

Unveiling diversity for quality traits in Horsegram [*Macrotyloma uniflorum* (Lam.) Verdc.] landraces: A forgotten nutraceutical pulse crop of ancient India

Manju Kumari^{1,2}, Siddhant Ranjan Padhi^{1,2}, Sushil Kumar Chourey², Vishal Kondal², Swapnil S. Thakare³, Ankita Negi³, Veena Gupta², Mamta Arya², Jeshima KhanYasin², Rakesh Singh², Chellapilla Bhardwaj⁴, Atul Kumar⁴, Kailash Chandra Bhatt^{2*}, Rakesh Bhardwaj^{2*}, J C Rana⁵, Tanay Joshi⁶ and Amritbir Riar⁶

Supplementary Table S1. Observed values for the traits investigated in the study

S.No.	IC Number	State	Protein (g/100g)	Starch (g/100g)	Sugars (g/100g)	Phytic acid (mg/g)	Phenols (mg GAE/g)
1	IC432011	Maharashtra	24.15	29.81	5.94	17.00	10.40
2	IC432059	Maharashtra	23.29	30.25	7.94	21.15	9.06
3	IC278831	Himachal Pradesh	22.57	30.03	8.30	8.56	8.42
4	IC278832	Himachal Pradesh	23.61	29.58	9.24	10.77	9.09
5	IC383470	Uttarakhand	22.20	30.33	8.50	10.66	8.32
6	IC406524	Uttarakhand	24.73	30.44	7.76	7.05	8.69
7	IC392511	Uttarakhand	23.51	29.64	5.63	5.52	7.86
8	IC469855	Uttarakhand	23.07	29.92	5.93	7.55	9.47
9	IC469794	Uttarakhand	22.87	28.76	5.01	10.62	9.19
10	IC263263	Uttarakhand	23.60	29.29	9.27	6.87	8.45
11	IC263264	Uttarakhand	22.72	30.39	7.98	12.79	8.92
12	IC263277	Uttarakhand	22.24	29.82	7.99	13.22	8.16
13	IC263294	Uttarakhand	24.75	26.62	8.06	11.67	9.39
14	IC356050	Uttarakhand	24.13	30.97	9.34	10.35	8.80
15	IC382656	Uttarakhand	23.68	30.78	6.75	10.58	8.27
16	IC561027	Jharkhand	24.23	28.40	5.51	4.64	7.00
17	IC561029	Jharkhand	24.74	27.21	5.76	5.12	8.82
18	IC382218	Himachal Pradesh	23.24	30.34	4.95	10.79	8.04
19	IC361651	Himachal Pradesh	23.24	30.05	5.07	10.86	8.45
20	IC310660	Rajasthan	23.85	29.16	7.78	10.85	6.89
21	IC278825	Himachal Pradesh	23.76	27.67	6.19	7.41	11.26
22	IC278827	Himachal Pradesh	23.46	28.99	8.13	10.84	8.03
23	IC278829	Himachal Pradesh	23.92	29.99	8.90	13.92	7.04
24	IC278830	Himachal Pradesh	24.42	28.30	8.72	8.82	8.11
25	IC281653	Uttarakhand	22.80	28.85	5.69	1.88	9.24
26	IC281651	Uttarakhand	23.10	31.14	6.00	4.79	7.61
27	IC281624	Uttarakhand	23.21	30.86	8.05	5.48	8.56
28	IC281835	Uttarakhand	22.46	30.83	5.94	9.63	7.26
29	IC281820	Uttarakhand	23.24	29.94	8.02	3.41	8.38
30	IC469752	Uttarakhand	21.79	31.52	5.16	8.20	8.83
31	IC469766	Uttarakhand	21.92	32.38	8.24	11.57	8.34
32	IC469827	Uttarakhand	22.07	30.49	5.35	10.18	8.11
33	IC396009	Chattisgarh	25.06	27.70	5.85	11.08	6.64
34	IC396012	Chattisgarh	23.53	28.31	6.50	5.95	6.80
35	IC561021	Jharkhand	24.19	29.69	5.47	6.55	7.74
36	IC263319	Uttarakhand	23.35	30.68	5.42	11.44	7.16

S.No.	IC Number	State	Protein (g/100g)	Starch (g/100g)	Sugars (g/100g)	Phytic acid (mg/g)	Phenols (mg GAE/g)
37	IC263325	Uttarakhand	23.63	29.00	5.90	12.42	8.67
38	IC263332	Uttarakhand	23.90	31.56	5.78	10.80	9.33
39	IC400120	Odisha	23.72	30.65	7.90	18.68	9.38
40	IC385840	Jharkhand	24.15	29.17	8.74	14.95	11.02
41	IC385919	Jharkhand	23.44	29.06	8.19	17.70	7.98
42	IC385923	Jharkhand	24.16	28.07	8.06	16.22	9.59
43	IC391416	Uttarakhand	24.55	27.91	7.83	9.86	8.57
44	IC391572	Uttarakhand	24.23	31.35	8.19	11.50	8.57
45	IC426475	Andhra Pradesh	24.88	29.53	8.19	15.79	7.82
46	IC397423	Madhya Pradesh	23.98	30.30	7.92	11.01	7.40
47	IC397441	Madhya Pradesh	23.40	29.14	8.09	13.69	7.72
48	IC397443	Madhya Pradesh	24.36	30.39	5.80	18.05	6.81
49	IC397461	Madhya Pradesh	22.62	29.28	8.31	9.20	8.94
50	IC397465	Madhya Pradesh	22.14	30.90	8.64	12.36	8.48
51	IC397479	Madhya Pradesh	23.83	29.32	9.16	13.74	7.73
52	IC397511	Madhya Pradesh	24.20	29.79	10.15	9.56	5.77
53	IC397588	Madhya Pradesh	24.04	31.10	9.11	13.26	7.58
54	IC397611	Madhya Pradesh	23.51	29.91	8.58	11.13	10.22
55	IC423538	Himachal Pradesh	23.26	29.83	7.88	6.02	8.05
56	IC423572	Himachal Pradesh	22.42	31.67	8.37	16.21	6.97
57	IC418359	Uttarakhand	23.34	32.15	8.24	12.48	8.65
58	IC259884	Odisha	22.75	29.84	8.57	9.12	7.41
59	IC273740	Chattisgarh	22.88	29.05	8.39	5.94	9.26
60	IC273742	Chattisgarh	24.07	29.88	8.07	8.54	8.01
61	IC273743	Chattisgarh	23.52	28.18	10.69	7.16	7.75
62	IC273750	Chattisgarh	24.13	28.37	8.48	5.74	8.36
63	IC273748	Chattisgarh	21.88	32.91	8.44	16.06	7.53
64	IC265920	Himachal Pradesh	22.40	30.39	12.10	10.34	6.22
65	IC317402	Odisha	23.82	29.73	7.78	8.36	5.93
66	IC276108	Arunachal Pradesh	23.58	30.32	6.40	11.74	8.25
67	IC262082	Uttarakhand	23.74	30.14	7.57	8.04	6.50
68	IC262106	Uttarakhand	21.93	30.17	9.64	1.66	8.85
69	IC262880	Himachal Pradesh	22.53	30.91	8.35	4.56	6.77
70	CRHG 19	Andhra Pradesh	22.24	31.34	8.15	5.16	6.54
71	CRIDA 18 R	Andhra Pradesh	23.73	29.51	8.16	7.23	8.64
72	VL 19	Uttarakhand	23.55	28.78	7.96	7.07	8.60
73	BSP 1521	Chattisgarh	23.86	28.35	9.53	1.07	9.04
74	VL 15	Uttarakhand	23.04	30.80	8.26	7.36	8.82
75	IC145357	Unknown	24.20	29.99	3.16	11.96	4.39
76	IC139562	Telangana	22.33	32.10	3.45	8.49	6.28
77	IC139429	Delhi	21.77	32.00	3.99	7.47	6.97
78	IC023489	Chattisgarh	24.88	28.20	3.30	15.15	4.56
79	IC330562	Tamil Nadu	23.18	31.84	2.88	5.00	4.83
80	IC336492	Bihar	22.92	31.50	2.47	4.75	4.29
81	IC007400	Unknown	24.32	27.09	3.84	8.43	5.76
82	IC625403	West Bengal	25.22	28.35	3.02	5.47	7.89
83	IC023437	Madhya Pradesh	23.83	31.01	2.62	9.34	4.61
84	IC071741	Tamil Nadu	23.78	29.38	3.92	5.36	6.44
85	IC426522	Andhra Pradesh	24.41	28.79	3.71	8.28	7.86
86	IC426521	Andhra Pradesh	23.99	30.03	3.37	5.89	5.50
87	IC426538	Andhra Pradesh	24.66	29.08	3.47	7.65	6.61
88	IC426571	Andhra Pradesh	25.02	28.11	3.58	4.87	6.94

S.No.	IC Number	State	Protein (g/100g)	Starch (g/100g)	Sugars (g/100g)	Phytic acid (mg/g)	Phenols (mg GAE/g)
89	IC089016	Tamil Nadu	24.29	30.10	4.31	11.84	8.46
90	IC019431	Odisha	24.18	30.18	3.64	2.83	4.98
91	IC139560	Telangana	23.51	31.89	3.30	4.47	7.02
92	IC094617	Madhya Pradesh	22.78	30.97	2.69	5.73	5.38
93	IC105564	Jharkhand	22.32	31.95	4.64	10.57	3.85
94	IC033124	Maharashtra	23.83	30.26	2.69	9.48	6.05
95	IC343814	Andhra Pradesh	22.56	32.60	2.83	8.94	6.55
96	IC341255	Maharashtra	22.82	31.58	2.60	9.28	4.84
97	IC426452	Telangana	22.84	31.61	5.75	14.37	7.01
98	IC426464	Telangana	22.11	31.82	3.13	5.87	5.39
99	IC426463	Telangana	21.77	33.00	2.68	12.33	5.48
100	IC022772	Chattisgarh	24.95	27.00	0.86	16.71	3.96
101	IC022770	Chattisgarh	24.65	28.78	1.39	14.27	5.61
102	IC541565	Unknown	24.20	30.32	3.80	12.20	6.10
103	EC501564	Ethopia	24.95	29.56	3.57	11.91	8.40
104	IC022779A	Madhya Pradesh	23.09	31.34	3.42	7.30	4.79
105	IC022781	Madhya Pradesh	23.38	31.39	1.60	10.14	3.76
106	IC426580	Andhra Pradesh	24.18	30.52	3.20	7.03	5.14
107	IC426579	Andhra Pradesh	25.11	28.77	2.79	4.64	5.77
108	IC045726	West Bengal	23.92	30.14	3.23	11.70	5.72
109	IC045717A	Tamil Nadu	24.57	28.94	3.58	6.38	7.01
110	IC047114	Andhra Pradesh	24.79	28.27	3.92	13.25	5.85
111	IC049553	Maharashtra	23.49	30.83	3.80	17.05	4.80
112	IC044023	Kerala	25.04	27.66	4.79	11.13	6.36
113	IC105820	Jharkhand	23.75	31.01	3.02	18.84	5.21
114	IC120835	Unknown	24.27	30.40	3.04	11.64	4.57
115	IC071784	Tamil Nadu	22.40	29.74	3.62	11.32	6.10
116	IC071773	Tamil Nadu	24.39	29.81	3.20	21.21	5.60
117	IC139561	Tamil Nadu	24.57	30.68	2.67	5.27	5.31
118	IC120838	Unknown	25.20	27.74	3.23	17.12	5.15
119	IC123022	Unknown	23.54	28.81	3.71	11.11	5.46
120	IC256885	Odisha	26.15	28.49	2.59	12.80	5.17
121	IC328712	Andhra Pradesh	24.45	28.27	2.99	4.29	6.14
122	IC023482	Madhya Pradesh	26.70	28.96	1.31	14.16	3.38
123	IC071733	Tamil Nadu	24.39	30.60	3.20	21.21	5.60
124	IC044021	Kerala	26.05	28.11	3.29	19.21	4.74
125	IC385836	Jharkhand	23.57	30.94	2.36	16.60	5.21
126	IC022756	Chattisgarh	24.10	30.24	3.36	17.53	4.95
127	IC022840	Unknown	23.60	30.49	3.22	16.37	5.01
128	IC123029	Unknown	23.76	29.80	4.28	11.46	5.40
129	IC139512	Kerala	25.94	30.22	3.60	14.40	3.93
130	IC071825	Tamil Nadu	23.78	28.88	3.16	14.24	4.81
131	IC201115	Chattisgarh	23.75	29.31	2.49	11.79	4.70
132	IC022795	Chattisgarh	25.76	30.00	2.46	5.21	3.81
133	IC023439A	Chattisgarh	25.29	27.03	3.30	5.48	4.86
134	IC201108	Chattisgarh	25.76	28.75	3.01	9.38	6.96
135	IC071757	Tamil Nadu	24.78	28.11	3.96	8.38	5.45
136	IC094599A	Jharkhand	23.70	29.53	4.53	7.96	6.63
137	IC0369691	Andhra Pradesh	24.48	26.20	3.14	10.00	5.35
138	IC015735	Jharkhand	24.72	27.61	5.95	5.43	7.79
139	IC015728	Jharkhand	23.25	28.80	4.75	3.62	6.00

Supplementary Table S2. Extent of variance explained by principle components

Principle Component	Eigen Value	Variance %	Cumulative Variance%
PC-1	1.987	39.73	39.73
PC-2	1.430	28.59	68.33
PC-3	0.999	19.99	88.32
PC-4	0.294	5.88	94.20
PC-5	0.290	5.80	100.00

Supplementary Table S3. Percent contributions of the variables in principle components

SN.	Variable	PC-1	PC-2	PC-3	PC-4	PC-5
1	Sugars	34.96%	1.54%	5.32%	15.72%	42.46%
2	Starch	21.87%	8.51%	3.66%	62.70%	3.26%
3	Protein	14.15%	36.03%	15.77%	20.80%	13.26%
4	Phytic acid	1.00%	35.10%	63.44%	0.20%	0.26%
5	Phenols	28.02%	18.84%	11.81%	0.58%	40.76%
	Total	100.00%	100.00%	100.00%	100.00%	100.00%

Supplementary Table S4. Correlations between variables and Principle Components

S.N.	Variable	PC-1	PC-2	PC-3	PC-4	PC-5
1	Sugars	-0.78	0.13	0.23	0.35	0.45
2	Starch	-0.62	-0.30	-0.19	-0.69	0.12
3	Protein	0.50	0.62	0.39	-0.40	0.25
4	Phytic acid	0.13	-0.61	0.78	-0.04	-0.04
5	Phenols	-0.70	0.45	0.34	-0.07	-0.44

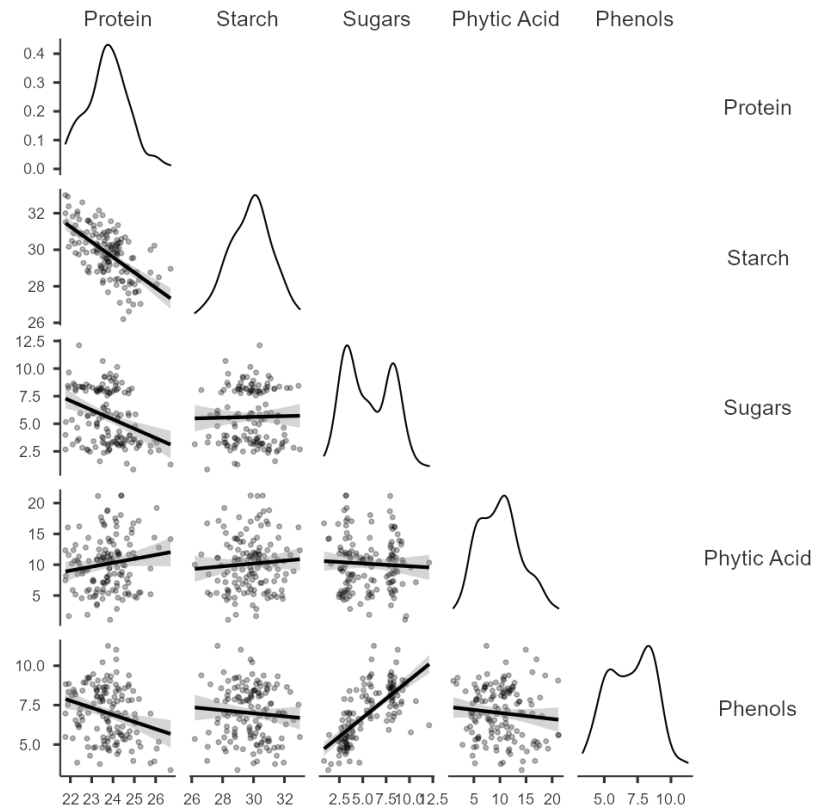
Supplementary Table S5. HCA clustering pattern and composition

States Name	No. of States Represented in cluster					Total
	I	II	III	IV	V	
Uttarakhand	17	0	6	6	0	29
Chhattisgarh	4	3	4	1	4	16
Madhya Pradesh	4	2	2	5	1	14
Andhra Pradesh	2	3	6	1	1	13
Himachal Pradesh	8	0	2	2	0	12
Jharkhand	0	2	5	3	2	12
Tamil Nadu	1	3	3	0	3	10
Unknown	0	6	0	0	2	8

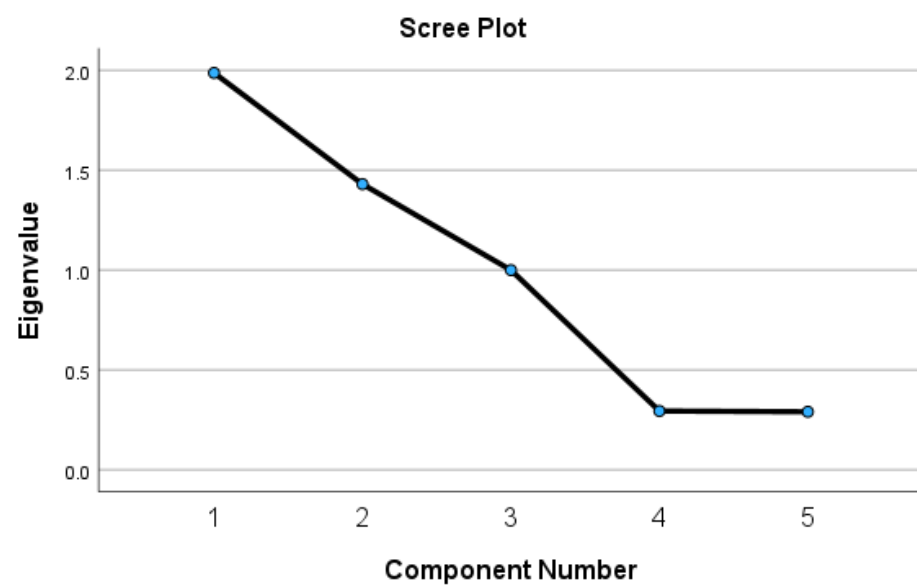
Maharashtra	0	2	0	2	1	5
Odisha	2	0	1	1	1	5
Telangana	1	1	2	1	0	5
Kerala	0	1	0	0	2	3
West Bengal	0	1	1	0	0	2
Rajasthan	1	0	0	0	0	1
Arunachal Pradesh	1	0	0	0	0	1
Delhi	1	0	0	0	0	1
Bihar	0	0	1	0	0	1
Ethopia	1	0	0	0	0	1
Total	43	24	33	22	17	139

Supplementary Table S6. State-wise mean values of the traits investigated in the study

SN	State/ Country of origin	No of Accessions	Phenols mg GAE/g	Sugars g/100g	Protein g/100g	Starch g/100g	phytic acid mg/g
1	Andhra Pradesh	13	6.52	4.42	24.19	29.31	7.92
2	Arunachal Pradesh	1	8.25	6.40	23.58	30.32	11.74
3	Bihar	1	4.29	2.47	22.92	31.50	4.75
4	Chattisgarh	16	6.43	5.38	24.25	28.88	9.82
5	Delhi	1	6.97	3.99	21.77	32.00	7.47
6	Ethopia	1	8.40	3.57	24.95	29.56	11.91
7	Himachal Pradesh	12	8.04	8.02	23.24	29.81	9.93
8	Jharkhand	12	7.24	5.58	23.85	29.29	10.68
9	Kerala	3	5.01	3.89	25.68	28.66	14.91
10	Madhya Pradesh	14	6.61	6.24	23.70	30.27	11.33
11	Maharashtra	5	7.03	4.59	23.52	30.55	14.79
12	Odisha	5	6.57	6.10	24.13	29.78	10.36
13	Rajasthan	1	6.89	7.78	23.85	29.16	10.85
14	Tamil Nadu	10	5.96	3.45	24.01	29.81	11.02
15	Telangana	5	6.24	3.66	22.51	32.08	9.11
16	Unknown	8	5.23	3.53	24.14	29.33	12.54
17	Uttarakhand	29	8.47	7.22	23.22	30.19	8.78
18	West Bengal	2	6.81	3.12	24.57	29.25	8.59
Total/Overall mean		139	7.00	5.61	23.74	29.81	10.15



Suplimentary Fig. 1 Correlogram scatter plot matrix explaining extent of variation, data distribution and correlation of biochemicals



Supplementary Fig. 2 PCA Scree plot