RESEARCH PROGRAM ON Livestock and Fish

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More meat, milk and fish by and for the poor

Opportunities from multi-dimensional crop improvement and the supporting role of Near Infrared Spectroscopy(NIRS) networks

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ICARDA Science for Better Livelihoods in Dry Areas

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CIAT International Center for Tropical Agriculture Since 1967 / Science to cultivate change

SLU

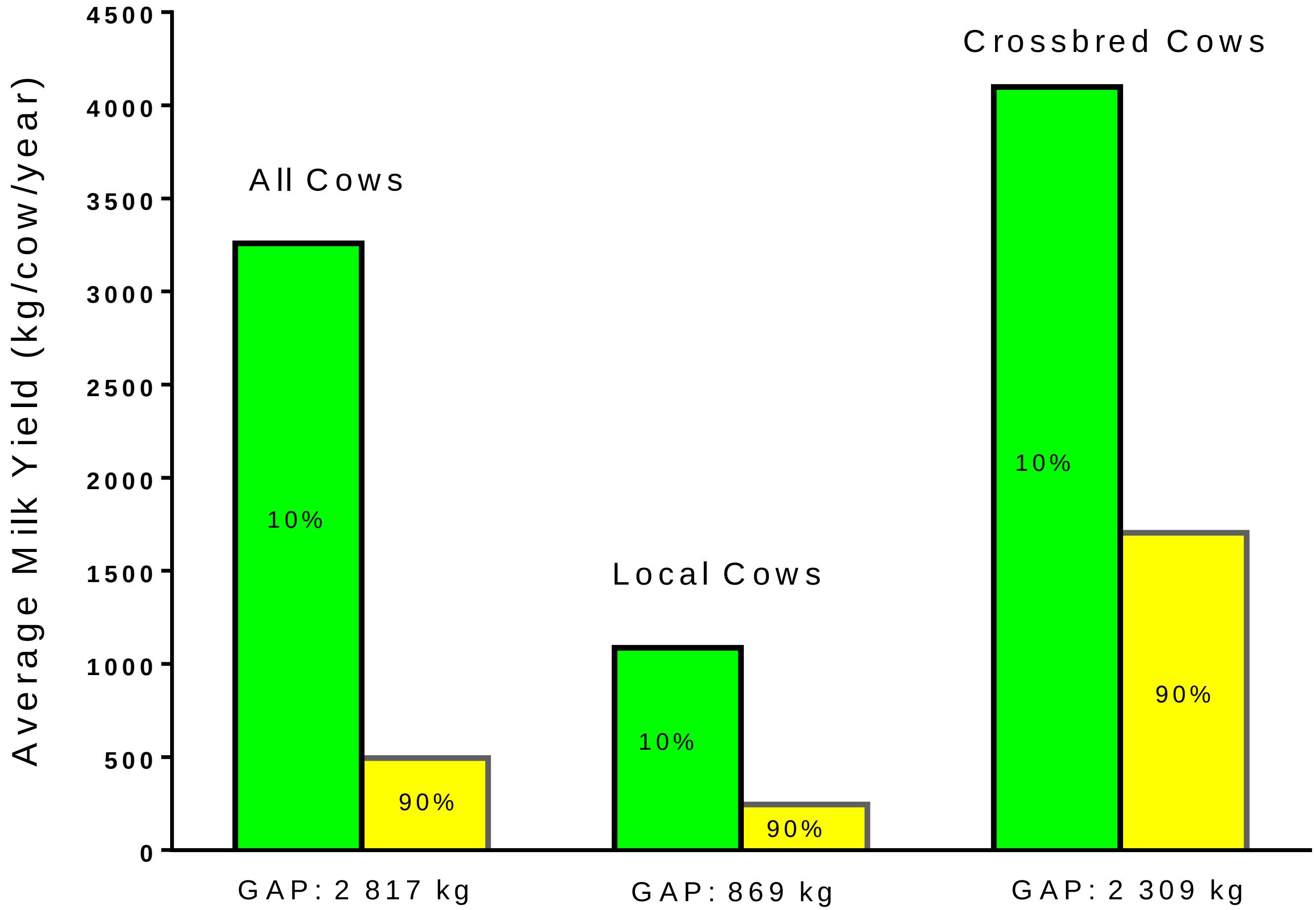
Topics

- Why pay attention to crop residues: feed supply-demand scenarios, context, fodder markets
- Impact of differences in crop residue fodder quality on livestock productivity
- Exploit existing cultivar variations and targeted genetic enhancement, trade-offs
- NIRS hubs as logistical support infrastructure for phenotyping in multidimensional crop improvement

Feed resource supply - demand scenarios in India

Feed resource	Contribution to overall feed resources (%)
Greens from CRP, forests, grazing	8.0
Planted forages	15.1
Crop residues	70.6
Concentrates	6.3
Deficit: feed availability versus feed requirement (%)	
Dry matter (i.e. crop residue quantity)	-6
Digestible crude protein	-61
Total digestible nutrients	-50

(NIANP 2012; Blümmel at al. 2014)



Yield differences in milk production between the 10% most productive farmers and the remaining 90% in India when managing comparable dairy genetics

(Derived from VDSA-India 2013 and Blümmel et al. 2016b)

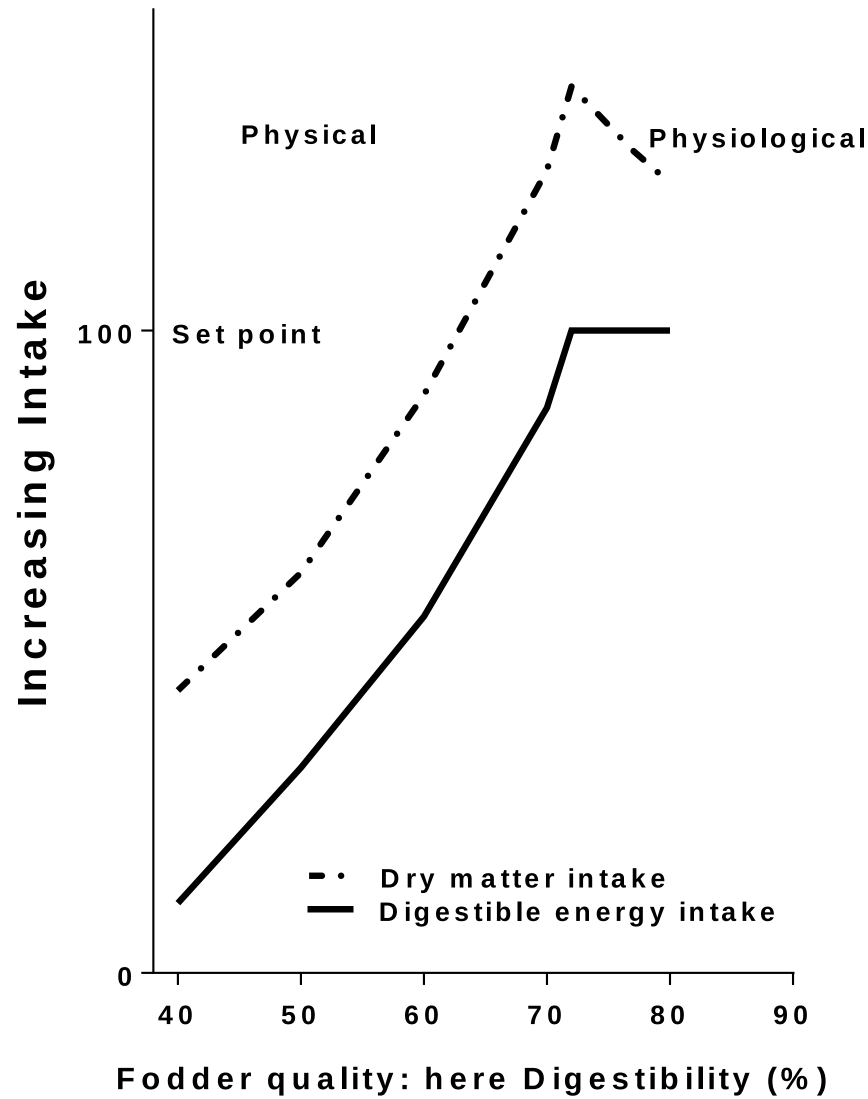
Crop residues are becoming more important

Kahsay Berhe (2004) study in Yarer Mountain area

Table 24. Area under different land use categories in 1971/72 and 2000

Land cover types	Area in 1971/72 (ha)	(%)	Area in 2000 (ha)	(%)
Agriculture	7186	25	16204	56.38
Forestry	2581	8.99	2696	9.37
Water reservoirs	190	0.66	312	1.09
Wetlands	0	0	132	0.46
Pasture	18784	65.35	9397	32.7
Total	28741	100	28741	100

- Cultivated land has doubled at the expense of pasture in 30 years
- Switch in source of nutrition for livestock from grazing to CR

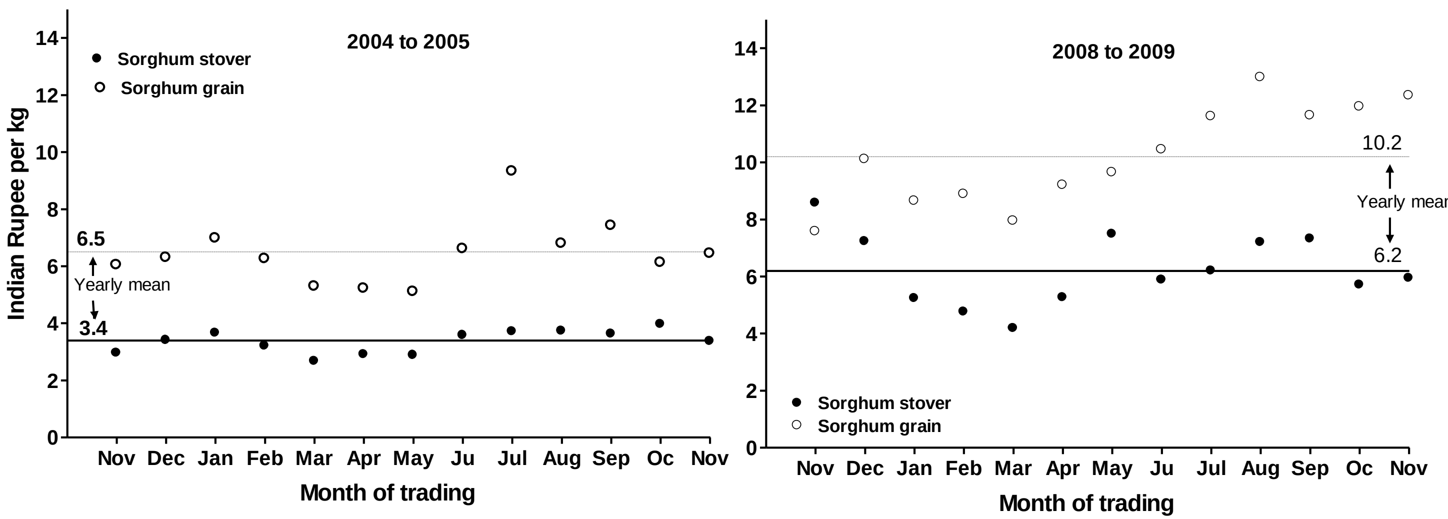


Relationship between fodder quality and voluntary feed intake

Sorghum stover trading in Hyderabad

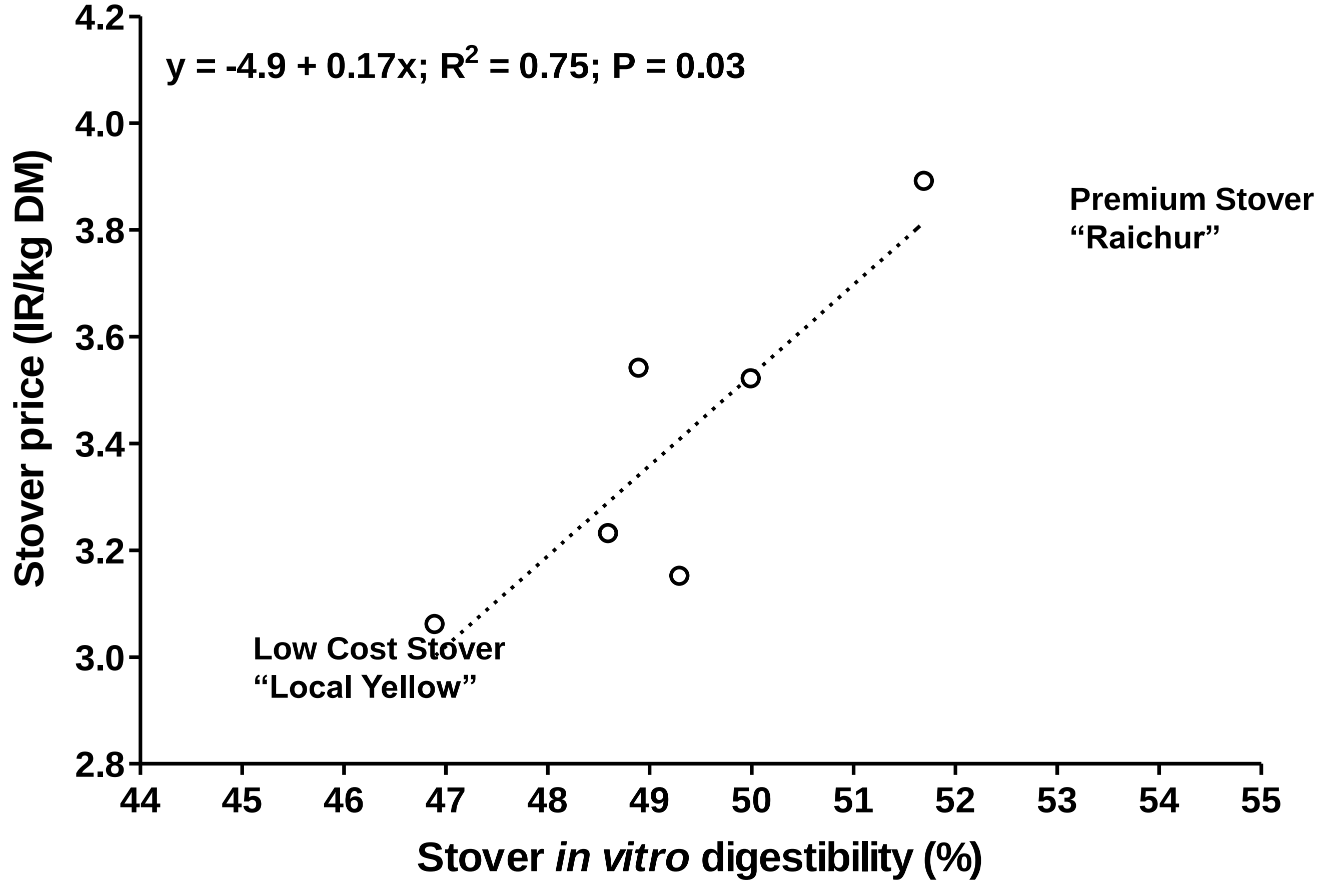
Changes in grain: stover value in sorghum traded in Hyderabad from 2004-5 to 2008-9

Comparisions of average cost of dry sorghum stover traded in Hyderabad and average of cost of sorghum grain in Andhra Pradesh 2005 to 2005 and 2008 to 2009



Sharma et al. 2010

Relation between digestibility and price of sorghum stover



Blümmel and Parthasarathy, 2006

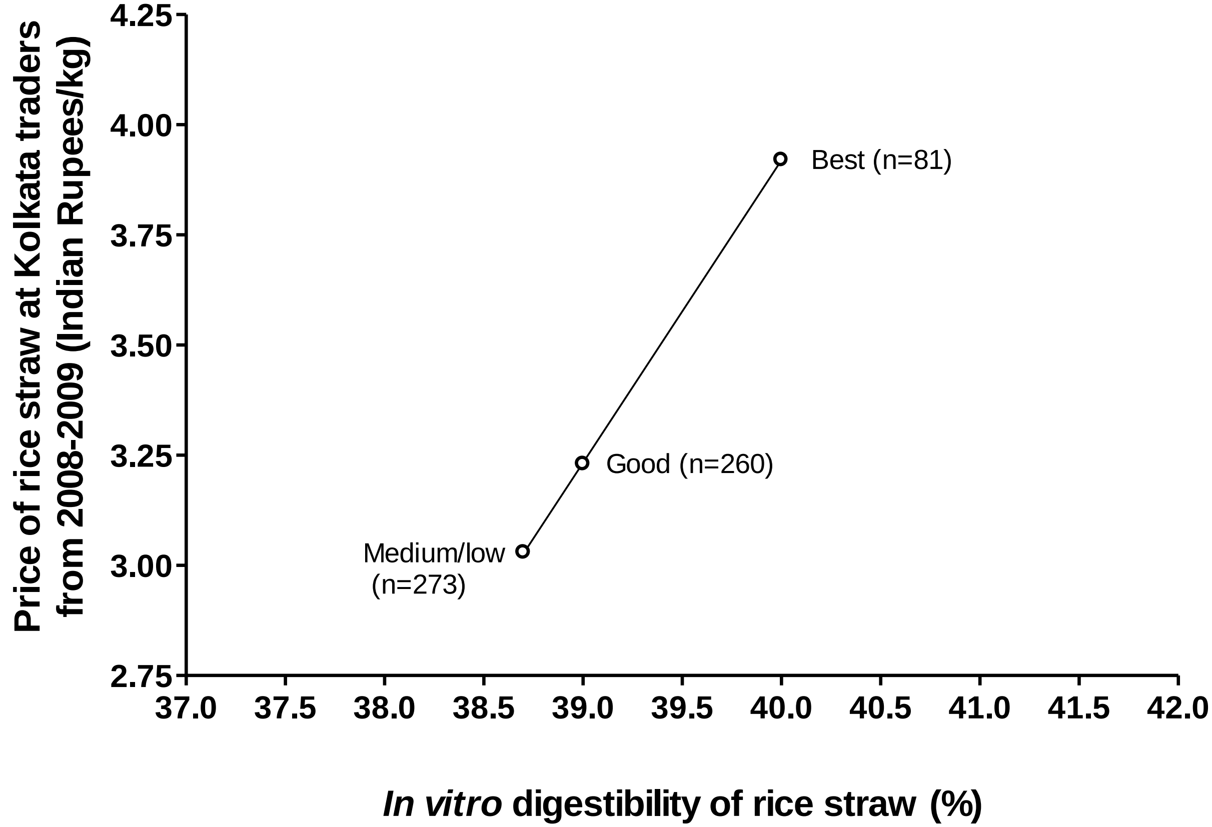
Price variations in different sorghum stover traded concomitantly in Mieso in April 2007

Stover	ETB/kg Trader	ETB/kg Farm
Sweet Sorghum (SS)	0.65	0.20
"Grain" Sorghum (GS)	0.50	0.13
Price premium	30%	54%

Note: In India SS stover have about 3-4 units higher digestibility than GS stover

Source: calculated from Gebremedhin et al. 2009

Price: quality relations in rice straw traded monthly in Kolkata from 2008 to 2009



Teufel et al. (2012)

Conclusions: why pay attention to crop residues as fodder

- Feed supply – demand scenarios underline key role of crop residues as feed sources
- Fodder market surveys show high monetary value, narrowing crop residue-grain price ratios
- Driving factor: more quality fodder required with shrinking natural resource basis

Impact of variations in crop residue fodder quality on livestock productivity

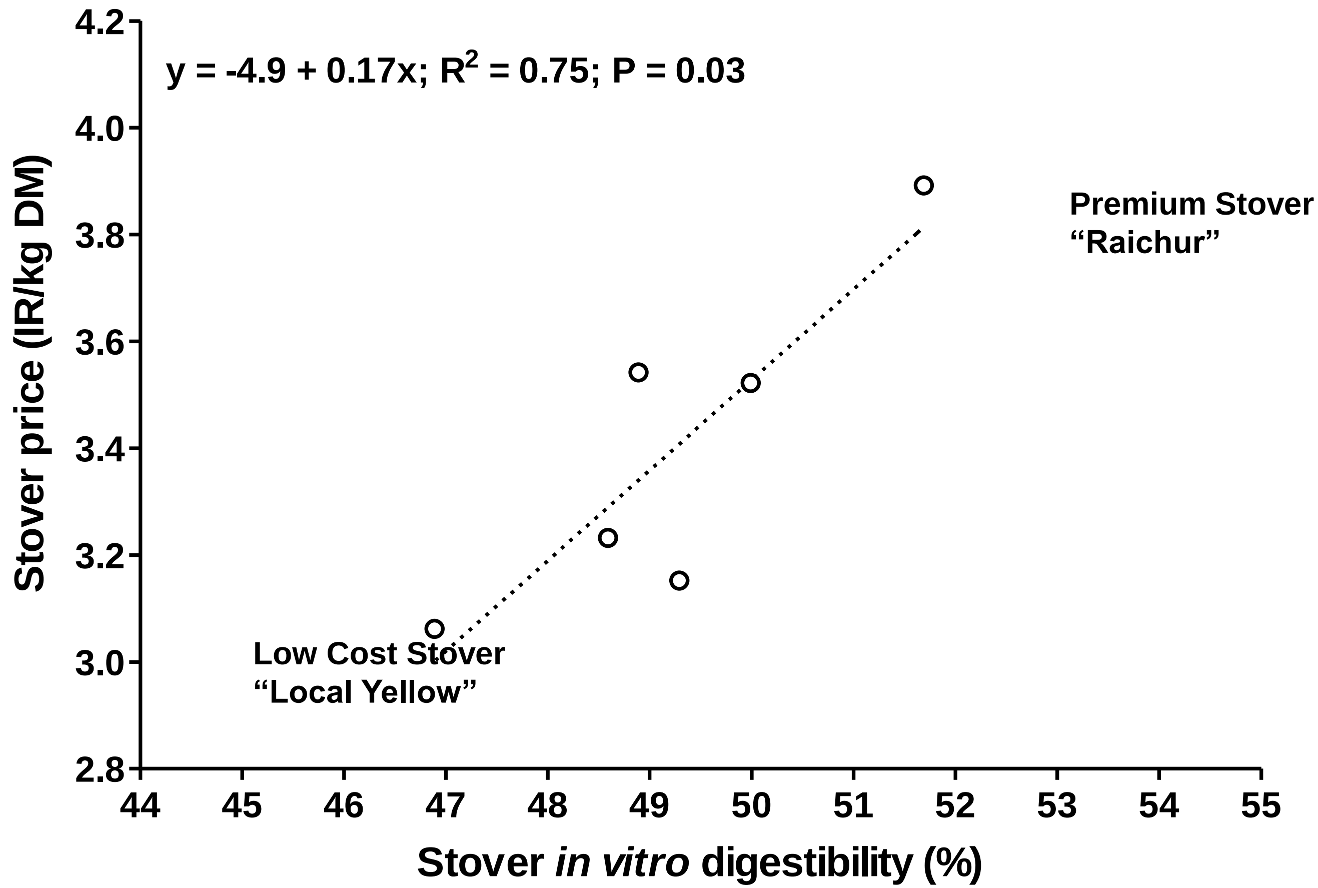
- Effect of superior stover as basal diet
- What magnitude of fodder quality difference matter and why
- Livestock productivity levels on entirely crop residue based diets

Feed block manufacturing: supplementation, densification

Ingredients	%
Sorghum stover	50
Bran/husks/hulls	18
Oilcakes	18
Molasses	8
Grains	4
Minerals, vitamins, urea	2

Courtesy: Miracle Fodder and Feeds PVT LTD

Relation between digestibility and price of sorghum stover



Blümmel and Parthasarathy, 2006

Comparisons of feed blocks based on lower (47%) and higher (52%) digestible sorghum stover and tested with commercial dairy buffalo farmer in India

	Block Premium	Block Low
CP	17.2 %	17.1%
ME (MJ/kg)	8.46 MJ/kg	7.37 MJ/kg
DMI	19.7 kg/d	18.0 kg/d
DMI per kg LW	3.8 %	3.6 %
Milk Potential*	15.5 kg/d	9.9 kg/d

* 21 and 14 kg/d in crossbred cattle

Modified from Anandan et al. (2009a)

Live weight gains in Indian Deccan sheep fed exclusively on groundnut haulms

Groundnut cultivars	Gain (g/d)
ICGV 89104	137
ICGV 9114	123
TMV 2	111
ICGS 76	76
ICGS 11	76
DRG 12	66
ICGS 44	65
ICGV 86325	83
ICGV 92020	95
ICGV 92093	109
Prob > F	0.02

Prasad et al. 2010

Live weight changes in Ethiopian Arsi-Bale sheep fed exclusively on Faba bean straws

Cultivars	Grain Yield	Straw Yield	Weight Gain (g/d)
Mosisa	4.28[a]	5.68[a]	52.2[ab]
Walki	4.21[a]	4.42[c]	64.6[a]
Degaga	4.20[a]	4.31[c]	43.2[bc]
Shallo	4.06[a]	4.98[b]	37.5[c]
Local	2.89[b]	3.65[d]	48.3[bc]

Wegi et al., 2016

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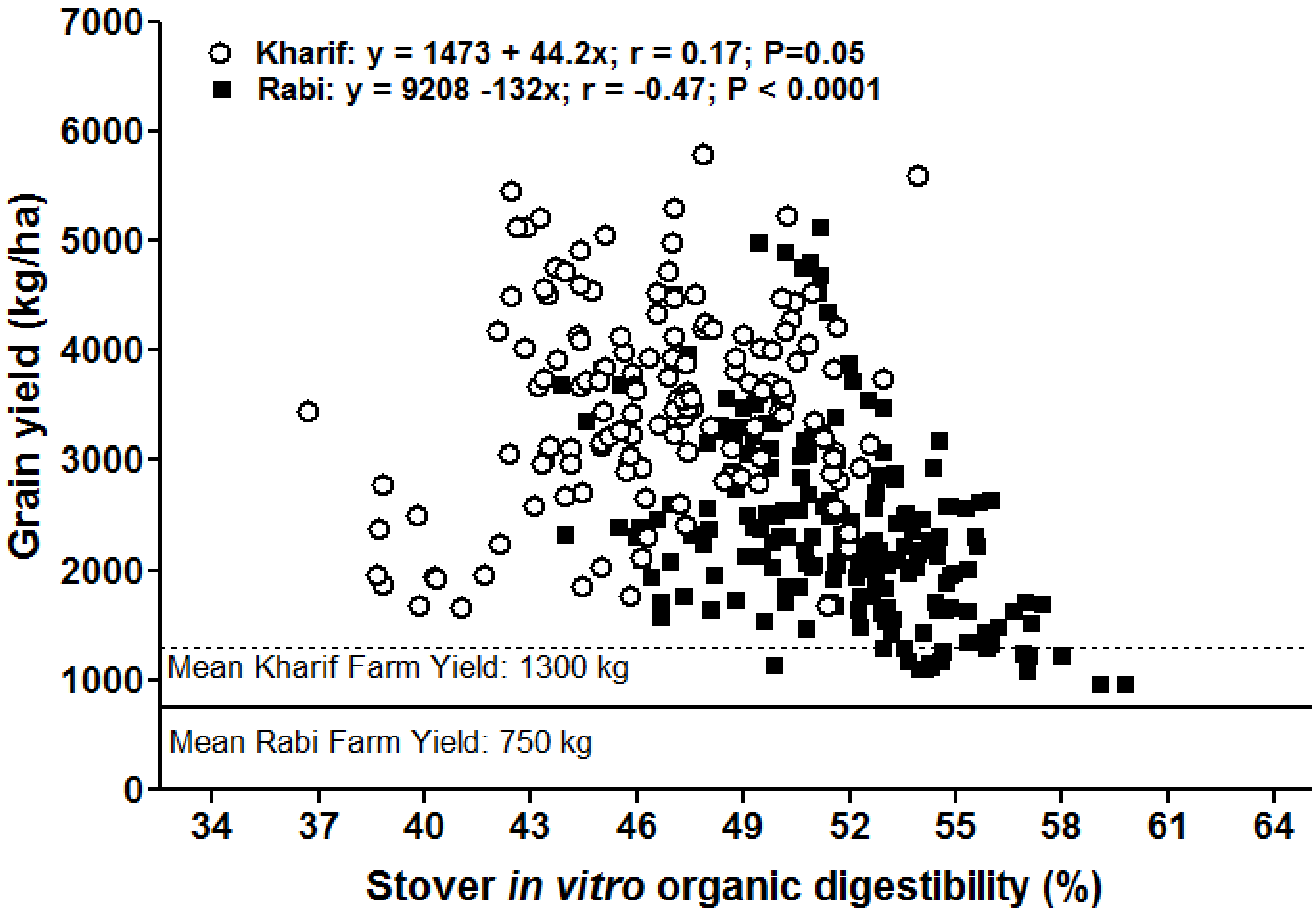
Conclusions: Impacts of variations in crop residue fodder quality on livestock productivity

- "Intuitively" small difference in fodder quality of stover do matter: additive effect of higher diet quality and higher intake

- Informed choice of cultivar can have very substantial effect on livestock productivity

Exploit existing cultivar variations

- Phenotyping new cultivars submitted for release testing for fodder traits
    - Laboratory infrastructure: stationary NIRS, mobile NIRS
- Phenotyping during crop improvement for fodder traits



Stover fodder trait analysis in new sorghum cultivar release testing in India 2002 to 2008

(Blümmel et al. 2010)

South-south transfer of superior dual purpose sorghum cultivars: tested 2 years x 3 locations in Ethiopia

Cultivar	**CP %**	**IVOMD %**	**ME MJ/kg**	**SY kg/ha**
ICSC 93046	7.6	58.8	8.87	15 814
ICSV 91005	7.5	58.3	8.75	17 734
ICSR 196	7.9	55.2	8.19	10 386
ICSR 56	6.9	54.8	8.23	9 698
NT J2	6.6	54.8	8.19	11 675
E-36-1	7.0	53.7	8.00	9 256
ICSR 93034	6.6	53.6	8.00	10 176
A 2267-2	6.3	52.6	7.82	10 046
Seredo	6.1	52.6	7.86	8 069
ICSV 96143	6.6	51.8	7.64	6 295
WSV-387	6.5	51.7	7.64	7 911
ICSV 111	5.9	50.8	7.56	7 372
		Statistical summary		
LSD	0.5	1.6	0.25	1 726
h^2	0.65	0.49	0.50	0.47

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Adie et al. 2016

Conclusions: exploit existing cultivar variations

- Livestock nutritionally-significant variations exist in all key cereal and legume crops (except perhaps wheat)
- Short impact pathways, quick, relatively little investment
- Modifying cultivar release criteria promising entry point

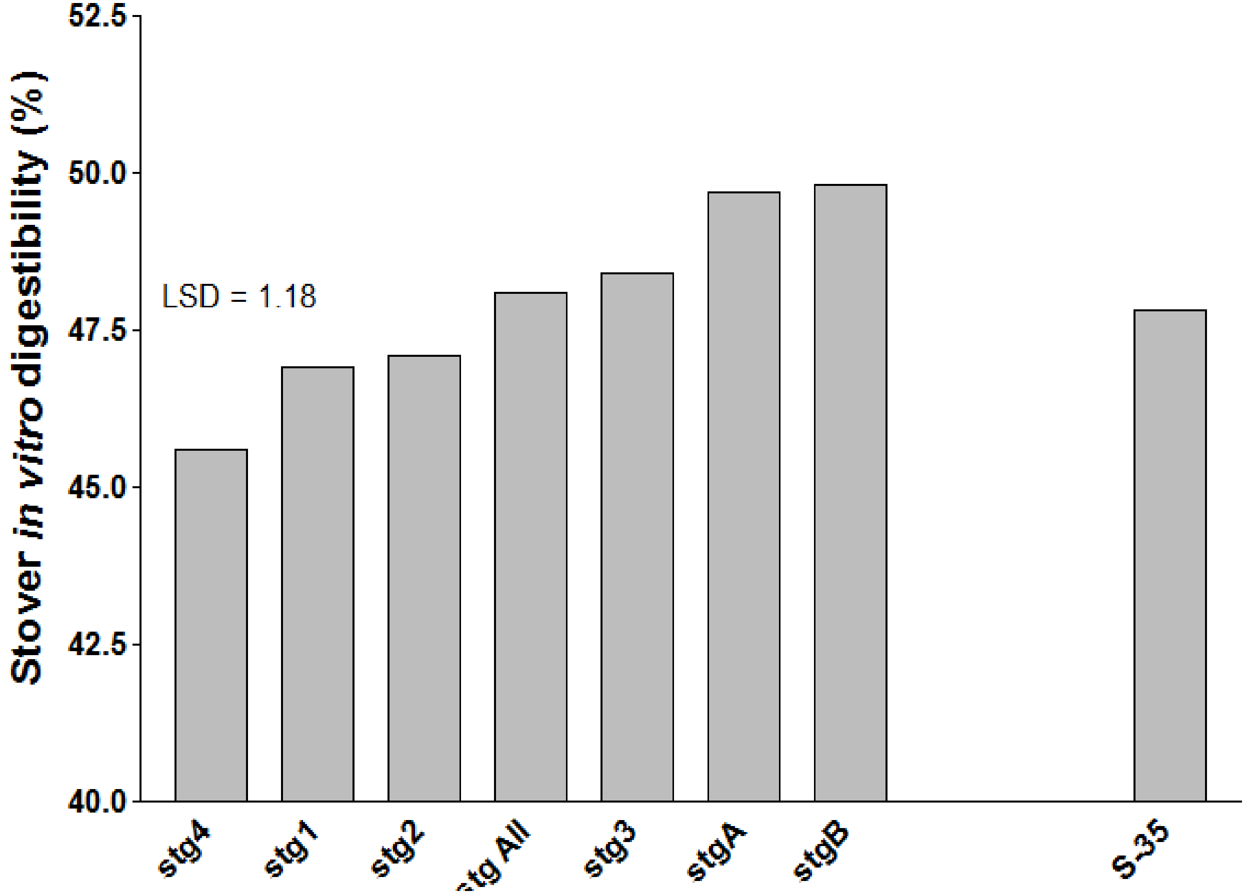
Targeted genetic enhancement

- Targeted genetic enhancement towards dual and multi purpose traits
  - Conventional breeding (recurrent selection, hybridization)
  - Molecular breeding (QTL introgression, Genetic selection)

Response in stover *in vitro* digestibility to 2 cycles of selection of pearl millet variety ICMV 221

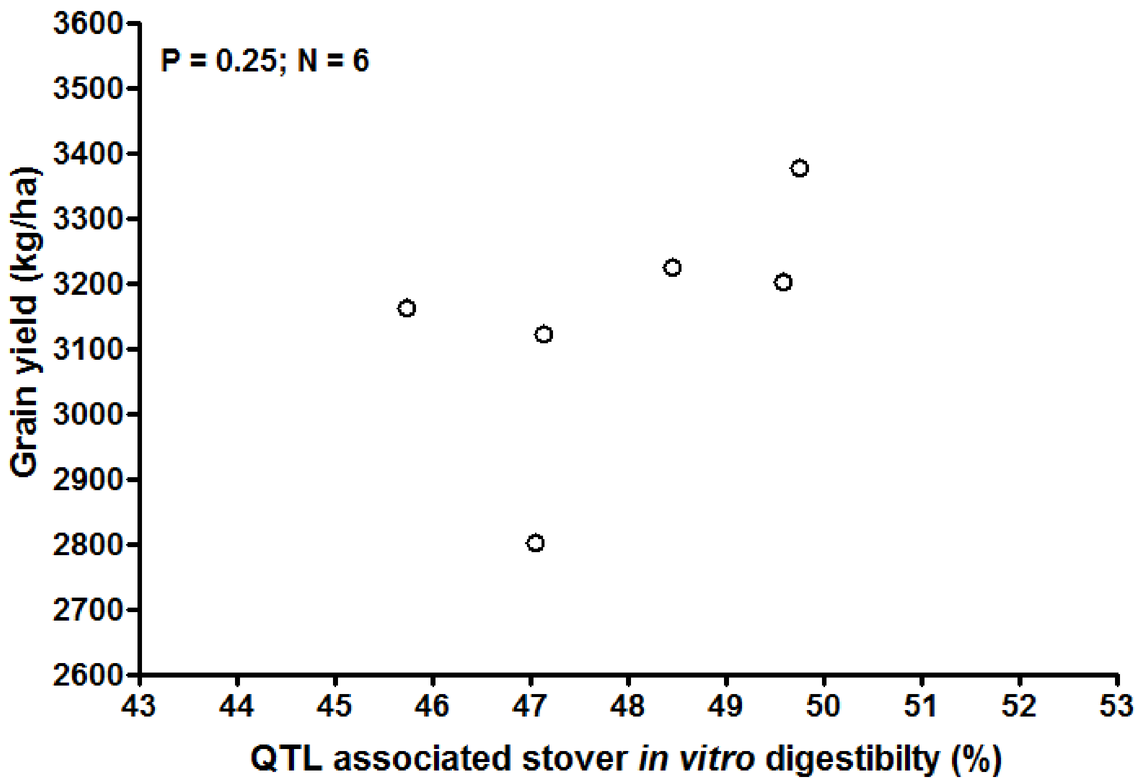
	Digestibility %	Grain Yield kg/ha	Stover yield kg/ha
Original	43.6	2 669	3 095
H1	44.5	2 596	3 460
L1	42.1	2 592	2 889
H2	45.8	2 564	3 168
L2	42.0	2 408	2 731

Choudhary et al (in preparation)



Effect of introgression of different stay green QTL's on stover digestibility of a Rabi sorghum background

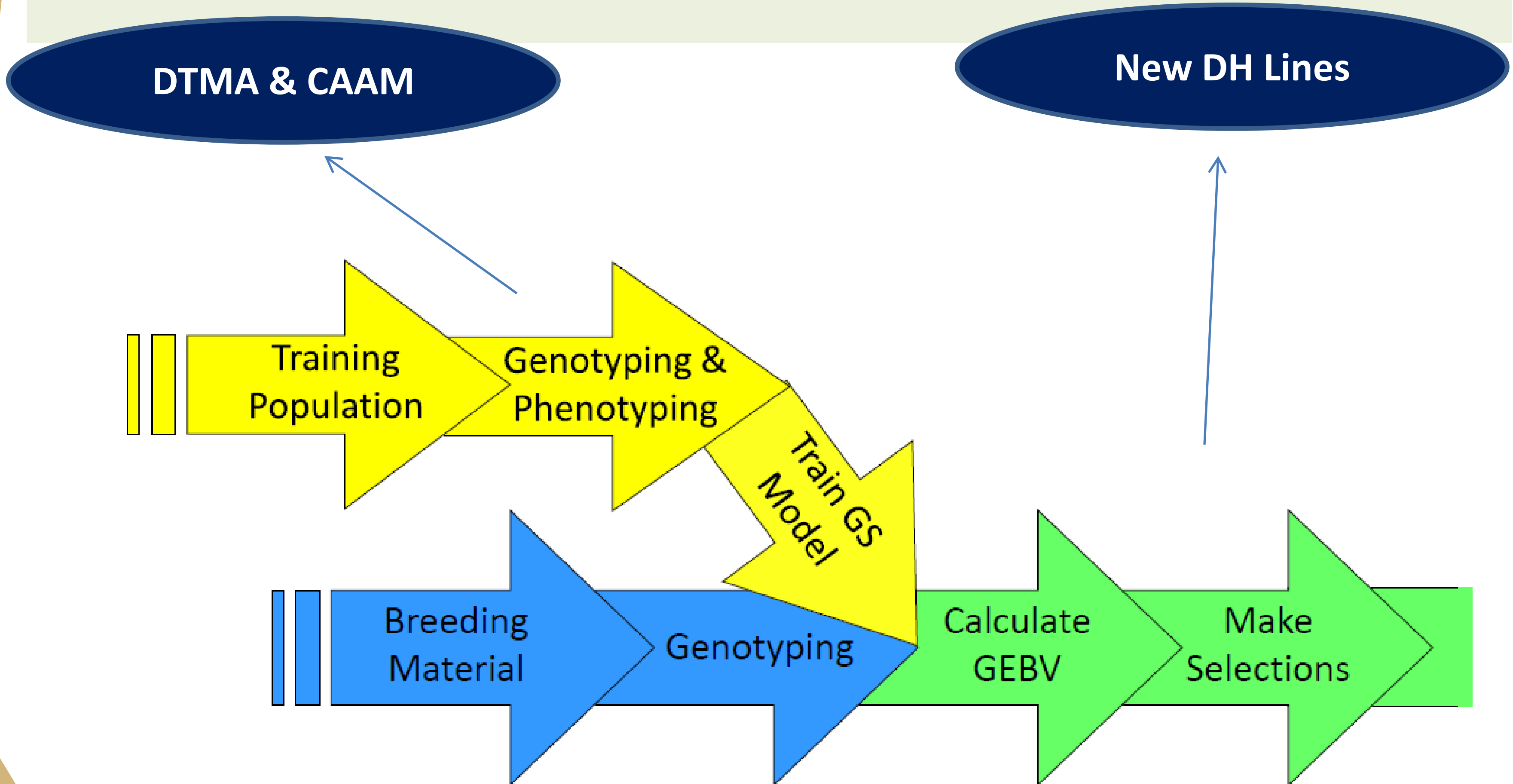
(Blümmel at al. 2015)



Relationships between QTL associated stover digestibility and grain yields in S-35 background across years and treatments

(Blümmel at al. 2015)

Dual Purpose Maize: Genomic Selection



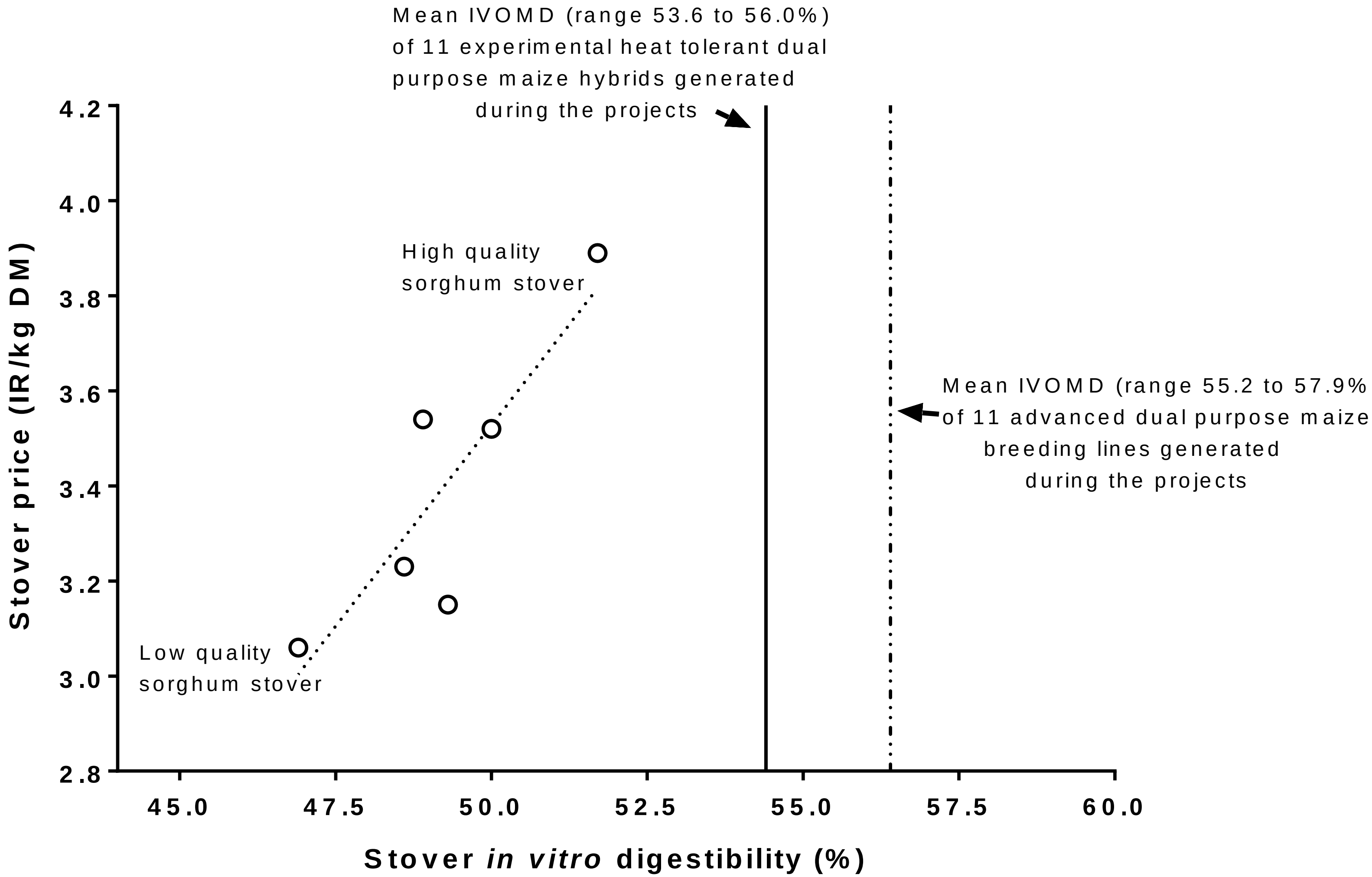
(Babu et al. 2016)

Predicting performance of DH maize lines for fodder quality

ID	IVOMD - Predicted	IVOMD-Observed
DH_9_157	High IVOMD and ME	57.1
DH_3_33	High IVOMD and ME	56.7
DH_3_63	High IVOMD and ME	55.8
DH_9_15	High IVOMD and ME	55.7
DH_8_4	High IVOMD and ME	55.6
DH_3_149	High IVOMD and ME	55.5
DH_3_24	High IVOMD and ME	55.4
DH_6_1	Low IVOMD and ME	55.4
DH_3_10	High IVOMD and ME	55.0
DH_3_21	High IVOMD and ME	54.9
DH_3_138	High IVOMD and ME	54.6
DH_3_35	High IVOMD and ME	54.5
DH_3_61	High ME	54.4
DH_3_83	High IVOMD and ME	54.1
DH_9_165	High IVOMD	53.6
DH_9_134	High IVOMD	53.6
DH_9_153	High IVOMD and ME	53.5
DH_3_47	High IVOMD and ME	53.4
DH_3_62	High IVOMD and ME	53.4
DH_3_87	High IVOMD and ME	53.4
DH_3_82	High IVOMD	53.3

HTMA - GS	Pred. Accuracy
IVOMD	0.44
ME	0.45

(Babu et al.2016)



Breeding advance in dual purpose maize stover fodder quality relative to different sorghum stover traded in rainfed India in the past decade

Blümmel et al. (2016a)

Conclusions: targeted genetic enhancement

- Longer term, higher investments
- Great impact opportunities
- Multi-trait options
- New tools becoming available and more affordable

Required infrastructure for phenotyping for crop residue fodder quality

- Stationary Near Infrared Spectroscopy (NIRS)
- Mobile NIRS

Qualitative trait prediction in plant breeding based on Near Infrared Spectroscopy (NIRS)

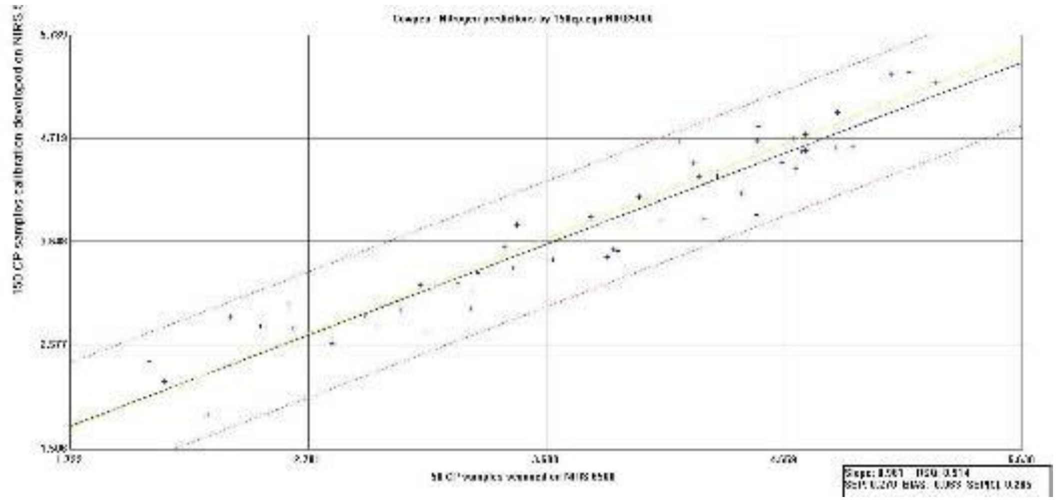
Physico-chemical
***c.* 60 000 US $**
Calibration
Validation

Non-evasive
***c.* 200 samples/d**
>30 traits

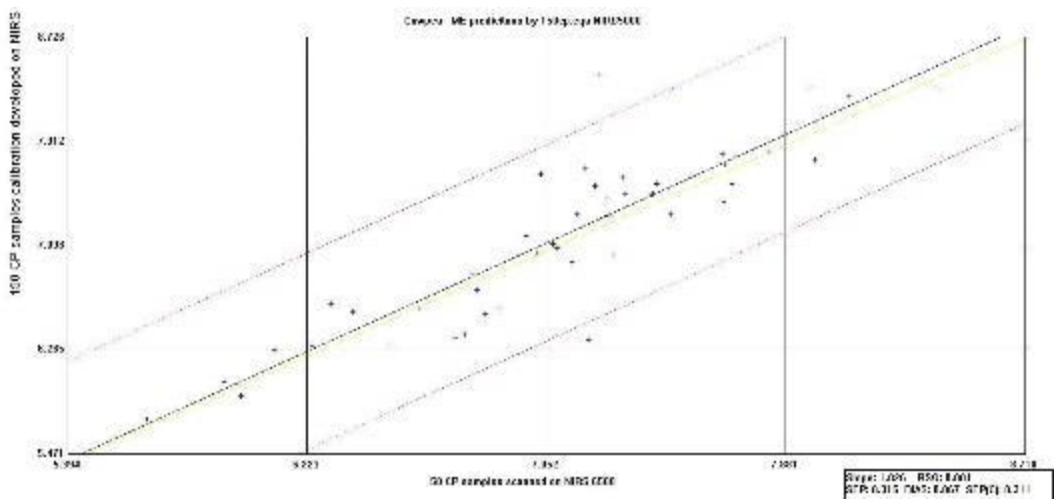
NIRS equations sharable across compatible instruments

Transfer of NIRS equations for phenotyping for fodder quality traits: example cowpea

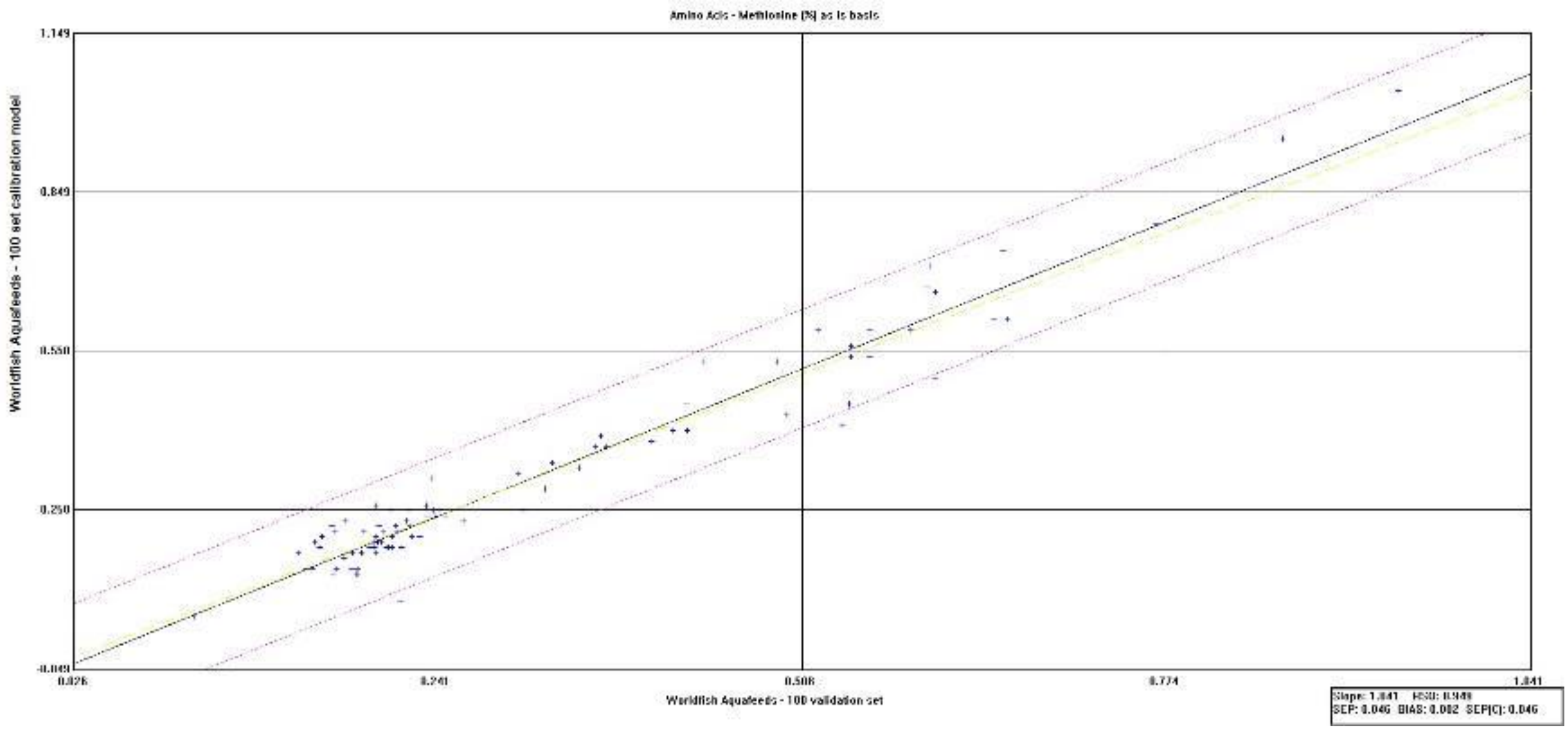
ILRI FOSS 5000



ILRI FOSS 6500



Methionine Prediction by NIRS



Mobile handheld NIRS

- About 40 000 US$ but price decreasing

- Application currently developed and validated at ILRI India and Ethiopia

Phazir ➡

⬅ Luminar 5030

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Conclusions: NIRS infrastructure for phenotyping in multidimensional crop improvement

- Multi-dimensional crop improvement can be mainstreamed using NIRS
- NIRS hubs minimize new investments and optimze older ones (South Asia, East Africa, West Africa)
- Sample grinding the real bottleneck and rate limiting procedure
- Mobile NIRS a way out?

Where to go from here

- ❑ Develop the East African NIRS hub based on ILRI-EIAR-Private Sector collaboration
- ❑ Screen released and pipeline key cereal and legumes crops for food-feed-fodder traits
- ❑ Explore feed and fodder value chains around improved crop residues

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