RESEARCH PROGRAM ON Livestock

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Research report

Improved sorghum and pearl millet forage cultivars for intensifying dairy systems

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ILRI INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE

ICARDA Science for Better Livelihoods in Dry Areas

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1. DESCRIPTION OF PROGRESS DURING REPORTING PERIOD

Improved sorghum and pearl millet forage cultivars for intensifying dairy systems

Activities

Activities were structured around the three objectives outlined in the work plan: 1) Identify sorghum and pearl millet forages with superior fodder quantity and quality and initiate dissemination to dairy producers, 2) Screen diverse germplasm sources of sorghum and pearl millet for superior forage quantity and quality and identify promising parental lines; and 3) Explore the feasibility of specialized small holder maize, sorghum and pearl millet forage production as a cash crop.

Objective 1): Released and pipeline cultivars of sorghum and pearl millet forages were analysed in the laboratory followed by on-station livestock productivity trials with sheep at the ILRI research facility in Patancheru in India. Selected cultivars were then comprehensively tested with dairy animals in institutionally different contexts with Dodla Dairy Pvt Ltd, a private sector dairy company working with 250 000 small holders in India and operating a dairy experimental research and extension farm in a public - private partnership with the state of Andhra Pradesh, the Mulkanoor Women Dairy Cooperative comprising more than 21 000 women dairy farmers, and with individual small-holder farmers. The performance of sorghum and pearl millet cultivars in terms of milk production was compared with maize forages (Dodla Dairy) and with the respective forage and green grass feeding systems practiced by the Mulkanoor Women Cooperative and individual farmers.

Objective 2): Sorghum and pearl millet forage lines, accessions and cultivars from the national Indian system (Indian Institute for Millet Research, IIMR, Indian Grassland and Fodder Research Institute, IGFRI) the CG (International Crops Research Institute for the Semi-Arid Tropics, ICRISAT) and private sector seed industry (Advanta) have been analyzed in the laboratory for forage quality traits (protein, neutral (NDF) and acid (ADF) detergent fibre, acid detergent lignin (ADL), *in vitro* organic matter digestibilities (IVOMD), metabolizable energy (ME) content and anti-nutritional factors such as HCN), G x E effects, relationships between forage quality and forage biomass and mode of genetic inheritance of forage quality traits. Lines have been identified that increase sorghum and pearl millet forage biomass and fodder quality under a wide range of biophysical and management conditions.

Objective 3): Opportunities from forage production as a cash crop were explored through market surveys of forage trading for urban and peri-urban dairy production, contract farming, and independent small holder forage production. The green forage markets in greater Hyderabad were surveyed monthly by phone to ascertain what forages were sold and at what prices. The markets were physically visited quarterly to collect forage samples and to investigate forage price –

quality relationships. Options for forage contract farming were investigated with Dodla Dairy that created arrangements to buy green maize and sorghum forages from 1 200 small holders. Dodla Dairy send forage harvesters when forages were planted on adjoining (individual or accumulating) 10 acres. Farmers could also deliver green forages to the dairy receiving about 20% higher prices.

Please report on activities as outlined in your work packages for the period covered by this report and describe any changes to this, including the reasons for these. Do include any additional activities undertaken that are not in your work packages, providing the background to their inclusion.

Outputs

Please present the outputs the project has produced during the reporting period and comment on their quality.

1) Identify sorghum and pearl millet forages with superior fodder quantity and quality and initiate dissemination to dairy producers

- Seven sorghum and five pearl millet commercial forages were compared with a reference maize forage *in vitro* and *in vivo* and while sorghum forages resulted in a similar nitrogen balance in sheep of about 3 to 4 g/day, pearl millet supported nitrogen balances were below 1 g per day [Objective 1-Table 1, page 7]
- One superior multi-cut annual sorghum (CHS 24 MF) and 2 pearl millet (ICMV 15111 and ICMV 05777 from ICRISAT cultivar release work) forage cultivars have been identified and disseminated to dairy producers. In the large commercial Dodla Dairy farm the selected sorghum and pearl millet cultivars could support similar levels of milk production (about 20 kg/d) than maize forages [O1-T2, p. 7]. In intensifying small holder dairy farms selling milk to Dodla Dairy, sorghum forage feeding increased mill production by about 40% (15.8 vs 11.1 kg/d) compared to existing farmers practice [O1-T3, p. 8]
- One perennial multi-cut sorghum cultivar (CO_{29}-FS) has been identified that yields more than 75 tons of dry forage (more than 450 tons of fresh forage) per year from 7 cuts on low quality waste water sources. This cultivar has been disseminated to 30 female and 50 male interested farmers in the Mulkanoor Women Dairy Cooperative and in the un-organized farmers Bhanoor village cluster. In small holder farms of Bhanoor Village Cluster feeding of CO_{29}-FS increased milk yield by about 30% (7.81 vs 6.0 kg/d) [O1-T4, p. 8].

2) Screen diverse germplasm sources of sorghum and pearl millet for superior forage quantity and quality and identify promising parental lines

- Highly significant differences among lines were observed in key fodder traits in 32 single cut and 40 multi-cut forage sorghum lines from the private sector initiative to develop new sorghum forage cultivars with higher fodder quality [O2-T1, p. 9].
- Seventeen pearl millet forage hybrids, nine populations/open-pollinated varieties and three commercial checks were investigated and compared for two years (2016 and 2017) under two management systems (multi-cut and single cut) for biomass yield and fodder quality. Significant differences were observed for all traits with little or no trade-offs between traits. A major advantage of hybrids resides with shortening the days required till flowering (O2-T2 and T3; p. 10 13)
- Using a three-way hybrid breeding approach to generate 10 pearl millet forage hybrids, dry biomass yield of 8 tons per ha were achieved with the highest yielder having the second highest IVOMD of 49.5% (O2-T4, p. 14).
- Investigation of 65 brown mid rib (bmr 3, 6, 7, 8, 9, 12, 18, 19, 21, 24)) pearl millet forages showed that the bmr trait could increase IVOMD to almost 60% (58.2) which is approximately 10 percent units higher than observed in the best non bmr pearl millet forages indicating that bmr cultivars could play an important role in increasing fodder quality in pearl millet forages (O2-T5, p 15).
- A new pearl millet forage breeding pool was generated from material with very diverse genetic backgrounds from East and West Africa and South Asia that are adapted to a diverse range of biophysical conditions that surpass commercial check cultivars in yield and quality traits. No trade-offs ($P>0.05$) were observed between biomass yield and fodder quality traits (O2-T6, T7 and T8, p 16 to 20).
- In 80 single cross and 50 top cross pearl millet forage hybrids fresh and dry biomass yield, crude protein and IVOMD were controlled by non-additive gene effects in breeding materials suggesting a hybridization approach (O2-T9; p. 21)
- Markers have been identified that account for about 24% of the variations in pearl millet forage crude protein content and IVOMD (O2-T10; 20).

3) Explore the feasibility of specialized small holder maize, sorghum and pearl millet forage production as a cash crop.

- Well-established fodder markets have been identified with attractive pricing for grass forages, and with discernible price-quality relations. Packaging in small and large forage bundles suggest that smaller producers will have access to those markets (O3-Figure1, p 22)
- The perennial forage sorghum CO_{29}-FS cultivar was disseminated to farmers after extensive on-station testing (where it could be cut 7 times per year yielding more than 450 000 kg/ha of fresh biomass) and on farmers fields yielded on average 26 562 and 23 595 kg/ha/cut in the Bhanoor Village Cluster and Mulkanoor Women Dairy Cooperative respectively. The value of this forage would be about 50 000 Indian Rupees per cut (about 800 US $) using the above forage fodder market data (O3-T1, p 23).

- Our Partner, Dodla Dairy, successfully pilot-tested contract farming of green forage production for silage with 1 200 farmers. Farmers received 1 700 India Rupees per ton of green maize as standing in the field resulting in a gross income of about 40 000 India Rupees per ha (fresh maize yields varied between 20 and 25 tons per ha). Non- descript sorghum forage was purchased by the dairy at 1 500 Indian Rupees per ton. Superior multi-cut annual sorghum CHS 24 MF is expected to fetch the same price as maize (O3 – T 2, p.23).

2. TIME: PROBLEMS AND DELAYS

Please report on any issues or problems that have impacted on the development and implementation of the project during the reporting period.

The work plan and activity calendar assumed the project start to be around March 2016 but the actual project start was delayed until June 2016. June/July is the beginning of the Monsoon season in Southern India which is equivalent to planting time. This caused some problems for an 18-month project and some activities directly related to seasonal activities were delayed but all planned activities were implemented.

3. FINANCIAL REPORTING: EXPENDITURES

In this section you should detail the expenditure of the project so far. Against the budget headings you should set out the expenditure for the reporting period, noting any significant over/under spend giving reasons for this. You should also state the total expenditure to date against each budget heading.

4. CHANGES TO PROJECT

Please report on any changes in project partners, delays in initiating parts of the project, issues that may arise in responding to public concerns or litigation could be included here. If the State forecasts a possible need for an amendment due to workplan modifications, budget realignments, time-extensions.

Major revisions had taken place between submission of the original proposal and the funded proposal but not during the 18 - month project phase.

5. RISK AND MITIGATION

Please detail what impact any potential upcoming risks may have on the achievement of project targets, and set out how you plan to mitigate these risks.

Key risk factors for crop livestock production in the semi-arid tropics are drought and water scarcity (rainfed and irrigation). The work with sorghum and pearl millet forages, which are more water-use efficient and bio-physically robust than maize, therefore already attempts to reduce and mitigate risks. Our major partner Dodla Dairy is a private sector player working with about 250 000 small holders in Southern India and the Mulkanoor Women Dairy Co-operative, with more than 21 000 members, will help assure that outputs of the project will not remain on the shelf but will be used and scaled by smallholders. On the breeding side, groundwork has been implemented that will take the breeding of sorghum and pearl millet for forage quality further.

6. EXECUTIVE SUMMARY AND RECOMMENDATIONS

The project had three major rationales: 1) sorghum and pearl millet forages are water-use efficient and suitable for a range of challenging bio-physical environments with good biomass yield but selection for fodder quality neglected, 2) genetic and management options exist to address and improve biomass fodder quality of sorghum and pearl millet; and 3) opportunities for forages-as-cash crops need to be explored besides their direct as on-farm feed resources. The underlying but overarching hypothesis of the proposed work was that an increasing demand for short duration, water use efficient single and multi-cut forages exists and that, while sorghum and pearl millet fit this bill, opportunities to improve their fodder quality has not been given the necessary attention. One of the key outcomes of the present project is that public and private forage improvement started exploring improvement of forage biomass **and** forage fodder quality concomitantly.

In released sorghum and pearl millet forage cultivars, the average forage fodder quality was indeed inferior to that of maize forage. Discussions with public and private sorghum and pearl millet forage breeders confirmed that breeding and selection efforts to date focussed primarily on forage biomass production (though under bio-physical constraints and challenges) neglecting forage fodder quality. Still, some sorghum and pearl millet cultivars could be identified that match maize forage fodder quality, resulting in similar levels of commercial milk production. To increase the probability of identifying sorghum and pearl millet forage cultivars with higher fodder quality, routine analysis for pertinent fodder quality traits is required and ILRI India has set up a hub that does this based on Near Infrared Spectroscopy equations for sorghum and pearl millet forages developed in the present project. This hub is being used by public and privet forage improvement.

For the targeted improvement of sorghum and pearl millet through forage breeding, highly significant differences in key fodder quality traits were found between parental lines, OPVs and hybrids. Exploitable genotype dependent differences for example in *in vitro* organic matter digestibility (IVOMD) appear greater in existing breeding material in sorghum than in pearl millet. Thus, genotypic variations in IVOMD in sorghum tended to be in the range of 5 to 7 percentage points whereas in pearl millet it was 3 to 5 percentage points. Brow mid-rib lines in pearl millet had higher ranges in IVOMD of about 7 to 10 percentages and total IVOMD surpassed that of the best non bmr lines by at least 4 to 5 percentage units. Consequently, bmr can play an important role in increasing overall fodder quality in pearl millet. In both crops genotypic variations in fresh and dry biomass yields were by magnitudes higher than variations in fodder quality. Hybridization using three-way-hybridization approaches can have substantial effects on shortening days too maturity, while maintaining yield and quality potential of later maturing cultivars. In sorghum and in pearl millet lines and breeding approaches are now available that increase forage biomass yields **and** forage fodder quality above the level currently available in popular commercial check cultivars. Gene actions for forage fodder quality traits has been described and markers with high association with key forage fodder quality traits have been identified that will facilitate further improvement in fodder quality.

It has been established that there is an attractive market for forages-as-cash crops and that this market appears best served with perennial rather than annual sorghum forages. Small holders are probably best to split the produced forages between their own animals and the fodder market. A significant niche appears in sorghum and pearl millet contract farming for silage preparation. Preliminary ex-ate assessments strongly suggest that forage-as-cash crops can be more enumerative than food crop production.

8. WORKPLAN FOR THE NEXT PERIOD (ANNUAL PLAN)

The current project had a duration of only 18 months which in crop and forage improvement is a very short time. The work area that is short duration and water use efficient sorghum and pearl millet forages would very much benefit from a second phase. This rational for a second phase is outlined below under proposed Future Work.

9. ANNEXES

Publicity

Please list activities undertaken regarding Article 4 in OFID Agreement

List the dissemination that has been done (or is being done) about project findings and outcomes, e.g. Journal articles, conference presentations. Have all project deliverables been submitted. For each, note the URL (your website) on the project or other web site. List any publicity the project has received, e.g. press coverage, awards.

Govintharaj P., Shashi Kumar Gupta, Marappa Maheswaran, Pichaikannu Sumathi1, Michael Blummel, Roma Das, Anil Kumar, Abhishek Rathore. 2017 Molecular and morphological genetic diversity in forage type hybrid parents of pearl millet. BMC Biology, submitted.

Govintharaj P., S.K. Gupta, M. Blummel, M. Maheswaran1, P. Sumathi1, D. Atkari, A. K. Vemula, A. Rathore, M. Raveendran1, V.P. Duraisami1. 2018. Genotypic variation in forage linked morphological and biochemical traits in hybrid parents of pearl millet. Animal Nutrition and Feed Technology, accepted.

Vinutha K., S., A.A. Khan, D. Ravi, K.V.S.V. Prasad, Y. Ramana Reddy, M. Blümmel. Comparison of the fodder quality of sorghum and pearl millet forages relative to a maize forage reference. In preparation for Animal Nutrition and Feed Technology.

Govintharaj P. 2018. Genetic diversity, heterosis and gene action studies for forage traits and identification of fodder quality QTLs in pearl millet (*Pennisetum glaucum* (L) R. Br). Doctoral Thesis, in preparation.

Future work

As mentioned above, the current project had a duration of only 18 months which in forage improvement and in estimation of the impact of improved forages is a very short time span. Forage breeding, even incorporating molecular technologies, is a longer term effort and making best use of the superior sorghum and pearl millet forage cultivars and lines identified in the 1st phase would clearly be supported by a 2nd phase. This is true for the new pipeline cultivars identified which would be disseminated as well as for the new breeding pool generated that could be fully employed in the generation of even further improved sorghum and peal millet cultivars. This work would be in close collaboration with ICRISAT, the private seed sector and NARES. Similarly, several years would be required for a meaningful impact assessment of improved forage sand for supporting further scaling of the technologies.

ANNEXES OBJECTIVE 1

Objective 1-Table 1: Laboratory and on-station *in vivo* evaluation of released sorghum and pearl millet forages for nitrogen, (protein), neutral (NDF) and acid (ADF) detergent fibre, acid detergent lignin (ADL), *in vitro* organic matter digestibilities (IVOMD), metabolizable energy (ME) content and dhurrin (DH) content and intake of silages prepared from the forages and of nitrogen retention in sheep. A widely used maize forage cultivar is included in the comparison as a reference forage (Vinutha et al, in preparation)

Crop	Variety	Nitrogen (%)	NDF (%)	ADF (%)	ADL (%)	ME (MJ/kg DM)	IVOMD (%)	DH_F DH_S ppm		Silage Intake (g/d)	N bal (g/d)
Maize	P 3576			**33.4**	**1.7**	**65.6**	**61.9**	**2.62**	**0.00**	**352**	**3.3**
Sorghum	CSH 20 MF	1.9	68.3	37.4	4.3	8.5	57.3	73.02	0.19	254	2.5
Sorghum	CSH 24 MF	2.1	67.8	36.0	4.1	9.1	60.4	60.77	1.08	303	2.8
Sorghum	GK 909	1.9	66.4	37.7	4.5	8.6	57.8	85.59	0.22	343	3.2
Sorghum	GK 917	2.1	69.1	38.5	4.4	8.7	58.6	105.63	0.41	319	3.7
Sorghum	HC 308	1.9	63.9	34.3	3.8	9.2	61.5	29.90	0.17	278	3.0
Sorghum	SPSSV-30	1.8	60.6	33.1	3.7	9.6	63.3	225.84	7.40	306	3.1
Sorghum	SSG Priya Hybrid 5000	2.4	68.3	36.6	4.3	9.1	62.4	84.39	1.78	274	2.4
Mean Sorghum		**2.0**	**66.3**	**36.2**	**4.2**	**9.0**	**60.2**	**95.02**	**1.61**	**297**	**3.0**
Pearlmillet	AVKB 19	1.9	57.9	30.1	3.6	9.2	62.23	0.99	2.03	113	0.03
Pearlmillet	ICMA 00444 × IP 6202	1.3	60.9	31.6	3.9	9.1	59.78	0.27	1.44	130	0.2
Pearlmillet	Milkon	1.5	62.2	34.4	4.3	8.3	55.91	0.82	0.18	131	0.8
Pearlmillet	PAC 931	1.5	59.2	30.1	3.4	9.1	61.14	0.00	2.50	172	1.5
Pearlmillet	Poshan	1.6	63.0	35.8	4.4	8.5	57.15	2.67	2.24	137	0.6
Mean Pearlmillet		**1.6**	**60.6**	**32.4**	**3.9**	**8.8**	**59.2**	**0.95**	**1.68**	**137**	**0.63**
Overall Mean		**1.82**	**64.10**	**34.5**	**4.01**	**8.95**	**59.96**	**51.73**	**1.51**	**239**	**2.08**
	LSD	**0.17**	**2.46**	**2.75**	**0.40**	**0.49**	**3.07**	**28.0**	**1.44**	**55.9**	**1.01**
	P @ 5%	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.0001**	**<0.0001**	**<0.001**	**<0.001**

Objective 1 - Table 2: Comparisons of milk yields on reference maize silages and silages prepared from selected sorghum and pearl millet cultivars. Experiments were conducted with Holstein Friesian Cattle at the Experimental and Extension Farms of our partner Dodla Dairy

Measurement	Reference Maize Forage	CSH 24 MF Sorghum Forage	P < F
Dry Matter intake (kg/d)	22.2	22.6	ns
Milk Yield (kg/d)	19.5	20.6	ns
	Reference Maize Forage	ICMV 15111 Pearl Millet Forage	
Dry Matter intake (kg/d)	14.1	19.2	0.0001
Milk Yield (kg/d)	22.0	18.2	0.006
	Reference Maize Forage	ICMV 05777 Pearl Millet Forage	
Dry Matter intake (kg/d)	21.0	21.8	ns
Milk Yield (kg/d)	16.8	18.6	ns

Objective 1 - Table 3: Comparisons of average dairy production across seven small holder farms delivering milk to Dodla Dairy feeding silage from annual multi-cut sorghum cultivars CSH 24 MF with on farm feeding practices (FP)

	Dry matter intake (kg/d)	Milk yield (kg/d)	Dry matter intake (kg/d)	Milk yield (kg/d)
	Farmers Practice (FP)		Sorghum forage CSH 24 MF	
Mean across farms	17.4	11.1	14.6	15.8
FP vs CSH 24 MF	P = 0.16		P = 0.03	

Objective 1 - Table 4: Effect of perennial multi-cut sorghum cultivar CO_{29}-FS feeding in two small holder farms in the Bhanoor Village Cluster on daily milk production. CO_{29}-FS replaced previous roughage feeding on an approximately equal weight basis. In both feeding systems animals had about 7 hours of grazing

	DM Forage intake (g/d)	**DM Concentrate intake (kg/d)**	**Milk yield (kg/d) d**
CO_{29}-FS Feeding	0.81	3.38	7.81
Farmers practice	0.83	3.38	6.01

ANNEXES OBJECTIVE 2

Objective 2 – Table 1: Means, ranges and statistical differences in laboratory fodder quality in 32 single cut and 40 multi-cut private sector sorghum forages

Trait	Mean	Range	Probability
Single Cut Sorghum Forages (n = 32)			
Nitrogen (%)	0.89	0.76 – 1.04	<0.0001
Neural Detergent Fiber (%)	60.6	58.2 – 64.4	<0.0001
Acid Detergent Fiber (%)	35.5	33.5 – 37.6	<0.0001
Acid Detergent Lignin (%)	5.1	4.8 – 5.5	<0.0001
Metabolizable Energy (MJ/kg)	7.5	6.8 – 8.0	<0.0001
In vitro organic matter digestibility (%)	51.3	47.3 – 54.0	<0.0001
Multi-Cut Sorghum Forages (n=40)			
	Mean	Range	Probability
Nitrogen (%)	1.54	1.07 – 1.99	0.0002
Neural Detergent Fiber (%)	68.3	64.7 – 71.4	0.004
Acid Detergent Fiber (%)	41.5	38.4 – 44.5	0.05
Acid Detergent Lignin (%)	5.4	5.1 – 5.7	0.04
Metabolizable Energy (MJ/kg)	6.6	6.2 – 7.2	0.06
In vitro organic matter digestibility (%)	48.0	44.8 – 52.4	0.01

ANNEXES OBJECTIVE 2

Objective 2 – Table 2: Two-year (2016 and 2017) investigations of different cultivar-types of ICRISAT pearl millet forages under multi-cut and single cut management for days to 50% flowering (DtF), fresh (FB) and dry (DB) biomass yield, *in vitro* organic matter digestibility (IVOMD) and nitrogen content.

		Multi-Cut Management								**Single Cut Management**			
	DtF	**FB (t/ha)**		**DB (t/ha)**		**IVOMD**				**FB**	**DB**	**IVOMD**	**N**
		1st	**2nd**	**1st**	**2nd**	**1st**	**2nd**	**1st**	**2nd**				
	Cultivar type: Hybrids												
ICMA 00444 X IP 6202	52	19.7	20.7	4.1	6.4	52.3	48.8	1.9	1.4	28.7	7.5	49.8	1.1
ICMA 00999 X IP 6202	57	22.4	26.4	4.7	7.9	50.1	47.3	2.1	1.4	34.5	8.8	48.4	0.9
ICMA 01888 X IP 6140	59	18.4	21.8	4.3	5.7	50.3	46.4	2.1	1.3	24.8	6.0	48.3	1.2
ICMA 09888 X IP 13150	61	20.2	21.5	5.1	5.7	51.3	48.7	2.1	1.5	29.2	8.4	46.6	1.2
ICMA 09888 X ICMV 05555	61	19.6	24.0	4.6	6.2	50.8	47.2	2.0	1.5	31.5	14.2	42.7	1.2
ICMA 93222 X ICMV 05666	56	19.8	15.9	5.8	4.6	50.6	44.9	1.8	1.3	22.5	6.9	45.8	1.1
ICMA 09888 X IP 11431	62	17.7	24.8	4.3	7.0	52.5	45.8	2.0	1.3	27.3	8.4	47.1	1.2
ICMA 08999 X IP 6202	65	20.8	26.8	4.6	7.1	50.2	48.1	1.8	1.5	39.1	13.6	45.9	1.3
ICMA 04444 X ICMV 05222	49	19.6	21.3	4.8	6.1	49.6	47.4	2.2	1.6	25.3	9.5	46.3	1.2
ICMA 04444 X IP 6140	44	17.5	13.2	5.7	4.5	51.2	47.1	1.8	1.6	19.7	5.9	47.2	1.3
ICMA 02555 X IP 15564	56	16.8	16.5	3.6	4.7	52.6	46.0	2.0	1.3	20.7	4.7	43.9	1.1
ICMA 08999 X ICMV 05777	60	18.0	25.6	4.8	6.6	51.3	48.1	2.0	1.6	27.1	9.0	45.7	1.3
ICMA 02555 X ICMV 05555	50	17.8	17.3	4.1	4.9	52.0	48.1	2.1	1.4	22.2	8.5	44.1	1.0
ICMA 02555 X IP 22269	56	14.8	18.8	3.7	5.0	51.4	47.1	1.8	1.4	23.8	7.7	49.3	1.3
ICMA 04444 X IP 22269	57	15.8	22.2	4.6	6.4	51.1	46.3	1.9	1.3	27.5	8.7	47.5	1.0
ICMA 08999 X ICMV 05555	56	13.6	22.5	4.4	7.8	51.8	48.9	2.0	1.6	25.6	8.4	48.4	1.2
ICMA 01888 X ICMV 05222	60	15.5	22.4	3.6	5.9	52.2	45.7	1.9	1.4	24.6	7.8	47.5	1.2
Mean	**57**	**18.1**	**21.3**	**4.5**	**6.0**	**51.3**	**47.2**	**2.0**	**1.4**	**26.7**	**8.5**	**46.7**	**1.2**
	Cultivar type: Populations/germplasm accessions												
ICMV 05222	69	12.0	28.4	2.9	7.8	51.7	48.0	2.2	1.3	38.7	11.4	47.3	1.3
ICMV 05555	61	12.7	28.3	2.5	8.3	51.3	48.3	2.0	1.5	32.5	11.7	47.8	1.1

ICMV 05777	58	14.9	27.9	3.1	9.7	50.6	46.8	2.1	1.3	33.0	11.1	46.9	1.2
IP 22269	62	16.6	27.9	3.4	7.1	50.3	48.2	2.0	1.6	37.8	13.4	46.1	1.4
IP 10151	75	11.5	29.2	2.3	12.7	49.4	50.1	2.1	1.5	36.1	14.4	46.2	1.4
ICMV 08111	66	12.1	28.6	2.2	9.4	51.6	49.5	2.3	1.5	39.5	12.7	47.6	1.3
IP 15535	66	13.2	24.7	2.8	7.6	50.5	50.1	1.9	1.5	35.2	11.6	47.8	1.4
IP 20409	61	13.6	30.4	3.3	9.7	51.3	50.4	2.2	1.6	38.9	14.9	46.7	1.3
ICMV 15111 (IP 6107)	58	16.2	17.1	4.4	4.5	51.4	48.0	1.8	1.5	18.8	6.7	45.7	1.1
Mean	**64**	**13.6**	**26.9**	**3.0**	**8.5**	**50.9**	**48.8**	**2.1**	**1.5**	**34.5**	**12.0**	**46.9**	**1.3**
	Cultivar type: Local Checks												
PAC 981 (Nutrifeed)	64	12.4	29.6	2.5	10.0	52.1	48.4	1.8	1.4	33.4	14.1	41.5	1.2
Milkon	61	18.5	23.4	3.7	7.0	48.9	48.7	2.1	1.6	23.9	7.6	43.3	1.0
Poshan	65	16.0	20.6	4.6	6.4	51.3	49.4	2.1	1.7	22.5	6.9	46.8	1.3
Mean	**63**	**15.6**	**24.5**	**3.6**	**7.8**	**50.8**	**48.3**	**2.0**	**1.6**	**26.6**	**9.5**	**43.9**	**1.2**
	Overall statistics												
Grand mean	59	16.4	23.2	3.9	6.9	51.1	47.9	2.0	1.5	28.9	9.6	46.5	1.2
s.e.	6.1	1.96	2.03	0.45	1.00	0.17	0.58	0.03	0.07	0.23	0.73	0.60	0.09
cv%	10.4	12.00	8.70	11.60	14.50	0.30	1.20	1.30	4.80	0.80	7.60	1.30	7.20
Min	**44**	**11.5**	**13.2**	**2.2**	**4.5**	**48.9**	**44.9**	**1.8**	**1.3**	**18.8**	**4.7**	**41.5**	**0.9**
Max	**75**	**22.4**	**30.4**	**5.8**	**12.7**	**52.6**	**50.4**	**2.3**	**1.7**	**39.5**	**14.9**	**49.8**	**1.4**
Mean Comparison of Hybrids, Population/Germplasm and Checks													
		Multi-Cut Management								**Single Cut Management**			
	DtF	**FB (t/ha)**		**DB (t/ha)**		**IVOMD**				**FB**	**DB**	**IVOMD**	**N**
		1st	**2nd**	**1st**	**2nd**	**1st**	**2nd**	**1st**	**2nd**				
Mean: Hybrid	**57**	**18.1**	**21.3**	**4.5**	**6.0**	**51.3**	**47.2**	**2.0**	**1.4**	**26.7**	**8.5**	**46.7**	**1.2**
Mean: Population/Germplasm	**64**	**13.6**	**26.9**	**3.0**	**8.5**	**50.9**	**48.8**	**2.1**	**1.5**	**34.5**	**12.0**	**46.9**	**1.3**
Mean: Checks	**63**	**15.6**	**24.5**	**3.6**	**7.8**	**50.8**	**48.3**	**2.0**	**1.6**	**26.6**	**9.5**	**43.9**	**1.2**

Objective 2 – Table 3: Correlations (r) between days to 50% flowering (DtF), *in vitro* organic matter digestibility (IVOMD) and nitrogen content (N) and fresh (FB) and dry (DB) biomass yield of different cultivar-types of ICRISAT pearl millet forages under multi-cut and single cut management

	Multi Cut Management				Single Cut Management	
	CUT 1		**CUT 2**			
Trait	**FB**	**DB**	**FB**	**DB**	**FB**	**DB**
Cultivar type: Hybrids (n=17)						
N	0.25 [0.33]	-0.12 [0.65]	0.12 [0.65]	0.22[0.39]	-0.05[0.84]	0.16[0.54]
IVOMD	-0.54 [0.02]	-0.52 [0.03]	0.25 [0.33]	0.38[0.13]	0.038[0.88]	-0.35[0.16]
DtF	0.12 [0.64]	-0.23 [0.38]	0.73 [0.001]	0.45 [0.07]	0.62 [0.008]	0.46 [0.06]
Cultivar type: Population/germplasm accession (n=9)						
N	-0.58 [0.10]	-0.60 [0.09]	-0.01 [0.97]	-0.05[0.88]	0.69[0.04]	0.67[0.04]
IVOMD	-0.02 [0.95]	0.21 [0.59]	0.26 [0.50]	0.41[0.27]	0.45[0.22]	0.17[0.65]
DtF	-0.74 [0.02]	-0.64 [0.06]	0.38 [0.32]	0.59 [0.09]	0.48 [0.18]	0.47 [0.19]
Cultivar types: Checks (n=30						
N	0.91 [0.27]	0.90 [0.28]	-0.99 [0.01]	-0.98 [0.11]	0.07 [0.95]	0.10 [0.93]
IVOMD	-0.93 [0.24]	-0.32 [0.79]	-0.90 [0.28]	-0.82 [0.38]	-0.83 [0.37]	-0.81 [0.39]
DtF	-0.64 [0.55]	0.16 [0.89]	-0.03 [0.98]	0.12 [0.92	0.16 [0.89]	0.19 [0.88]

Objective 2-Table 4: Fresh (FB) and dry (DB) biomass yields and *in vitro* organic matter digestibility (IVOMD) and crude protein (CP) of 10 ICRISAT three-way pearl millet forage hybrids harvested after 45 and 93 days after sowing in 2016 at Patancheru

Parental lines used in Three Way Hybrids	Yields in tons per ha				Forage quality traits in %			
	FB^{st}	FB^{nd}	FB^{tot}	DB^{tot}	$IVOMD^{st}$	$IVOMD^{nd}$	CP^{st}	CP^{nd}
(10999A5 x ([ICMB 95111 x (ICMB 96555 x IP 10437)-3]-7-2-1-B-2-15-1] x B-bulk (3981-3989/S06 G1)}-3-2-4-B x HHVDBC HS-155-1-1-1-2-1-1-B)-4-3-2-3-1-4) x IP 6202	17.5	11.5	29.0	4.4	47.8	41.9	10.7	7.5
(10999A5 x [78-7088/3/SER3 AD//B282/(3/4)EB x PBLN/S95-359]-7-4-B-B-2-B-BxHHVDBC Medium HS-15-1-1-1-1-3-1-20-2-5-4-4) x IP 6202	11.2	17.7	28.8	8.0	49.5	NA	10.6	NA
(10999A5 x [(ICMB 95111 x 9035/S92-B-3)-17-5-1-B-B-B x ICMB 99111]-3-2-1-3-6-B) x IP 6202	17.7	14.9	32.7	5.3	47.0	45.7	11.0	8.1
(10999A5 x [78-7088/3/SER3 AD//B282/(3/4)EB x PBLN/S95-359]-7-4-B-B-2-B-BxHHVDBC Medium HS-15-1-1-1-1-3-1-20-2-5-4-4) x ICMV 05555	19.9	13.6	33.5	5.8	47.2	42.9	8.3	7.2
(10999A5 x [(ICMB 95111 x 9035/S92-B-3)-17-5-1-B-B-B x ICMB 99111]-3-2-1-3-6-B) x IP 13150	20.3	7.1	27.4	5.3	44.1	44.5	7.1	8.4
(10999A5 x ([ICMB 95111 x (ICMB 96555 x IP 10437)-3]-7-2-1-B-2-15-1] x B-bulk (3981-3989/S06 G1)}-3-2-4-B x HHVDBC HS-155-1-1-1-2-1-1-B)-4-3-2-3-1-4) x IP 22269	17.6	10.0	27.6	3.9	48.5	45.5	8.6	8.6
(10999A5 x (ICMB 03111 x {(MC 94 S1-34-1-B x HHVBC)-16-2-1-1-1-1-B-B-5 x (MC 94 S1-34-1-B x HHVBC)-10-4-1-2-1-B-B-1-30-2-4-3-1)-19-3-1-4-B) x IP 13150	21.1	11.1	32.2	6.2	48.5	47.8	12.6	8.9
(02555A5 x (HHVDBC Medium HS-83-1-3-2-B-3-3 x HHVDBC Medium HS-15-1-1-1-2-2-4)-8-2-3-B-1) x IP 22269	19.5	14.1	33.6	6.2	46.2	47.6	8.2	8.7
(02555A5 x (HHVDBC Medium HS-83-1-3-2-B-3-3 x HHVDBC Medium HS-15-1-1-1-2-2-4)-8-2-3-B-1) x IP 13150	16.6	10.1	26.8	3.9	50.3	45.6	10.5	8.8
(10888A5 x ([(ICMV-IS 94206-15 × B-lines)-B-6 × MRC S1-405-1-2-B]-B-4-1-1-1-6-B x MRC S1-9-2-2-B-B-4-B-B-B-B)-20-2-2-B-2) x IP 13150	19.5	10.1	29.7	5.5	47.6	46.5	8.4	7.7
Check cultivar PAC 981	17.8	18.7	36.5	6.9	49.1	46.6	10.2	7.5

Objective 2- Table 5: Opportunities from 65 ICRISAT pearl millet brown mid rib lines to increase forage quality in pearl millets: Forage nitrogen (ND) and *in vitro* organic matter digestibility (IVOMD)

	N (%)	IVOMD (%)	N (%)	IVOMD (%)
	First Cut		Second Cut	
Mean	2.1	50.1	1.9	54.2
Minimum	1.4	49.1	1.2	51.8
Maximum	2.8	57.6	2.6	58.2

Objective 2-Table 6: Fresh (FB) and dry (DB) biomass yield in tons per ha of at 1st (CUT 1) and 2nd (Cut 2) of a new pearl millet forage trial generated in 2017 from a very wide range of potential forage pearl millets adapted to diverse bio-physical conditions in Africa and Asia as breeding stock for a new pearl millet forage breeding program at ICRISAT

	Cut 1	Cut 1	Cut 2	Cut 2	Cut 1 + 2	
	FB	**DB**	**FB**	**DB**	**FBtot**	**DBtot**
ICMV 1601: 20 progenies derived from a landrace from Niger and forage variety ICMV 05555	25.83	3.35	10.95	2.48	36.78	5.83
ICMV 1602: 12S2 derived from ICMV 055555	19.99	2.72	6.84	1.63	26.83	4.35
ICMV 1603: 12 S3 derived from three landraces from Burkina Faso, Niger and Mali	25.35	3.39	16.15	5.77	41.49	9.16
ICMV 1604: 6S3 progenies derived from a land race in Benin	21.83	2.96	14.12	3.56	35.95	6.52
ICMV 1605: 13 S3 landraces derived from land races in Burkina Faso and Chad	28	3.29	10.94	2.5	38.95	5.79
ICMV 1606: 15 S3 progenies derive from landraces in Burkina Faso, Cameroon and Senegal	25.08	3.76	11.84	2.7	36.93	6.45
ICMV 1607: 21 DS3 progenies derived form a Cameroon landrace	33.02	4.76	11.6	3.45	44.62	8.22
ICMV 1608: 14 progenies derived from landraces in Burkina Faso and Cameroon	33.39	4.06	10.62	3.07	44.01	7.13
ICMV 1609: 11 progenies from a landrace in Cameroon and forage variety ICMV 05222	23.31	3.4	10.3	2.48	33.62	5.88
ICMV 1610: 16 S2 progenies developed from forage varieties ICMV 0.5222 and 0.5555	25.23	3.75	11.93	3.55	37.16	7.3
ICMV 1611: 13 S3 progenies developed from two land races from Burkina Faso	24.4	4	15.22	4.24	39.63	8.24
ICMV 1612: 8 S3 progenies from two land races in India and Burkina Faso	14.44	2.42	16.4	5.02	30.85	7.44
ICMV 1613: 6 S3 developed from two landraces in Mali and Chad	22.95	3.18	16.82	4.24	39.77	7.42
ICMV 1614:19 S2 progenies derived from forage varieties ICMV 05666 and 05777	20.52	2.91	14.43	3.73	34.95	6.63
ICMV 1615: 4 S2 progenies derived from forage variety ICMV 05666	32	3.67	14.6	2.83	46.6	6.5
ICMV 1616: 20 S2 progenies derived from forage variety ICMV 05555	31.72	3.51	8.35	1.77	40.06	5.27
ICMV 1617: $ S 2 progenies derived from forage variety ICMV 05555	26.47	3.61	13.35	3.7	39.83	7.3
ICMV 1618: 15 S3 progenies derived from two land races from Chad and Cameroon	27.33	3.71	10.99	2.29	38.32	6

	Cut 1	Cut 1	Cut 2	Cut 2	Cut 1 + 2	
	FB	DB	FB	DB	FBtot	DBtot
ICMV 1619: 14 S 3 progenies derived from two land races in Mali and Burkina Fas0	23.67	3.61	13.61	4.37	37.28	7.99
ICMV 1620: 9 S 3 progenies derived from 2 landraces in India and Chad	20.45	3.52	12.78	3.81	33.23	7.34
ICMV 1621: 12 S 3 progenies from a landrace from India	25.12	3.71	11.17	3.02	36.28	6.73
ICMV 1622: 16 S 3 progenies from a landrace in Cameroon	23.14	3.33	13.38	3.8	36.53	7.13
ICMV 1623: 9 S 3 progenies derived from a landrace from Burkina Faso	13.5	2.13	16.35	5.35	29.85	7.48
Checks						
IP 22269	29.16	3.86	11.83	2.56	41	6.42
MRB 8	25.53	3.97	10.3	2.93	35.83	6.91
ICMV 05555	25.35	3.19	15.64	3.82	40.99	7.01
ICMV 05222	27.42	3.34	14.67	3.94	42.09	7.28
ICMV 05777	31.32	4.52	15.13	4.26	46.45	8.77
IP 10151	23.1	3.22	12.86	3.75	35.96	6.97
PAC 981 (Nutrifeed)	26.59	3.55	17.63	4.85	44.21	8.4
s.e.	**3.538**	**0.462**	**3.407**	**0.958**	**2.916**	**0.921**
cv%	**14.1**	**13.3**	**26.2**	**27.2**	**7.6**	**13.2**
Grand mean	**25.17**	**3.48**	**13.03**	**3.52**	**38.2**	**7**

Objective 2-Table 7: Crude protein (CP, %) neutral (NDF, %) and acid detergent fibre, acid detergent lignin (ADL, %) and *in vitro* organic matter digestibility (IVOMD, %) in 1st (CUT 1) and 2nd (Cut 2) cut of a new pearl millet forage trial generated in 2017 from a very wide range of potential forage pearl millets adapted to diverse bio-physical conditions in Africa and Asia as breeding stock for a new pearl millet forage breeding program at ICRISAT

	Cut 1 (50 days)					**Cut 2 (90 DAYS)**				
	CP	**NDF**	**ADF**	**ADL**	**IVOMD**	**CP**	**NDF**	**ADF**	**ADL**	**IVOMD**
ICMV 1601: 20 progenies derived from a landrace from Niger and forage variety ICMV 05555	11.4	64.9	41.4	5.3	49.6	11.7	65.3	45.6	5.7	41.0
ICMV 1602: 12S2 derived from ICMV 055555	13.1	63.2	39.5	5.0	52.7	12.3	64.8	40.4	5.2	48.0
ICMV 1603: 12 S3 derived from three landraces from Burkina Faso, Niger and Mali	12.3	63.9	40.5	5.3	49.7	11.9	65.7	41.6	5.3	47.2
ICMV 1604: 6S3 progenies derived from a land race in Benin	11.9	63.8	40.5	5.2	51.1	10.9	66.1	42.8	5.4	45.6
ICMV 1605: 13 S3 landraces derived from land races in Burkina Faso and Chad	12.7	63.8	40.3	5.2	50.8	11.7	65.9	42.7	5.4	46.1
ICMV 1606: 15 S3 progenies derive from landraces in Burkina Faso, Cameroon and Senegal	12.6	63.9	41.0	5.2	50.4	11.3	63.9	44.5	5.8	40.0
ICMV 1607: 21 DS3 progenies derived form a Cameroon landrace	11.2	64.7	42.1	5.4	48.0	11.6	63.8	41.9	5.5	43.8
ICMV 1608: 14 progenies derived from landraces in Burkina Faso and Cameroon	12.6	63.4	39.8	5.2	50.9	13.1	64.9	39.9	5.1	48.6
ICMV 1609: 11 progenies from a landrace in Cameroon and forage variety ICMV 05222	12.4	63.6	40.2	5.1	51.0	11.5	66.1	42.7	5.5	44.5
ICMV 1610: 16 S2 progenies developed from forage varieties ICMV 0.5222 and 0.5555	11.6	64.4	41.5	5.3	50.3	12.1	65.7	41.2	5.2	47.1
ICMV 1611: 13 S3 progenies developed from two land races from Burkina Faso	12.1	63.2	40.1	5.2	50.9	11.9	65.2	42.3	5.6	44.4
ICMV 1612: 8 S3 progenies from two land races in India and Burkina Faso	12.8	63.0	38.6	5.3	49.6	11.6	66.3	41.7	5.2	47.1
ICMV 1613: 6 S3 developed from two landraces in Mali and Chad	11.8	64.1	40.7	5.2	51.2	12.5	66.4	41.2	5.2	47.3
ICMV 1614:19 S2 progenies derived from forage varieties ICMV 05666 and 05777	11.2	64.7	41.6	5.3	50.4	10.8	65.8	44.8	5.7	42.0

	Cut 1 (50 days)					Cut 2 (90 DAYS)				
	CP	NDF	ADF	ADL	IVOMD	CP	NDF	ADF	ADL	IVOMD
ICMV 1615: 4 S2 progenies derived from forage variety ICMV 05666	12.3	64.6	40.9	5.2	50.3	11.7	63.8	44.6	5.9	39.9
ICMV 1616: 20 S2 progenies derived from forage variety ICMV 05555	11.9	64.7	41.5	5.1	51.1	12.3	65.5	40.9	5.3	47.7
ICMV 1617: $ S 2 progenies derived from forage variety ICMV 05555	12.7	63.1	39.7	5.0	52.7	12.5	65.3	40.7	5.2	48.1
ICMV 1618: 15 S3 progenies derived from two land races from Chad and Cameroon	11.8	64.0	41.3	5.2	50.7	12.0	65.9	41.9	5.1	48.2
ICMV 1619: 14 S 3 progenies derived from two land races in Mali and Burkina Fas0	12.1	64.0	40.9	5.3	49.5	11.4	65.4	43.2	5.5	43.7
ICMV 1620: 9 S 3 progenies derived from 2 landraces in India and Chad	11.8	64.6	41.4	5.2	50.7	11.2	66.9	42.2	5.2	47.7
ICMV 1621: 12 S 3 progenies from a landrace from India	11.7	64.6	42.0	5.3	49.7	10.6	67.3	44.8	5.7	43.5
ICMV 1622: 16 S 3 progenies from a landrace in Cameroon	11.8	64.0	40.8	5.3	49.5	12.7	63.4	45.5	5.7	39.7
ICMV 1623: 9 S 3 progenies derived from a landrace from Burkina Faso	11.8	64.3	41.0	5.3	50.7	13.4	64.2	39.0	5.3	46.8
Checks										
IP 22269	12.0	64.5	41.6	5.3	49.7	12.0	65.8	42.1	5.4	45.3
MRB 8	11.5	65.3	42.3	5.3	49.6	11.6	63.3	42.0	5.4	47.3
ICMV 05555	12.2	64.1	40.5	5.2	50.4	12.5	66.6	41.5	5.2	47.1
ICMV 05222	12.1	64.8	40.7	5.3	50.5	13.0	65.4	40.7	5.3	47.6
ICMV 05777	12.3	63.3	40.0	5.2	49.6	12.7	66.0	41.4	5.2	47.1
IP 10151	13.0	63.1	39.3	5.2	51.0	13.4	63.1	42.3	5.7	42.1
PAC 981 (Nutrifeed)	12.4	64.3	41.1	5.1	51.8	11.3	67.5	44.7	5.6	43.6
s.e.										
cv%										
Grand mean	11.4	64.9	41.4	5.3	49.6	11.7	65.3	45.6	5.7	41.0

Objective 2-Table 8: Correlations (r) between forage quality traits crude protein (CP) neutral (NDF) and acid detergent fibre (ADF), acid detergent lignin (ADL, *in vitro* organic matter digestibility (IVOMD) and fresh (FB) and dry (DB) biomass yields 1st (CUT 1) and 2nd (CUT 2) cut of a new pearl millet forage trial generated in 2017 from a very wide range of potential forage pearl millets adapted to diverse bio-physical conditions in Africa and Asia as breeding stock for a new pearl millet forage breeding program at ICRISAT

	CUT 1		CUT 2	
Trait	FB	DB	FB	DB
		New pearl millet forage breeding lines		
CP	-0.07 [0.75]	-0.22 [0.32]	0.03 [0.89]	0.13 [0.57]
NDF	0.23 [0.27]	0.19 [0.39]	0.03 [0.89]	0.05 [0.81]
ADF	0.30 [0.15]	0.40 [0.06]	0.01 [0.96]	-0.20 [0.37]
ADL	-0.07 [0.74]	0.11 [0.59]	0.07 [0.73]	-0.12 [0.56]
IVOMD	-0.14 [0.52]	-0.32 [0.13]	-0.10 [0.66]	0.10 [0.64]
		Check pearl millet forages		
CP	-0.30 [0.51]	-0.39 [0.39]	-0.04 [0.94]	0.05 [0.91]
NDF	-0.06 [0.97]	-0.02 [0.97	0.81 [0.02]	0.52 [0.23]
ADF	0.14 [0.77]	0.25 [0.58]	0.36 [0.42]	0.39 [0.39]
ADL	0.14 [0.77]	0.13 [0.78]	-0.08 [0.86]	0.10 [0.83]
IVOMD	-0.50 [0.25]	-0.64 [0.12]	-0.11 [0.82]	-0.20 [0.67]

Numbers in square brackets are probabilities

Output 2-Table 9: Additive and non—additive gene effects in 80 single cross hybrids (Set 1) and 50 top cross hybrids (Set 2) for fresh (FB) and dry (DB) biomass, crude protein (CP), *in vitro* organic matter digestibility (IVOMD), neutral (NDF) and acid (ADF) detergent fibre and acid detergent lignin (ADL).

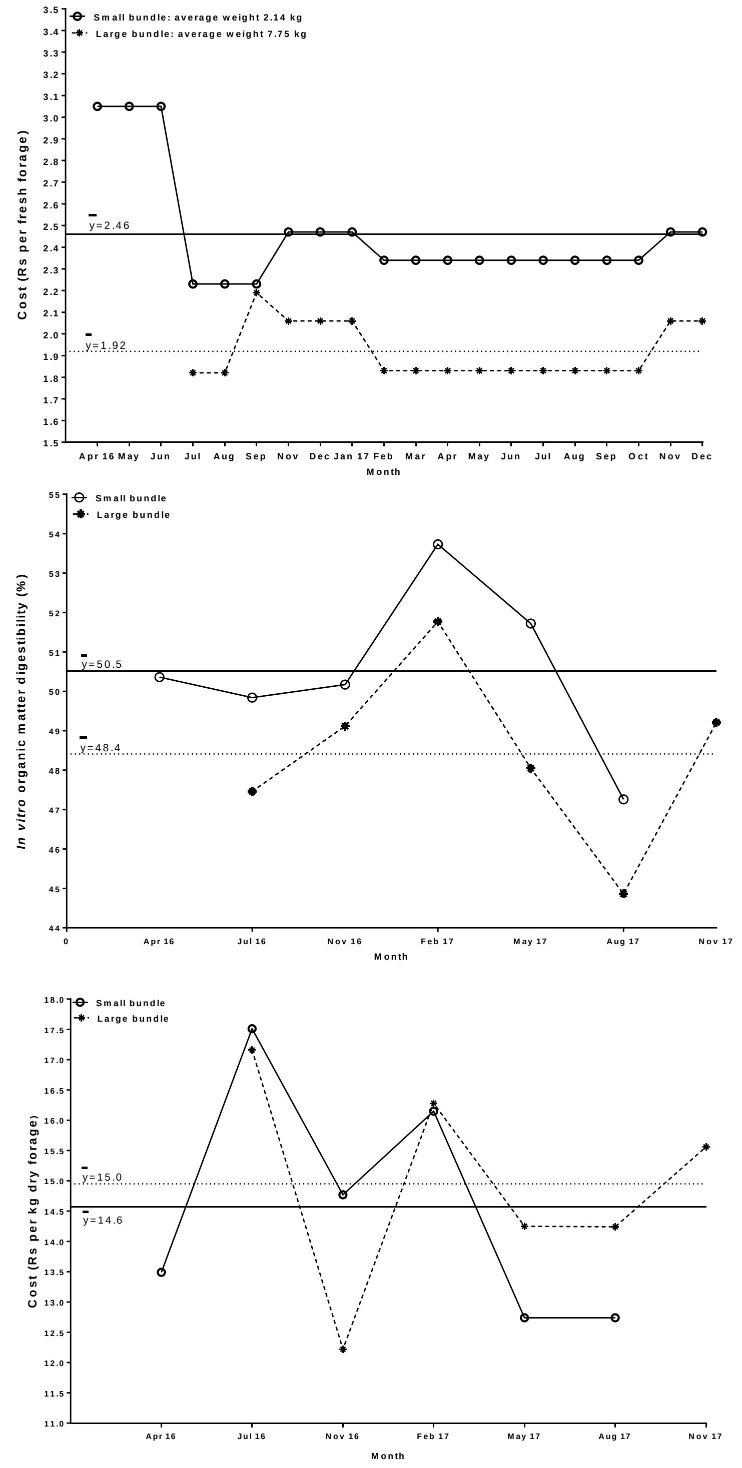
Traits	**Additive**						**Non-additive**					
	Set I			Set II			Set I			Set II		
	1st	2nd	80-d	1st	2nd	80-d	1st	2nd	80-d	1st	2nd	80-d
Positive traits												
FB	√					√		√	√	√	√	
DB		√					√		√	√	√	√
CP		√			√		√		√	√		√
IVOMD							√	√	√	√	√	√
Negative traits												
NDF							√	√	√	√	√	√
ADF							√	√	√	√	√	√
ADL		√		√			√		√		√	√

Objective 2 – Table 10: Trait-linked markers identified for crude protein(CP) and *in vitro* organic matter digestibility (IVOMD) for two different harvest in 116 ICRISAT forage type hybrid parents of pearl millet in grown for two consecutive years in Patancheru. Only associations with the three highest R^2 are reported

Trait	Harvests/Cut	Marker	Chromosome	P < F	Marker R^2
CP	1st	S3_19632520	3	6.61E-05	23.85
CP	1st	S2_231339450	2	8.97E-05	23.89
CP	1st	S1_90741561	1	1.98E-04	21.49
IVOMD	1st	S5_82634390	5	9.42E-05	23.19
IVOMD	1st	S4_4383036	4	3.12E-04	19.57
IVOMD	1st	S4_75421741	4	6.18E-04	20.25
CP	2nd	S4_97017965	4	9.09E-04	15.16
CP	2nd	S4_1475832	4	9.65E-04	14.73
CP	2nd	S3_192432163	3	1.20E-04	20.11
IVOMD	2nd	S1_259863146	1	1.48E-04	18.59
IVOMD	2nd	S7_104636841	7	1.88E-04	19.11
IVOMD	2nd	S7_122585514	7	3.56E-04	18.21

Both Tables modified from Govintharaj 2018

ANNEX OBJECTIVE 3



Objective 3- Figure 1:Cost of fresh and dry grass forage and grass forage digestibility sold in small and large bundles at fodder markets in greater Hyderabad in 2016 and 2017

Objective 3-Table 1: Average fresh (FB) and dry (DM) biomass yield perennial forage sorghum CO_{29}-FS distributed to and grown by small holder farmers in the Bhanoor Village Cluster (BVC) and Mulkanoor Women Dairy Cooperative (MWDC).

	First Cut (kg/ha)		**Second Cut (kg/ha)**		**Third Cut (kg/ha)**	
	FB	**DB**	**FB**	**DB**	**FB**	**DB**
BVC	27 942	5 525	29 837	7 280	21 906	5 456
MWDC	27 670	5 680	19 520	4 237	Ongoing	

Objective 2 – Table 2: Contract farming of maize and sorghum forages implement by Dodla Dairy targeting with 1 200 farmers: prices farmers realize per ton of fresh forage

Forage	Harvesting done by Dodla	Harvesting done by farmer and delivered to Dodla
Maize	1 700 India Rupees per tom	2 000 Indian Rupees per ton
Sorghum	1 500 Indian Rupees per ton	Not observed