correlation. Correlations among the nutritive value parameters of straw in each trial were identified using Pearson's correlation. All statistical procedures were carried out using Statistical Analysis System software (SAS, 2012).

3 Results

3.1 Grain and straw yields

The effect of genotype on grain yield and straw yield was significant ($P<0.001$) in all trials (Table 2). The genotypic range of grain yield and straw yield for *desi* across locations was 2.34 - 4.7t/ha and 2.1 - 5.66 t/ha respectively. The genotypic range of grain yield and straw yield in late maturing *kabuli* across locations was 1.04 - 4.0 t/ha and 1.49 - 8.74 t/ha respectively and a range of 1.08 - 3.05 t/ha and 1.43 - 5.53 t/ha respectively for early maturing *kabuli*. The effect of location and G×L for grain yields and straw yields was significant ($P<0.05$) in all trials (Table 4).

3.2 Straw quality traits

Table 3 shows a highly significant ($P<0.001$) effect of genotype on straw nutritive traits. Considering the means of *desi* trials, the magnitude of range (g/kg) was 3.1 in CP, 12 in IVOMD, 3 in NDF, 0.9 in Ca and 0.047 in P. The magnitude of genotypic range (g/kg) considering all locations of *desi* population was 32 in CP, 52 in IVOMD, 65 in NDF. 6.2, in Ca and 0.48 in P. In late maturing *kabuli* trials, the magnitude of range among the trial means (g/kg) was 2.2 for CP, 16 for IVOMD, 24 for NDF, 0.6 for Ca and 0.231 for P. Considering all locations, the magnitude of genotypic range in late maturing *kabuli* genotypes (g/kg) in case of CP, IVOMD, NDF, Ca and P was 31.6, 122, 81, 8.9 and 0.945 respectively. In early maturing *kabuli*, the magnitude of genotypic range (g/kg) in CP, IVOMD, NDF, Ca and P was 16.4, 58, 119, 4.3 and 1.08 respectively. The effect of location and GxL was significant ($P<0.05$) in all trials for CP, IVOMD and NDF (Table 4). Genetic-location interaction was not significant for Ca in all trials. GxL interaction was not significant for P in *desi*.

Table 2 Genotypic variation ingrain yields and straw yields in *desi* and *kabuli* chickpea genotypes

Trial code Grain yield (t/ha)	Mean	Min	Max	Range	SEM
NVT-D-AK	3.11	2.34	3.88	1.54	0.321
NVT-D-CD	3.68	2.5	4.7	2.2	0.552
PVT-K-LMS-MN	2.12	1.08	3.05	1.97	0.353
NVT-K-PE-AK	2.87	1.63	3.88	2.22	0.281
NVT-K-PE-CD	2.06	1.15	3.52	2.37	0.332
PVT-K-PE-AK	2.63	1.46	4	2.54	0.264
PVT-K-PE-CD	1.7	1.04	3.39	2.35	0.433
Straw yield (t/ha)					
NVT-D-AK	2.69	2.1	3.41	1.31	0.4
NVT-D-CD	4.88	3.39	5.66	2.27	0.632
PVT-K-LMS-MN	2.79	1.43	5.53	4.1	0.493
NVT-K-PE-AK	3.95	1.6	5.2	3.6	0.521
NVT-K-PE-CD	4.17	2.19	6.87	4.68	0.752
PVT-K-PE-AK	4.28	1.49	7.1	5.61	0.752
PVT-K-PE-CD	5.30	3.7	8.74	5.04	0.24

The effect of genotype on grain and straw yields is significant ($P<0001$) in all trials

Table 3 Genotypic variation in straw nutritive parameters in *desi* and *kabuli* chickpea genotypes

Trial code	Mean	Min	Max	Range	SEM
CP (g/kg DM)					
NVT-D-AK	51.5	39	59.8	20.8	2
NVT-D-CD	48.4	34	64	30	2.21
PVT-K-LMS-MN	59.9	51.1	67.5	16.4	3.72
NVT-K-PE-AK	49.5	37.1	56.9	19.8	2.82
NVT-K-PE-CD	49.9	39.1	56.4	17.3	3.11
PVT-K-PE-AK	48.2	33.2	60.9	27.7	2.92
PVT-K-PE-CD	50.4	36.9	64.8	27.9	4.43
IVOMD (g/kg DM)					
NVT-D-AK	496	487	516	29	4.32
NVT-D-CD	484	464	512	48	4.61
PVT-K-LMS-MN	477	448	506	58	8.22
NVT-K-PE-AK	494	479	507	28	4.34
NVT-K-PE-CD	483	477	492	15	4.13
PVT-K-PE-AK	499	482	521	39	5.82
PVT-K-PE-CD	490	470	536	66	6.41
NDF (g/kg DM)					
NVT-D-AK	724	712	743	31	9.72
NVT-D-CD	727	688	753	65	11.2
PVT-K-LMS-MN	750	679	798	119	13.6
NVT-K-PE-AK	716	701	740	39	9.1
NVT-K-PE-CD	740	720	763	43	9.22
PVT-K-PE-AK	721	682	749	67	16
PVT-K-PE-CD	730	692	755	63	12.7
Ca (g/kg)					
NVT-D-AK	15.3	13.7	17.9	4.2	0.64
NVT-D-CD	14.4	11.7	16.9	5.2	0.454
PVT-K-LMS-MN	11.5	9	13.3	4.3	0.56
NVT-K-PE-AK	15.2	13.4	18.4	5	0.6
NVT-K-PE-CD	14.1	11.8	17.7	5.9	0.48
PVT-K-PE-AK	15.2	12.1	20.5	8.4	0.483
PVT-K-PE-CD	13.6	11.6	18.1	6.5	0.818
P (g/kg)					
NVT-D-AK	0.343	0.135	0.615	0.48	0.072
NVT-D-CD	0.39	0.289	0.615	0.326	0.043
PVT-K-LMS-MN	1	0.7	1.78	1.08	0.088
NVT-K-PE-AK	0.135	0.06	0.266	0.206	0.032
NVT-K-PE-CD	0.20	0.09	0.4	0.31	0.065
PVT-K-PE-AK	0.111	0.017	0.21	0.193	0.036
PVT-K-PE-CD	0.342	0.03	0.962	0.932	0.08

The effect of genotype on nutritive value parameters is significant (P<0001)in all trials. CP, crude protein; IVOMD, *in vitro* organic matter digestibility; NDF, neutral detergent fiber; Ca, calcium; P, Phosphorus.

Table 4 Mean of squares of the effect oflocation and genotype-location interaction

Source of variance						
	Trial type	Chickpea type	Maturity type	Locations	Location	G×L
Grain yield	NVT	*desi*	Early maturing	Akaki, ChefeDonsa	9.70	0.657
Straw yield					156	149
CP					1017	188
NDF					1295	674
IVOMD					6652	377
Ca					26	1.91†
P					0.077	0.024†
Grain yield	NVT	*kabuli*	Late maturing	Akaki, ChefeDonsa	25.1	1.15
Straw yield					0.26	2.96
CP					145	85
NDF					15674	342
IVOMD					2984	113
Ca					81.2	1.59†
P					2.15	0.11
Grain yield	PVT	*kabuli*	Late maturing	Akaki, ChefeDonsa	46	1
Straw yield					11	3.18
CP					5698	690
NDF					303	825
IVOMD					964	280
Ca					97.5	1.5†
P					1.14	0.079

G×L, genotype-location interaction; †P>0.05 otherwise P≤0.05; CP, crude protein; IVOMD,*in vitro* organic matter digestibility; NDF, neutral detergent fiber; Ca, calcium; P, Phosphorus; NVT, national varieties trial; PVT, preliminary varieties trial.

3.3 Correlations between nutritive value parameters

Table 5 shows the correlations between nutritive value parameters of chickpea straw in each trial. In *desi* types, early and late maturing *kabuli types*, NDF correlated strongly and negatively with IVOMD while other correlations were either moderate or weak.

3.4 The correlation between grain and straw traits

The correlations between grain yield and straw traits are presented in Table 6. Grain yield either correlated positively (P<0.05) or did not correlate to straw yield in all trials. The correlations between grain yield and nutritive value traits straw were insignificant in *desi* trials. In early maturing *kabuli* genotypes, grain yield correlated moderately and positively with NDF (r= 0.396; P<0.05) and Ca (r= 0.347; P<0.05). In late maturing *kabuli* genotypes, the correlation between grain yield and CP was weak and positive in NVT-K-PE-AK(r= 0.28; P<0.05), moderate and positive in PVT-K-PE-AK (r= 0.41; P<0.05) and moderate but negative in NVT-K-PE-CD(r= -0.37; P<0.05). Genotypes in the trial NVT-K-PE-AK showed a weak and negative correlation between grain yield and Ca(r= -0.298; P<0.05). The correlation between grain yield and P was ignored as P content of straw was very low (<1.78 g/kg).

Table 5 Correlations among nutritive value parameters of chickpea straw

	CP	NDF	IVOMD	Ca
Desi				
CP		0.61	-0.553	-0.46
NDF			-0.796	Ns
IVOMD				0.234
Early maturing kabuli				
CP		ns	ns	-0.508
NDF			-0.7	Ns
IVOMD				Ns
Late maturing kabuli				
CP		0.309	-0.324	-0.227
NDF			-0.702	ns
IVOMD				-0.164

CP, crude protein; IVOMD,*in vitro* organic matter digestibility; NDF, neutral detergent fiber.

Table 6 Correlation coefficients between grain yield and straw traits of chickpea

Trial code	Grain yield				
	Straw yield	CP	IVOMD	NDF	Ca
Desi					
NVT-D-AK	0.36	ns	ns	ns	ns
NVT-D-CD	0.62	ns	ns	ns	ns
Early maturing kabuli					
PVT-K-LMS-MN	ns	ns	ns	0.396	0.347
Late maturing kabuli					
NVT-K-PE-AK	0.64	0.28	ns	ns	-0.298
NVT-K-PE-CD	0.65	-0.37	ns	ns	ns
PVT-K-PE-AK	0.53	0.41	ns	ns	ns
PVT-K-PE-CD	0.78	ns	ns	ns	ns

ns, $P > 0.05$ otherwise $P \leq 0.05$; CP, crude protein; IVOMD,*in vitro* organic matter digestibility;
NDF, neutral detergent fiber

4 Discussion

4.1 Grain and straw yields

High demand for crop residue biomass for livestock feeding inEthiopia under mixed systems has been reported (Alkhtib et al., 2016a). Although, genotypes in the current study were bred for high grain production, wide genotypic range in straw yield was found in both *desi* and *kabuli* trials. In agreement with our results, wide genetic variation in grain and straw yields has been reported in several crops including maize (Ertiro et al., 2013), pearl millet (Blümmel et al., 2010) and durum wheat (Tolera et al., 1999). Wide variability in straw yield can be exploited to improve the straw yield of chickpea. The current results showed that effect of genotype on straw yield depends on the location. Such effects of genetic-environment interaction on crop residue yield was reported by (Ertiro et al., 2013) in maize. This suggests that the effect of location should be considered during efforts targeting enhancement of straw yield of both *desi* and *kabuli* chickpea.

4.2 Straw nutritive traits

Significant differences were observed among the various genotypes for straw nutritive value which is in agreement with Kafilzadeh & Maleki (2012). Wide genetic variability in parameters of nutritive value of crop residues has been reported by Ertiro et al. (2013) in maize, Vadiveloo & Fadel (2009) in rice, Singh & Shukla (2010) in groundnut. Crude protein content in feeds is very important to achieve optimum rumen activity in addition to ensure adequate dry matter intake. Risco & Melendez (2011) recommend a minimum of 70-80 g/kg and 100-110 g/kg of CP in the diet of non-lactating and lactating animals to sustain rumen fermentation. The genotype with the highest content of straw CP in this study had a value of 67.5 g/kg, which does not ensure optimum activity of the rumen for non-lactating ruminants. However, crude protein content of crop residue can be improved through agronomic practices, particularly by applying a feasible level of nitrogen fertilization (Blümmel et al., 2007).Rejection of high grain yielding varieties of maize by farmers has been reported because of low dry matter intake of the varieties by livestock (Hellin et al., 2013). Dry matter intake of low-quality roughages is closely and negatively associated with the content of NDF (Horrocks & Vallentine, 1999). Wide genotypic variation in NDF content of chickpea straw was found in this current study. This suggests that dry matter intake of chickpea straw could be improved by exploiting the natural variability in the straw content of NDF. However, dry matter intake is affected by other factors. Thus, it is imperative to test the palatability of straws of chickpea genotypes developed with desired food-feed traits before release. The Ca of chickpea straw in all genotypes except one in PVT-K-LMS-MN was either equal or higher than Ca content of green vetch which was reported to be 12 g/kg (Heuzé et al., 2015). That implies the possibility of improving Ca of chickpea by selection. However, P content of chickpea straw was considerably lower than vetch straws which have been reported to have 1.3 g/kg on average (Heuzé et al., 2015). Thus, no important increase in P content of chickpea straw is expected to be achieved by selection. It is noteworthy that if chickpea straw constitutes a major portion of diet of lactating cattle, mal absorption of Ca could be encountered unless the diet is supplemented by an adequate source of P. Results of this study showed that the content of CP, NDF and IVOMD were dependent on location. Therefore, recommendations of chickpea genotypes with desirable food-feed traits should be location-based. The insignificant effect of GxL on Ca content showed that the relative Ca content of chickpea genotypes is independent of location.

4.3 Correlations among nutritive value parameters

The correlations among nutritive value parameters in all trials were generally moderate or weak (except NDF with IVOMD). The results of study revealed that no single parameter consistently showed strong correlations with the other parameters. That means no single parameter can represent the nutritive value of straw, rather data on chemical composition and digestibility has to be collected for all parameters of nutritive value during screenings of genotypes for straw nutritive value. This result is contrary to Alkhtib et al. (2016b) who reported that NDF can represent the nutritive value of faba bean straw.

4.4 Correlation between the grain yield and straw traits

Correlations between grain yield and straw yield were inconsistent across genotypes and populations, which is in agreement with Ertiro et al. (2013) in maize. Straw yield correlated either positively with grain yield or insignificantly in some trials. That means improving chickpea for straw yield will not decrease grain yield. The correlation between grain yield and straw yield was inconsistent across trials in all types of chickpea. That means grain yield cannot be used to predict straw yield in chickpea. Whenever straw yield is considered as a selection criteria by chickpea breeders, it has to be measured alongside grain yield. The correlation between grain yield and straw nutritive value parameters were either insignificant or less than 0.41 ($r^2<0.16$). That means that no significant change in grain yield of chickpea would be associated with any improvement of straw nutritive value. This is in agreement with Alkhtib et al. (2016b) who reported neutral relationships between grain yield and straw nutritive value in faba bean.

Conclusion

The existence of wide ranges among genotypes for grain and straw yields and straw nutritive traits is promising for selection of genotypes with superior food-feed traits. The weak relationship between grain and straw traits in most of the trials implies the independent improvement of both food and feed traits. However, currently, breeding programs do not consider straw traits as criteria either for varietal evaluation or for release of new genotypes. Chickpea improvement efforts should give attention to p-investigated. Data on the straw nutritive value in the current study is based on *in vitro* evaluation, therefore, there is need to confirm these results with animal performance trials before giving final recommendations to farmers. Chickpea straw has high content of Ca, but a very low content of P. When chickpea straw is used as a basal diet for lactating livestock, a feasible supplementation of chickpea straw with a source of P has to be applied to ensure an optimum utilization of ca. This study shows promise to the possibility for simultaneous improvement of grain yield and straw traits to address the high demand existing for dual-purpose, food-feed type of chickpea genotypes in mixed crop-livestock farming systems using appropriate breeding approaches.

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Conflict of Interest

Authors would hereby like to declare that there is no conflict of interest that could possibly arise.

References

Adeyanju A, Ishiyaku M, Echekwu C, Olarewaju J (2012) Generation mean analysis of dual purpose traits in cowpea (*Vigna unguiculata*). African Journal of Biotechnology 11 : 10473-10483.

Alkhtib, A., Wamatu J, Ejeta T, Rischkowsky B (2017) Integrating the straw yield and quality into multi-dimensional improvement of lentil (*Lens culinaris*). Journal of the Science of Food and Agriculture, 97: 4135–4141.

Alkhtib A, Wamatu J, Kassie G, Rischkowsky B (2016a) Analysis of crop residue use in small holder mixed farms in Ethiopia. Renewable Agriculture and Food Systems 32:454-462.

Alkhtib A, Wamatu J, Wegi T, Rischkowsky B (2016b) Variation in the straw traits of morphological fractions of faba bean (*Vicia faba L.*) and implications for selecting for food-feed varieties. Animal Feed Science and Technology 222: 122-131.

Ali Q, Ahsan M (2012) Estimation of genetic variability and correlation analysis for quantitative traits in chickpea (*Cicer arietinum L.*). International Journal for Agro Veterinary and Medical Sciences 6: 241-249.

AOAC (2000) Official Methods of Analysis. AOAC International, Gaithersburg.

Aslamshad M, Pervez H, Zafar Z, Zia-Ul-Haq M, Nawz H (2009) Evaluation of biochemical composition and physiochemical parameters of from seeds of *desi*chickpea varieties cultivation in arid zones of Pakistan. Pakistan Journal of Botany 41: 655-662.

Bampidisa V, Christodoulou (2011) Chickpeas (*Cicer arietinum L.*) in animal nutrition: A review. Animal Feed Science and Technology 168: 1-20.

Blümmel M, Bindinger F, Hash C (2007) Management and cultivar effects on ruminant nutritional quality of pearl millet (*Pennisetum glaucum (L.) R, Br.*) Stover. II. Effects of cultivar choice on stover quality and productivity. Field Crops Research 103: 129-138.

Blümmel M, Khan A, Vadez V, Hash C, Rai K(2010) Variability in stover quality traits in commercial hybrids of pearl millet (*Pennisetum glaucum (l.) r. br.*) and grain-stover trait relationships, hybrids. Animal Nutrition and Feed Technology 10S: 29-38.

Ertiro B, Twumasi-Afriyie S, Blümmel M, Friesen D, Negera D, Worku M, Abakemal D, Kitenge K (2013) Genetic variability of maize stover quality and the potential for genetic improvement of fodder value. Field Crops Research 153: 79-85.

Hellin J, Ernstein O, Beuchelt T, Camacho C, Flores D(2013) Maize stover use and sustainable crop production in mixed crop-livestock systems in Mexico. Field Crops Research 153: 12-21.

Heuzé V, Tran G, Baumont R(2015) Common vetch (*Vicia sativa*). Feedipedia, a programme by INRA, CIRAD, AFZ and FAO. Available on http://feedipedia.org/node/239 access on 25th April, 2016.

Horrocks RD, Vallentine JF (1999) Harvested Forages. Academic Pres, UK.

Kafilzadeh F, Maleki E(2012) Chemical composition, *in vitro* digestibility and gas production of straws from different varieties and accessions of chickpea. Journal of Animal Physiology and Animal Nutrition 96: 111-118.

Kassie M, Shiferaw B, Asfaw S, Abate T, Muricho G, Ferede S, Eshete M, Assefa K (2009) Current situation and future outlooks of the chickpea sub-sector in Ethiopia.EIAR (Ethiopian Institute of Agricultural Research) and ICRISAT (International Crops Research Institute for the Semi-Arid), India.

Malik S, Bakhsh A, Ahsan M, Iqbal U, Iqbal S (2009) Assessment of genetic variability and interrelationship among some agronomic traits in chickpea. International Journal of Agricultural Biology 12: 814-9596.

Menke K, Raab L, Salewski A, Steingass H,Fritz D, Schneider W (1979) The estimation of thedigestibility and metabolisable energy content of ruminant feeding stuffs from the gas production when they are incubated with rumen liquor.Journal of Agricultural Science 93:217-222.

MenkeK, Steingass H (1988) Estimation of the energetic feed value from chemical composition and *in vitro* gas production using rumen fluid. Animal Research and Development 28:7-55.

Risco C, Melendez P (2011) Dairy cattle diseases. Wiley-Blackwell, Iowa.

Samireddypalle A, Boukar O, Grings E, Fatokun CA, Kodukula P, Devulapalli R, Okike I, Blümmel M (2017) Cowpea and groundnut haulms fodder trading and its lessons for multidimensional cowpea improvement for mixed crop livestock systems in West Africa. Frontiers in Plant Science 8:1-9.

SAS (2012)SAS/STAT 12.1 User's GuideSAS Inc., Cary, NC, USA.

Singh S, Shukla G (2010) Genetic diversity in the nutritive value of dual purpose sorghum hybrids. Animal Nutrition and Feed Technology 10S: 93-100.

Perkin-Elmer Corporation (1996) Analytical methods for atomic absorption spectroscopy, USA.

Tolera A, Trygve B, Frik S (1999) The effect of variety on maize grain and crop residue yield and nutritive value of the stover. Animal Feed Science and Technology 79: 165-177.

Vadiveloo J, Fadel J (2009) The response of rice straw varieties to urea treatment. Animal Feed Science and Technology 151: 291-298.

Van Soest P, Robertson J (1985) Analysis of forage and fibrous foods, a laboratory manual for Animal Science. Cornell University, New York.

Wamatu J, Mersha A, Tolera A, Beyan M, Alkhtib A, Eshete M, Ahmed S, Rischkowsky B (2017) Selecting for food-feed traits in early and late maturing lentil genotypes (*Lens culinaris*). Journal of Experimental Biology and Agricultural Sciences 5: 697–705.