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Performance of Some Ethiopian Fenugreek (*Trigonella foenum-graecum* L.) Germplasm Collections as Compared with the Commercial Variety Challa

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Abstract: Systematic breeding efforts on fenugreek have so far been neglected in Ethiopia. For this, 143 random samples of fenugreek accessions along with a commercial variety were used in this study to evaluate the potential of the land races. The field experiment was conducted at Haramaya University research station during 2011 main cropping season. Treatments were arranged in a 12×12 simple lattice design. The highest biomass and seed yielding accessions were generally concentrated more in the categories of yellow and green seed colors. When compared with the commercial variety, above 27% of the tested accessions performed significantly better in terms of seed yield indicating that significant yield gains could be secured by simple selection. However, further evaluation over wider environments is necessary to arrive at conclusive points for such quantitative traits. Green and yellow seeded accessions are widely distributed over all the country and over half of the accessions (63%) had green seed color. High seed yield bearing accessions were those collected from northwest and central part of Ethiopia, while accessions collected from eastern and northwestern Ethiopia were strikingly bold seed size. This variability would provide a basis for improving the crop in breeding program.

Key words: Performance, Ethiopian fenugreek, *Trigonella foenum-graecum* L., commercial variety, Challa

INTRODUCTION

The grain legumes not only provide variety to human diet but also supply dietary proteins for vegetarians that abstain animal and fish proteins in their diet. Furthermore, considering the rapidly growing human population and thus the problem of malnutrition especially in Sub-Saharan Africa, use of legume species as a source of high-protein food is an amicable option. Moreover, legumes are also capable of symbiotic nitrogen fixation and thereby enriching the soil conditions that become suitable for crops following those (Bromfeild *et al*., 2001).

The genus *Trigonella* is one of the largest genera of the tribe Trifoliate in the family Fabaceae and sub-family Papilionaceae (Balodi and Rao, 1991). Among *Trigonella* species, *Trigonella foenum-graecum* (commonly known as fenugreek) is an annual species, with autogamous white flowers occasionally visited by insects. It is indigenous to countries on the eastern shores of the Mediterranean but widely cultivated in India, Egypt, Ethiopia, Morocco and occasionally in England (Polhill and Raven, 1981; Acharya *et al*., 2006). According to Hymowitz (1990), *T. foenum-graecum*, although important in food and medicine, is rarely grown outside its native habitat. Across the world only few known and well-defined cultivars are grown in specific areas.

Fenugreek is a chemurgic cash crop, usually cultivated as a break crop for cereal and it is considered as a good soil renovator (McCormick, 2004). The whole plant is used as forage and vegetable, while the seeds (whole, powdered into flour, or roasted) are used as human food and animal feed (Mir *et al*., 1993), spice, dyeing, flavouring, as well as for medical and (Westphal, 1974; Sharma *et al*., 1990) industrial purposes (Sharma *et al*., 1991). The aim of plant breeder is to develop improved varieties with increased yield and an acceptable grain quality and stability. This is the major breeding objective for fenugreek, as reported by Edison (1995) in countries such as India.

Systematic breeding efforts on this crop have so far been neglected and presence of variability in this crop offers much scope for its improvement. Only little of such vital information on fenugreek landraces is present under Ethiopian conditions. In view of filling up such a technical gap, this piece of research work was conceived by the author to address the objective of evaluating the potential of the land races as compared with the commercial variety for future improvement program.

MATERIALS AND METHODS

Experimental site: The field experiment was conducted at Haramaya University Research station located at 9°24'N and 42°03'E, in Ethiopia during 2011 main cropping season. Haramaya has an altitude of 1980 m.a.s.l. It was in semi-arid sub-tropical belt of eastern Ethiopia. The area receives an average annual rainfall of 870 mm. The soil is characterized as a fluvisol with a pH of 7.4.

Experimental material and design: One hundred forty-three random samples of fenugreek accessions along with a commercial variety, Challa, were considered in this study. The accessions were collected from the most important production complexes of Ethiopia representing different agro-ecologies of varying altitude, rainfall, temperature and soil type (Fig. 1).

The commercial variety, Challa was released by Ethiopian Institute of Agricultural Research, Debrezeit Agricultural Research Center, after fulfilling the requirements set by the National Variety Release Committee for national production primarily in areas with 1700-2600 m.a.s.l. and average annual rainfall of 700-1200 mm. It is typically characterized by average seed yield of 900-1800 and 800-1500 kg ha^{-1} on research and farmer fields, respectively. The list of the tested accessions is given along with their geographical origins in Table 1.

Treatments were arranged in a 12×12 simple lattice design. Seeding was done in a plot of four rows with 2 m length and regular spacing of 10 cm between plants and 25 cm between rows. The layout and randomization were as per the standard procedure set by Cochran and Cox (1957). Two seeds per hole were placed carefully to ensure the first germination. Thinning was made at the true leaf stage. Weeding and other cultural practices were done as per the recommendations.

Data collected and analysis: The following data were collected during 2011 from the central two rows of the plot or from five sample plants randomly from each plot. Mean values of these samples were utilized to estimate the performance of each germplasm accession for the traits under consideration. The following data such as; days to flowering, days to maturity, grain filling period, powdery mildew, number of pods per plant, plant height, number of seeds per plant, number of seeds per pod, number of nodes per plant, number of podding nodes per plant, number of primary branches per plant, number of secondary branches per plant, number of nodules/plant, fresh weight of nodules/plant, number of effective nodules/plant, biomass yield per plot, thousand seed weight, seed colour, seed yield and harvest index were collected and subject to the analysis.

Least Significant Difference (LSD) was used for mean separation as indicated hereunder:

$$LSD = t_{\alpha/2}(Rdf) \times SED$$

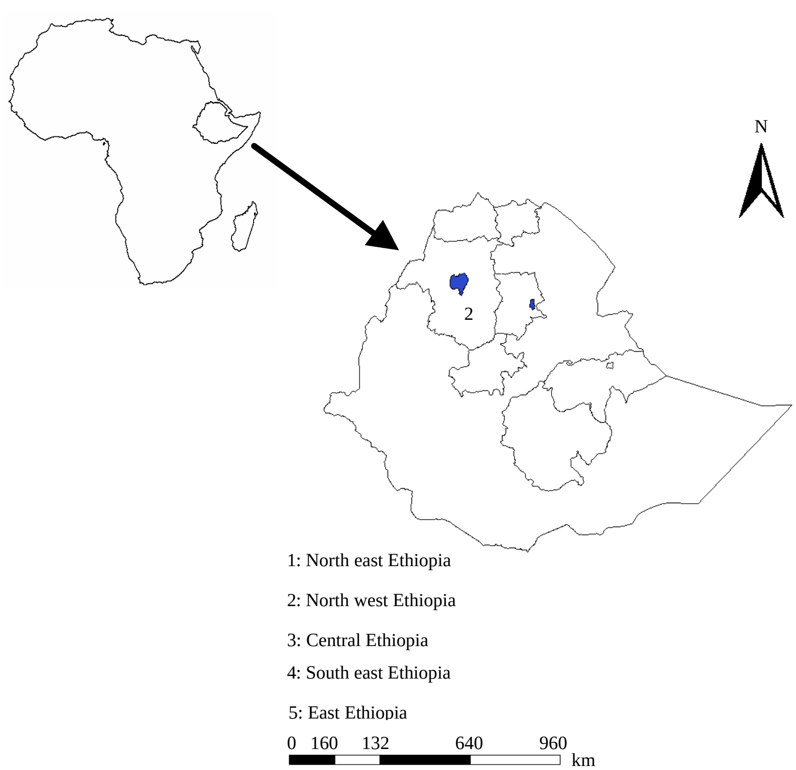

Fig. 1: Map of Ethiopia showing geographical locations from where the accessions of fenugreek were collected

Table 1: Geographic origins of the fenugreek accessions by administrative zone, woreda and altitude

Accession	Region	Zone[1]	District[2]	Altitude (m.a.s.l.)
FgColl53007	North Eastern	North Wello	Guba Lafto	2100
FgColl53010	North Eastern	North Wello	Dawuntna Delanta	2170
FgColl215261	North Eastern	North Wello	Guba Lafto	1910
FgColl213109	North Eastern	South Wello	Jama	NA
FgColl213110	North Eastern	South Wello	Were Ilu	NA
FgColl213111	North Eastern	South Wello	Were Ilu	NA
FgColl213112	North Eastern	South Wello	Were Ilu	NA
FgColl213114	North Eastern	South Wello	Were Ilu	NA
FgColl213115	North Eastern	South Wello	Were Ilu	NA
FgColl53014	North Eastern	South Wello	Legambo	2300
FgColl53102	North Eastern	South Wello	Were Ilu	2650
FgColl53104	North Eastern	South Wello	Tenta	2880
FgColl53105	North Eastern	South Wello	Mekdela	2640
FgColl212658	North Eastern	South Wello	Kutaber	2400
FgColl212656	North Eastern	South Wello	Tenta	2690
FgColl212657	North Eastern	South Wello	Mekdela	2750
FgColl213117	North Eastern	South Wello	Jama	NA
FgColl215729	North Eastern	South Wello	Were Babu	2450
FgColl215731	North Eastern	South Wello	Were Babu	2050
FgColl226090	North Eastern	South Wello	Debre Sina	2420
FgColl53012	North Eastern	South Wello	Were Ilu	NA
FgColl53013	North Eastern	South Wello	Were Ilu	NA
FgColl53019	North Eastern	South Wello	Were Ilu	NA
FgColl53103	North Eastern	South Wello	Were Ilu	2590
FgColl234027	North Eastern	Central Tigrai	Adwa	2100
FgColl234028	North Eastern	Central Tigrai	Laelay Maychew	2130
FgColl234030	North Eastern	East Tigrai	Wukro	2210
FgColl234031	North Eastern	East Tigrai	Ganta Afeshum	2150
FgColl234032	North Eastern	Central Tigrai	Naeder Adet	2120
FgColl234033	North Eastern	Central Tigrai	Naeder Adet	2120
FgColl235133	North Eastern	Central Tigrai	Laelay Maychew	2120
FgColl234034	North Eastern	East Tigrai	Wukro	2410
FgColl237511	North Eastern	Central Tigrai	Laelay Maychew	2100
FgColl207359	North Eastern	East Tigrai	Gulomahda	NA
FgColl207360	North Eastern	South Tigrai	Enderta	NA
FgColl207599	North Eastern	Central Tigrai	Laelay Maychew	NA
FgColl215585	North Eastern	South Tigrai	Ofla	NA
FgColl234023	North Eastern	Central Tigrai	Laelay Maychew	NA
FgColl234024	North Eastern	Central Tigrai	Laelay Maychew	NA
FgColl234025	North Eastern	Central Tigrai	Laelay Maychew	NA
FgColl234026	North Eastern	Central Tigrai	Adwa	NA
FgColl234029	North Eastern	Central Tigrai	Laelay Maychew	2100
FgColl235134	North Eastern	South Tigrai	Mekele	NA
FgColl53008	North Western	South Gondar	Tach Gayint	2480
FgColl53009	North Western	South Gondar	Este	2330
FgColl53062	North Western	North Gondar	Alefanataqusa	2010
FgColl53061	North Western	North Gondar	Gondar Zuria	1870
FgColl53071	North Western	East Gojam	Enarj Enawga	2380
FgColl236621	North Western	East Gojam	Enemay	2480
FgColl53080	North Western	East Gojam	Huletejuenese	2450
FgColl53096	North Western	West Gojam	Mecha	2090
FgColl53097	North Western	East Gojam	Enarj Enawga	2540
FgColl53107	North Western	East Gojam	Enarj Enawga	2550
FgColl53108	North Western	North Gondar	Wegera	2700
FgColl53109	North Western	North Gondar	Dabat	2610
FgColl212775	North Western	East Gojam	Shebel Berenta	2410
FgColl212776	North Western	East Gojam	Enemay	2580
FgColl212779	North Western	North Gondar	Dabat	2680
FgColl226091	North Western	North Gondar	Dembia	1820
FgColl236622	North Western	East Gojam	Enarj Enawga	2580
FgColl239065	North Western	West Gojam	Bahir Dar Zuria	2000
FgColl239066	North Western	West Gojam	Mecha	2050
FgColl239068	North Western	West Gojam	Bahir Dar Zuria	1930
FgColl53005	North Western	North Gondar	Chilga	NA
FgColl53021	North Western	East Gojam	Shebel Berenta	2410
FgColl53026	North Western	East Gojam	Enarj Enawga	NA
FgColl53050	North Western	East Gojam	Shebel Berenta	NA
FgColl53063	North Western	Awi	Dangila	NA

Table 1: Continue

Accession	Region	Zone[1]	District[2]	Altitude (m.a.s.l.)
FgColl53078	North Western	East Gojam	Enarj Enawga	2510
FgColl53079	North Western	East Gojam	Huletejuenese	2510
FgColl53098	North Western	East Gojam	Enemay	2550
FgColl53099	North Western	East Gojam	Enemay	2570
FgColl205176	North Western	North Gondar	Debark	NA
FgColl207356	North Western	North Gondar	Wegera	NA
FgColl207365	North Western	North Gondar	Dabat	NA
FgColl207367	North Western	North Gondar	Libo Kemekem	NA
FgColl207376	North Western	North Gondar	Jan Amora	NA
FgColl207370	North Western	North Gondar	Wegera	NA
FgColl207391	North Western	South Gondar	Tach Gayint	NA
FgColl212777	North Western	East Gojam	Enemay	2520
FgColl215334	North Western	East Gojam	Gonchasisoenese	NA
FgColl215335	North Western	East Gojam	Enbise Sar Midir	NA
FgColl239061	North Western	East Gojam	Enemay	2440
FgColl239064	North Western	East Gojam	Enarj Enawga	2530
FgColl239062	North Western	East Gojam	Enemay	NA
FgColl237982	Central	West Shoa	Becho	2110
FgColl229245	Central	North Shoa	Laybetna Tachbet	NA
FgColl229246	Central	North Shoa	Laybetna Tachbet	NA
FgColl229247	Central	North Shoa	Moretna Jiru	2760
FgColl53003	Central	North Shoa	Yaya Gulele	2720
FgColl53002	Central	North Shoa	Moretna Jiru	3150
FgColl53023	Central	North Shoa	Wara Jarso	2570
FgColl53086	Central	North Shoa	Gerar Jarso	NA
FgColl53087	Central	North Shoa	Mulona Sululta	NA
FgColl53088	Central	North Shoa	Moretna Jiru	2700
FgColl53106	Central	North Shoa	Siyadebrina Wayu	2600
FgColl212549	Central	North Shoa	Siyadebrina Wayu	2670
FgColl212550	Central	North Shoa	Weremo Wajetuna	NA
FgColl212552	Central	North Shoa	Weremo Wajetuna	2680
FgColl214942	Central	North Shoa	Mafudmezezo	NA
FgColl215096	Central	North Shoa	Lalona Mama Midir	NA
FgColl239073	Central	North Shoa	Berehna Aleltu	2450
FgColl230072	South Eastern	Bale	Ginir	2100
FgColl53064	South Eastern	Bale	Agarfa	2450
FgColl53091	South Eastern	Bale	Agarfa	NA
FgColl53100	South Eastern	Bale	Goro	2070
FgColl212876	South Eastern	Bale	Goro	1750
FgColl212877	South Eastern	Bale	Goro	1800
FgColl212878	South Eastern	Bale	Nensebo	NA
FgColl215405	South Eastern	Bale	Ginir	2070
FgColl215406	South Eastern	Bale	Goro	1850
FgColl53072	South Eastern	Arssi	Chole	2520
FgColl53074	South Eastern	Arssi	Chole	2660
FgColl53075	South Eastern	Arssi	Amigna	2435
FgColl216897	South Eastern	Arssi	Bekoji	2340
FgColl216898	South Eastern	Arssi	Bekoji	2740
FgColl216899	South Eastern	Arssi	Asasa	2550
FgColl230073	South Eastern	Bale	Ginir	2020
FgColl232194	South Eastern	Arssi	Merti	NA
FgColl236992	South Eastern	Arssi	Seru	2000
FgColl237984	South Eastern	Bale	Gaserana Gololcha	2330
FgColl239727	South Eastern	Bale	Ginir	2170
FgColl53006	South Eastern	Arssi	Asasa	NA
FgColl53085	South Eastern	Bale	Sinana Dinsho	2560
FgColl230070	South Eastern	Bale	Ginir	NA
FgColl232195	South Eastern	Arssi	Merti	NA
FgColl219250	Eastern	West Hararghe	Chiro	NA
FgColl223349	Eastern	West Hararghe	Guba Koricha	2200
FgColl53016	Eastern	West Hararghe	Tulo	2400
FgColl53017	Eastern	East Hararghe	Deder	NA
FgColl53018	Eastern	East Hararghe	Haramaya	2370
FgColl208679	Eastern	West Hararghe	Mieso	NA
FgColl208680	Eastern	East Hararghe	Goro Gutu	NA
FgColl53016	Eastern	West Hararghe	Tulo	2400
FgColl223350	Eastern	West Hararghe	Guba Koricha	2100
FgColl223351	Eastern	West Hararghe	Guba Koricha	2130

Table 1: Continue

Accession	Region	Zone[1]	District[2]	Altitude (m.a.s.l.)
FgColl223352	Eastern	West Hararghe	Guba Koricha	1980
FgColl223353	Eastern	West Hararghe	Guba Koricha	NA
FgColl230536	Eastern	East Hararghe	Gursum	2200
FgColl230540	Eastern	East Hararghe	Girawa	NA
FgColl230880	Eastern	East Hararghe	Girawa	2420
FgColl230883	Eastern	East Hararghe	Deder	2410
FgColl241140	Eastern	Jijiga	Jijiga	1920
Challa	Commercial cultivar			

NA: Not available, [1]The second highest administrative level next to the region and accommodates from 15-20 Woredas, [2]The next highest administrative level after zone and accommodates more than 20 peasant association

where, comparisons for two treatment mean:

$$\text{SED} = \sqrt{\frac{2 \times \text{EMS}}{r}}$$

And comparison of each treatment with grand mean (Singh and Chaudhary, 1999):

$$\text{SED} = \sqrt{\frac{n-1 \times \text{EMS}}{n \times r}}$$

Whereas, a criterion that can be used to test whether each collected accession is significantly higher than a standard check (in this case Challa) was done by the LSI (Least Significance Increase) procedure which was the one-sided version of the LSD procedure which consisted of a series of one-tailed t-tests. The value of Least Significance Increase was tested at the 5% level of significance, by the formula as shown bellow as used as (Clewer and Scarisbrick, 2001):

$$\text{LSI} = \left[\frac{\text{t (Rdf, 5\%)}}{\text{SED}} \times \sqrt{\frac{2 \times \text{EMS}}{r}}\right] = \text{t (Rdf, 5\%)} \times \text{SED}$$

where, Rdf is Residual degree of freedom; $t_{\alpha/2}$ is Tabulated value, SED is Standard error of deviation, EMS is Error mean square, r is number of replication and n is number of treatment.

RESULTS AND DISCUSSION

As pointed out earlier, this investigation was conducted to bring to light the objectives of evaluate the potential of the land races as compared with the commercial variety and the detail accounts of each of these are presented and discussed hereunder in light of the available literature.

Comparisons made between the performance of the commercial variety Challa and the landraces is given in Table 2. There were many accessions that significantly differed from the commercial variety. Out of the traits considered in the experiment except thousand seed weigh, all showed significantly maximum value among the tested accessions (Table 2). When compared with the commercial variety, more than 31% of them in number of primary branch per plant, 27% in seed yield, 25% in physiological maturity, 14% in number of podding nodes per plant and about 8% in reaction with powdery mildew of the tested accessions performed significantly better in terms of the mentioned traits indicating that significant yield gains could be secured by simple selection. However, further evaluation over wider environments is necessary to arrive at conclusive points for such quantitative traits.

In contradict to this; there were accessions inferior to the commercial variety, Challa, in their performance. Of these, 66.43% of the tested accessions were susceptible to the disease powdery mildew more than the commercial Challa. And few of them showed inferior performance in thousand seed weight, number of nodes, secondary branch and total nodules per plant as compared with the commercial. Similar with the findings of other scholars like and this finding is in consistent with the finding of Asfaw *et al.* (2003), Feysal (2006), Banyai (1973) and Provorov *et al.* (1996).

Identification of superior accessions: The commercial variety, Challa with a value of 125 days ranked 4th for earliness in days to maturity, 59th for thousand seed weight (17.9 g), 58th for number of effective nodules per plant (2.55), 72nd for earliness in days to flowering (51 days), 122nd for biomass yield (2560 kg ha^{-1}) and 131st for seed yield (920 kg ha^{-1}). Traits of the ten highest ranked accessions for biomass and seed yield, days to maturity, number of podding nodes per plant, number of effective nodules per plant and thousand seed weight in comparison with those of the commercial variety Challa are presented in Appendix (Table A). The result from this investigation is in agreement with the previous reports of Cornish *et al.* (1983), Pant *et al.* (1983), Schneiter *et al.* (1994) and Feysal (2006).

The highest biomass yielding accessions were generally characterized by earliness in days to flowering

Table 2: Number and proportion of germplasm collections exhibiting significantly lower or higher values of agronomic traits as compared with the commercial variety Challa

			Difference to Challa					
			Significantly less		Insignificant		Significantly greater	
Attribute	Commercial variety (Challa)	LSD (p<0.05)	No.	%	No.	%	No.	%
Days to 50% flowering	50.80	4.000	-	-	143	10.00	-	-
Days to 90% maturity	125.61	5.350	-	-	107	74.83	36	25.17
Grain filling period	73.83	5.940	-	-	137	95.80	6	4.20
Plant height (cm)	31.84	8.130	-	-	141	98.60	2	1.39
Biomass yield (g plant^{-1})	25.44	1.714	-	-	139	97.20	4	2.80
No. of pods plant^{-1}	12.75	7.270	-	-	127	88.81	16	11.19
No. of seeds plant^{-1}	126.51	100.670	-	-	139	97.20	4	2.80
No. of seeds pod^{-1}	9.93	5.400	-	-	140	97.90	3	2.10
Thousand seeds weight (g)	17.90	3.410	2	1.39	141	98.60	-	-
Seed yield (g plant^{-1})	92.40	4.160	-	-	104	97.90	40	27.78
Harvest index (%)	36.32	9.750	-	-	141	98.60	2	1.39
No. of nodes plant^{-1}	30.67	12.300	2	1.39	139	97.20	2	1.39
No. of podding nodes plant^{-1}	6.94	6.420	-	-	122	85.31	21	14.69
No. of primary branches plant^{-1}	2.18	1.270	-	-	98	68.53	45	31.47
No. of secondary branches plant^{-1}	0.46	1.180	1	0.69	135	94.41	7	4.90
No. of nodules plant^{-1}	14.42	9.670	1	0.69	139	97.20	3	2.10
No. of effective nodules plant^{-1}	2.55	2.430	-	-	140	97.90	3	2.10
Fresh weight of nodules (g plant^{-1})	0.13	0.100	-	-	142	99.30	1	0.69
Powdery mildew	4.00	0.720	95	66.43	34	23.78	14	9.79

but delayed in days to maturity implying that they need longer period for grain filling. They also had higher values of plant height, number of pods per plant, number of seeds per plant and pod, thousand seed weight, seed yield, number of nodes per plant, number of primary branches per plant and fresh weight of nodules per plant. The determining factor for biomass production in this study was plant height. Taller accessions produced more biomass. Heritability for plant height was high, despite the large environmental variance component (Fikreselassie *et al.*, 2012). These accessions have equal values for harvest index, number of podding nodes per plant, secondary branches per plant and number of total and effective nodules per plant. Accessions in this category were yellow and green in seed color. Seven of them collected from North-western, one of each were from North-eastern and eastern part of the country. From the top ten of high seed bearing accessions, seven of the accessions had green and three had yellow seed color. In general, eight of the accessions were collected from North-western and one of each were from North-eastern and South-eastern Ethiopia.

Accessions producing the highest number of effective nodules per plant were characterized by shorter period of flowering and maturity. These accessions were superior for all of the nodulation traits (total and effective number and fresh weight of nodule). They however, categorized as equal for grain filling period, harvest index and number of seeds per pod. All of these accessions had green seed color except one accessions from South-eastern with yellow seed and one from North-western with mixed seed color.

Accessions producing the highest thousand seed weight, required longer periods to flower and mature and thus longer grain filling periods. They were also superior in number of secondary branches per plant. However, they were intermediate, for biomass and seed yield, harvest index, plant height, number of nodes and primary branches per plant, total and effective number of nodules per plant. Among the tested accessions, four of them (FgColl207599, FgColl234029, FgColl234026 and FgColl234033) exhibited white seed color, while four accessions (FgColl53107, FgColl236622, FgColl207370 and FgColl53014) exhibited yellow and the remaining two accessions (FgColl239061 and FgColl53005) exhibited green seed color.

Accessions, which reached physiological maturity in the shortest period, were also characterized by earlier days to flowering and shorter grain filling periods but higher number of seeds per pod and harvest index. This is in consistent with the findings of McCormick (2004). They were characterized by lower biomass and seed yields. Among the top ten early flowering and maturing accessions, eight of them had green seed color, whereas the remaining two were yellow. Four of the top ten were collected from North-eastern, two each from North-western and Eastern and one accession from South-eastern part of the country.

Accessions bearing higher (>30.7) number of podding nodes per plant were found to be late to flower and mature and thus had longer grain filling period and also had higher number of pods and seed yield and number of primary and secondary branches per plant. From the accessions with such characteristics, five had white, four yellow and one accession had green seed color. While seven of them were collected from north-eastern, the remaining three were collected from north-western Ethiopia.

From the present investigation, there is a possibility for selecting accessions with both high biomass and seed yield. For instance, FgColl212777 (5760 and 1440 kg ha^{-1}), FgColl53078 (4600 and 1760 kg ha^{-1}) and FgColl53107 (4880 and 1600 kg ha^{-1}) collected from east Gojam, FgColl212656 (4480 and 1720 kg ha^{-1}) from south Wello and FgColl53023 (4320 and 1640 kg ha^{-1}) from north Shoa were best candidates for the traits. This indicates that simultaneous selection for both green manure and grain production is possible from this set of accessions. Another point of worth notice is that all these accessions have originated from the highlands ranging from 2510- 2690 m.a.s.l.

Differences among seed types: Table 3 summarizes the major characteristics of the 144 Ethiopian *T. foenum-graecum* landraces as they distributed over the four classes of seed color (green, mixed, white and yellow). The results reveal that most (91 = 63%) of the accessions exhibited Green (G) seed color and were collected from the main growing regions of the north-western (22%), north-eastern (32%), central (16%), south-eastern (13%) and eastern (15%) Ethiopia. These accessions exhibited a wide range of values particularly for days to flowering and maturity, biomass yield and thousand seed weight. Green-seeded accessions were most commonly characterized by early flowering and maturity time, low biomass yield and thousand seed weight.

The Mixed-seeded (M) accessions accounting for only 2.77% of the tested germplasm, were collected from North-western and South-eastern Ethiopia. These accessions were typically characterized by relatively late in maturity, higher seed and biomass yields per plant and intermediate seed size as was measured by thousand seed weight.

The White-seeded (W) accessions accounting for 9.72% of the tested material were exclusively collected from north-eastern Ethiopia. These white seeded accessions were generally characterized by being late in flowering and maturity, having higher thousand seed weight and moderate in biomass and low seed yield.

As with the green-seeded accessions, distribution of the yellow-seeded ones also found to represents the different regions of collection and accounted for 24.31% of the entire accessions used for the study. While more than half of the yellow seeded accessions were collected from north-western, one third was from south-eastern, two accessions each from central and eastern and only one accession was collected from north-eastern part of the country. The yellow-seeded accessions were generally early to flower but intermediate to mature and had higher seed and biomass yields.

It is evident from the result that more than half of the collections turned out to be green-seeded which, according to Duke *et al.* (1981), is the type preferred most in the north African markets. Taking into account, the wide distribution of such green-seeded accessions over the major growing regions of the country, it is possible to think of the market potential available for future exploitation of the genetic wealth. McCormick (2004) suggested that from 205 fenugreek accessions collected from different countries, green large-seeded accessions were mainly from Ethiopia and Egypt. But on the other hand, because of the growing demand for white seeded fenugreek across the world, enhancing the seed yield of white-seeded accessions of fenugreek warrants a great deal of attention of the researchers engaged in improving the crop.

Differences among regions of collection: Table 4 summarizes the agro-morphological attributes of the 144 *T. foenum-graecum* landraces studied as they grouped by the regions of collection. It is discernable from the results that the highest seed yield was not recorded from accessions originating from one region; instead, it was

Table 3: Main characteristics of the accessions of Ethiopian *T. foenum-graecum* belonging to different classes of seed color

Seed color	No. of accessions (%)	Major collection region and No. of accessions$^{\beta}$	Days to flowering		Days to maturity		Seed yield (kg ha^{-1})		Biomass yield (kg ha^{-1})		Thousand seed weight (g)		Powdery mildew (1-9 scale)	
			Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
G	91 (63.2)	1 (20), 2 (29), 3 (15), 4 (12), 5 (14), 6 (1)	48-54	51	124-135	129	736-1744	1196	1736-4584	3048	13.75-20.99	17.05	0.5-5.0	3.05
M	4 (2.77)	1 (3), 4 (1)	50-51	51	128-134	130	1220-1440	1372	2996-3988	3412	16.17-18.87	17.99	2.0-5.0	4.00
W	14 (9.72)	2	51-54	53	129-133	131	588-1404	1128	1656-3368	2904	16.11-20.42	18.31	0.5-400	3.12
Y	35 (24.31)	1 (19), 2 (1), 3 (2), 4 (11), 5 (2)	48-53	50	126-135	130	896-1656	1276	2176-5756	3340	14.47-19.97	17.86	1.0-6.0	3.17

G: Green seed color, M: Mixed seed color, W: White seed color and Y: Yellow seed color, $^{\beta}$Numbers in parentheses show the number of accessions included in each of the regions represented as 1: North-western Ethiopia, 2: North-eastern Ethiopia, 3: Central Ethiopia, 4: South-eastern Ethiopia and, 5: Eastern Ethiopia and 6: Commercial variety

Table 4: Main characteristics of the 144 Ethiopian *T. foenum-graecum* accessions collected from major collection regions

Main region of collection	Days to flowering		Days to maturity		Seed yield (kg ha^{-1})		Biomass yield (kg ha^{-1})		Thousand seed weight (g)		Powdery mildew (1-9 scale)		Seed color	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	No. of types	Main type
North-west (42)$^{\beta}$	48-53	51	126-135	130	884-1744	1324	2176-5752	3516	16.75-20.99	18.68	1.50-5.00	3.20	3	G and Y
North-east (44)	49-54	52	124-133	129	588-1724	1148	1656-4472	2924	14.70-20.42	17.16	0.50-5.0	3.07	2	G and W
Central (17)	49-54	52	128-133	131	920-1656	1232	2264-4336	3168	14.70-19.47	16.82	1.00-5.00	2.44	2	G
South-eastern (24)	48-52	50	126-133	129	740-1512	1204	1760-3400	2872	14.47-18.93	16.42	0.5-6.0	3.44	3	G and Y
Eastern (16)	49-52	50	125-131	129	820-1420	1124	1988-4228	2936	13.75-19.16	16.70	1.50-5.00	3.16	2	G
Commercial (1)	51		126		924		2544		17.90		4.00		1	G
Mean	50.87		129.71		1212		3116		17.39		3.10			

G: Green seed color; M: Mixed seed color; W: White seed color; Y: Yellow seed color, $^{\beta}$Number in parentheses show the number of accessions

recorded from accessions originating from north-west (1324 kg ha^{-1}), central highland (1232 kg ha^{-1}) and south-eastern (1204 kg ha^{-1}). Accessions from the central highlands of Ethiopia were mainly green in seed color with relatively moderate thousand seed weight (16.82 g) and biomass yield (3168 kg ha^{-1}). The accessions were relatively late in days to flower (52 days) and mature (129 days) as compared with the commercial variety Challa.

Germplasms from north-western Ethiopia were characterized by relatively high seed (1324 kg ha^{-1}) and biomass (3516 kg ha^{-1}) yields and thousand seed weight (18.68 g) and moderate days to flowering (51 days) and maturity (130 days). Of the four seed color types, green and yellow types were predominant.

Conversely, the accessions from north-eastern Ethiopian were late in days to flowering (52 days) but were early in terms of maturity (129 days) and exhibited low seed yield (1148 kg ha^{-1}). Accessions from this region had predominantly green and white seed colors accompanied with moderate thousand seed weight (17.16 g). The white-seeded fenugreek accessions were not found in most of the regions except the North-eastern region represented in this investigation. Now-a-day, white and bold seeded fenugreek is highly demanded among the world consumers and exporters because of its attractive appearance as one of the quality parameters important in the business sector.

Accessions from south-eastern Ethiopia were found to be early to flower (50 days) and mature (129 days) with moderately high seed (1204 kg ha^{-1}) but low biomass (2872 kg ha^{-1}) yields and thousand seed weight (16.42 g). The seed color of the accessions collected from this region was green and yellow. Accessions from Eastern Ethiopia were, on the other hand, early to flower (50 days) and mature (129 days) with moderately high biomass yield (2936 kg ha^{-1}) and thousand seed weight (16.70 g). Green seed color was predominant in the region. These range of regional variability in fenugreek is in consistent with different scholars engaged in different pulse crop species (Keneni *et al*., 2005a, b; Mussa *et al*., 2003; Alemayehu and Becker, 2002).

From the present investigation, higher seed yield bearing accessions were collected from north-west and central part of Ethiopia. For bold seeded accessions, eastern and north-western Ethiopia seem the preferred areas of collection. Beside the above traits of interest, accessions from Eastern part of the country were found to be earlier to flower and mature. Regarding the traits of seed color, the north-eastern region appeared as the only origin of white seeded cultivars used in this particular study. In the improvement point of view, this piece of information is critical for breeders who engage in improvement program in such away he/she can find the gene of interest from potential areas and can improve the crop as well as can converge or pool the gene for future use. The extent of variability also reported by other scholars (Acharya *et al*., 2006; Marzougui *et al*., 2007; Davoud *et al*., 2010) with the support of the present findings.

CONCLUSION

One hundred forty-three random samples of fenugreek accessions along with one commercial variety (Challa) were investigated in this study. The evaluation of 144 *T. foenum-graecum* indicated variation in yield, yield-associated traits and seed color. From this study, as the data suggest, there are better performing accessions than the currently growing accession Challa. The highest performing accessions were still quite diverse in other traits under study, indicating the potential for wider adaptation to different environments. Green-seeded accessions had greater proportion of high yielding accessions than yellow-seeded types. The highest biomass and seed yielding accessions were generally associated with the categories of yellow and green seed colors. The highest thousand seed weight-producing accessions, required longer time for flowering and maturity and grain filling period and white and yellow-seeded accessions were predominant. The varying characters of the superior accessions have implications for further work. Thus, the variation for the different characters found in fenugreek accessions included in this study could be exploited and used in fenugreek breeding programs. Among the three different types of seed color investigated, which was green, yellow and white, the white seeded fenugreek accessions had lower seed yield. Because of the high demand for this seed color across all over the world, enhancing the seed yield warrants a great deal of attention of the researchers engaged in improving of the crop. There are implications from the variations would provide a basis for a genetically diverse breeding among high performing accessions in this study. They program and provide diversity. It can be concluded that Ethiopian fenugreek landraces contains accessions that vary widely in the studied traits.

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APPENDIX

The commercial variety Challa was compared to ten highest ranking fenugreek accessions, as shown in Table A.

Table A: Traits of the ten highest ranking accessions of fenugreek for biomass and seed yields, days to maturity, number of podding nodes, effective nodules and thousand seed weight as compared to Challa

Accessions	DF	PH	BMY	PPP	SPPL	SPP	TSW	SY	HI	DM	GFP	NPPL	PNP	PBR	SBR	NOP	ENO	FW	SC
BMY (kg ha^{-1})																			
FgColl212777	49.8	37.7	5760	18.8	193.7	10.5	18.3	1440	42.1	130.2	77.4	32.5	12.7	3.9	1.2	11.2	2.7	0.11	Y
FgColl53078	49.6	39.5	4600	20.8	235.7	11.5	18.4	1760	37.4	132.9	78.8	39.4	17.2	3.4	1.2	9.9	1.2	0.10	G
FgColl212656	52.3	36.5	4480	23.6	268.1	11.3	16.3	1720	40.4	129.5	74.9	43.7	19.5	4.3	1.8	20.9	3.5	0.15	G
FgColl53023	49.2	37.1	4320	18.2	217.7	12.1	18.9	1640	38.2	133.2	81.4	32.6	12.0	3.1	0.4	11.2	1.3	0.17	Y
FgColl53107	49.5	36.4	4280	20.4	195.0	9.5	20.0	1600	37.6	132.0	77.7	36.2	14.6	3.4	1.6	11.9	2.7	0.17	Y
FgColl208680	50.5	34.1	4240	15.7	180.0	12.2	18.9	1360	44.4	128.0	74.6	30.4	8.4	4.4	0.5	24.5	3.1	0.18	Y
FgColl53097	51.2	36.8	4040	18.1	209.8	11.3	19.3	1600	41.4	130.6	77.0	32.3	11.3	3.3	0.4	12.3	2.1	0.15	G
FgColl239064	50.6	35.7	4000	16.8	189.9	11.4	18.9	1440	38.4	134.1	79.1	31.7	12.3	3.9	1.2	5.8	1.5	0.15	M
FgColl239066	50.2	40.4	3920	19.9	201.7	10.8	18.9	1520	38.9	130.9	76.4	36.8	13.0	3.2	0.6	8.0	0.8	0.12	G
FgColl207365	51.2	36.9	3880	26.7	221.3	9.2	17.1	1520	39.3	131.3	77.5	38.1	12.1	2.6	1.4	19.3	4.1	0.20	Y
Challa	50.8	31.8	2560	12.7	126.5	9.9	17.9	920	35.5	125.6	73.8	30.7	6.9	2.2	0.5	14.4	2.5	0.13	G
SYLD (kg ha^{-1})																			
FgColl53078	49.6	39.5	4600	20.8	235.7	11.5	18.4	1760	37.4	132.9	78.8	39.4	17.2	3.4	1.2	9.9	1.2	0.10	G
FgColl212656	52.3	36.5	4480	23.6	268.1	11.3	16.3	1720	40.4	129.5	74.9	43.7	19.5	4.3	1.8	20.9	3.5	0.15	G
FgColl53023	49.2	37.1	4320	18.2	217.7	12.1	18.9	1640	38.2	133.2	81.4	32.6	12.0	3.1	0.4	11.2	1.3	0.17	Y
FgColl53097	51.2	36.8	4040	18.1	209.8	11.3	19.3	1600	41.4	130.6	77.0	32.3	11.3	3.3	0.4	12.3	2.1	0.15	G
FgColl23906	51.0	35.2	3680	17.6	193.1	10.9	19.4	1600	43.8	129.3	74.5	33.2	11.2	3.7	0.4	14.1	3.6	0.11	G
FgColl53107	49.5	36.4	4280	20.4	195.0	9.5	20.0	1600	37.6	132.0	77.7	36.2	14.6	3.4	1.6	11.9	2.7	0.17	Y
FgColl205176	50.1	35.2	3880	14.9	215.8	15.0	18.3	1560	41.4	129.2	81.6	29.9	10.5	3.2	1.3	15.4	2.4	0.12	G
FgColl207365	51.2	36.9	3880	26.7	221.3	9.2	17.1	1520	39.3	131.3	77.5	38.1	12.1	2.6	1.4	19.3	4.1	0.20	Y
FgColl207367	49.6	38.9	3760	17.3	196.0	11.5	19.4	1520	41.6	128.1	78.5	32.4	10.0	3.3	1.2	16.2	2.0	0.11	G
FgColl239061	48.2	38.7	3640	15.4	176.8	11.2	21.0	1520	42.9	128.6	76.5	28.5	11.0	3.1	0.3	11.3	3.9	0.15	G
Challa	50.8	31.8	2560	12.7	126.5	9.9	17.9	920	35.5	125.6	73.8	30.7	6.9	2.2	0.5	14.4	2.5	0.13	G
DM																			
FgColl235134	50.5	27.1	1720	9.8	117.3	12.5	16.2	800	39.5	123.8	69.7	24.5	4.5	2.5	0.2	12.0	1.6	0.13	G
FgColl223351	49.8	35.8	2000	17.6	153.0	8.4	13.8	840	40.1	124.6	70.2	32.2	11.9	2.9	0.2	7.7	1.4	0.09	G
FgColl213109	50.6	33.6	3120	14.7	215.9	14.9	15.8	1320	43.1	125.4	72.2	25.1	8.9	3.1	0.3	3.4	0.4	0.08	G
Challa	50.8	31.8	2560	12.7	126.5	9.9	17.9	920	35.5	125.6	73.8	30.7	6.9	2.2	0.5	14.4	2.5	0.13	G
FgColl232195	49.9	33.2	3400	14.2	227.0	16.3	15.9	1440	42.1	125.7	71.1	26.0	6.2	2.5	0.3	9.4	2.2	0.19	G
FgColl236621	51.0	27.0	2280	11.3	126.6	11.3	17.4	920	42.5	125.7	71.1	21.8	6.8	2.5	0.3	18.9	2.5	0.14	Y
FgColl53010	52.4	32.4	2520	17.9	192.1	10.8	15.1	1160	45.0	125.8	71.5	28.6	11.7	4.0	0.2	15.2	2.5	0.13	G
FgColl53102	52.3	31.1	2520	16.3	142.7	8.7	16.4	960	37.9	126.0	70.0	32.8	10.3	3.8	0.8	7.5	1.5	0.08	G
FgColl239062	50.2	34.3	2960	14.9	150.7	10.3	18.0	1120	34.9	126.1	74.3	30.5	10.6	2.0	0.5	6.6	2.5	0.11	Y
FgColl219250	50.6	29.0	2440	12.2	155.5	12.5	16.9	1040	43.6	126.4	71.5	19.5	8.1	2.2	0.1	8.0	1.3	0.08	G
Challa	50.8	31.8	2560	12.7	126.5	9.9	17.9	920	35.5	125.6	73.8	30.7	6.9	2.2	0.5	14.4	2.5	0.13	G
PNPPL																			
FgColl212656	52.3	36.5	4480	23.6	268.1	11.3	16.3	1720	40.4	129.5	74.9	43.7	19.5	4.3	1.8	20.9	3.5	0.15	G
FgColl234032	53.1	32.4	3280	21.9	175.5	7.9	17.6	1280	37.5	131.0	74.8	42.2	17.3	3.9	1.4	6.4	1.1	0.10	W
FgColl53078	49.6	39.5	4600	20.8	235.7	11.5	18.4	1760	37.4	132.9	78.8	39.4	17.2	3.4	1.2	9.9	1.2	0.10	G
FgColl53063	52.9	37.3	3400	20.2	184.4	9.3	17.8	1320	37.5	131.6	77.5	33.9	16.8	3.2	0.8	12.6	1.6	0.09	G
FgColl53099	49.1	35.6	3720	20.2	183.1	8.9	18.7	1360	36.4	133.9	81.2	44.9	16.2	3.0	1.6	8.6	2.8	0.17	Y
FgColl234031	53.5	32.9	3200	21.5	169.1	8.2	17.3	1200	37.0	131.9	75.7	39.9	16.0	3.6	1.1	7.7	2.1	0.11	W
FgColl53104	53.2	33.6	3040	22.1	179.6	8.1	17.1	1240	40.2	128.9	71.2	26.9	15.9	4.0	1.4	17.5	2.6	0.13	G
FgColl234034	50.9	31.4	2920	19.8	157.7	8.3	17.3	1080	37.4	133.4	81.5	31.2	15.8	3.7	0.7	13.6	3.7	0.13	W
FgColl234033	52.1	33.1	3360	21.6	165.9	7.6	19.5	1280	37.1	132.2	77.3	33.7	15.3	3.1	2.0	13.8	1.8	0.14	W
FgColl207599	51.8	35.8	3160	19.1	158.1	8.2	20.4	1400	44.2	132.5	78.1	36.7	15.0	3.5	1.2	16.0	2.4	0.11	W
Challa	50.8	31.8	2560	12.7	126.5	9.9	17.9	920	35.5	125.6	73.8	30.7	6.9	2.2	0.5	14.4	2.5	0.13	G

Table A: Continue

Accessions	DF	PH	BMY	PPP	SPPL	SPP	TSW	SY	HI	DM	GFP	NPPL	PNP	PBR	SBR	NOP	ENO	FW	SC
ENOPPL																			
FgColl53005	51.7	37.5	3080	13.0	152.0	8.8	19.9	1240	40.5	130.6	77.5	30.6	11.3	3.0	1.2	24.6	6.8	0.15	G
FgColl53103	50.3	30.8	2360	11.9	124.1	10.2	16.7	840	37.9	127.8	75.7	20.9	7.2	3.2	0.0	11.1	6.2	0.18	G
FgColl232194	48.7	35.8	2960	18.8	194.8	10.7	15.8	1240	41.1	128.3	74.8	31.9	14.3	3.4	0.5	22.6	5.7	0.20	G
FgColl207376	50.1	31.5	3000	12.9	166.0	12.5	18.5	1200	40.2	129.1	77.6	24.9	8.3	2.4	0.2	14.2	4.8	0.15	M
FgColl213112	50.3	32.3	3000	17.6	181.5	10.7	15.6	1160	35.1	128.3	76.6	28.3	9.9	2.3	0.3	12.7	4.7	0.08	G
FgColl230540	48.8	34.5	3080	18.9	197.9	10.4	15.3	1200	39.3	128.2	76.8	28.8	9.1	3.6	0.4	12.6	4.5	0.20	G
FgColl212776	49.9	36.1	3280	17.3	157.3	8.8	19.2	1240	37.4	130.4	75.6	36.2	11.8	2.7	1.1	17.7	4.5	0.14	Y
FgColl212549	52.4	28.6	2280	9.6	139.1	14.1	16.9	920	42.1	129.7	73.4	20.3	5.2	1.5	0.0	15.0	4.5	0.15	G
FgColl223353	49.9	31.7	2400	14.0	158.1	10.8	15.8	1000	41.8	128.5	73.0	25.2	8.4	2.7	0.0	14.9	4.4	0.11	G
FgColl216898	49.6	32.9	2800	14.6	181.2	12.9	16.6	1200	42.0	127.3	74.8	27.5	8.0	3.6	0.7	15.3	4.4	0.11	G
Challa	50.8	31.8	2560	12.7	126.5	9.9	17.9	920	35.5	125.6	73.8	30.7	6.9	2.2	0.5	14.4	2.5	0.13	G
TSW																			
FgColl239061	48.2	38.7	3640	15.4	176.8	11.2	21.0	1520	42.9	128.6	76.5	28.5	11.0	3.1	0.3	11.3	3.9	0.15	G
FgColl207599	51.8	35.8	3160	19.1	158.1	8.2	20.4	1400	44.2	132.5	78.1	36.7	15.0	3.5	1.2	16.0	2.4	0.11	W
FgColl53107	49.5	36.4	4280	20.4	195.0	9.5	20.0	1600	37.6	132.0	77.7	36.2	14.6	3.4	1.6	11.9	2.7	0.17	Y
FgColl53005	51.7	37.5	3080	13.0	152.0	8.8	19.9	1240	40.5	130.6	77.5	30.6	11.3	3.0	1.2	24.6	6.8	0.15	G
FgColl234029	52.2	29.2	2520	10.6	108.5	9.9	19.8	880	35.4	129.8	75.5	25.6	5.6	2.2	0.2	9.2	1.0	0.14	W
FgColl234026	53.8	33.0	3240	15.3	160.8	10.6	19.7	1240	38.7	129.2	72.8	28.7	7.2	3.3	0.6	8.3	2.2	0.13	W
FgColl236622	49.4	39.0	3560	15.5	162.5	10.6	19.7	1280	36.9	130.7	77.5	34.2	10.5	3.0	0.9	8.7	0.9	0.09	Y
FgColl207370	50.7	30.4	3120	13.2	161.3	12.1	19.6	1280	40.6	130.4	77.6	25.8	7.2	3.2	0.7	9.1	1.4	0.10	Y
FgColl53014	51.6	33.7	3000	17.1	158.2	9.4	19.6	1200	40.1	130.1	75.2	29.3	9.1	3.4	1.8	9.8	2.4	0.15	Y
FgColl234033	52.1	33.1	3360	21.6	165.9	7.6	19.5	1280	37.1	132.2	77.3	33.7	15.3	3.1	2.0	13.8	1.8	0.14	W
Challa	50.8	31.8	2560	12.7	126.5	9.9	17.9	920	35.5	125.6	73.8	30.7	6.9	2.2	0.5	14.4	2.5	0.13	G

DF: Days to 50% flowering, PH: Plant height in cm, BMY: Biomass yield in g per plant, PPP: No. of pods per plant, SPPL: No. of seeds per plant, SPP: No. of seeds per pod, TSW: Thousand seeds weight in gram, SY: Seed yield in g per plant, HI: Harvest index in percentage, DM: Days to 90% maturity, GFP: grain filling period, NPPL: No. of nodes per plant, PNP: No. of podding nodes per plant, PBR: No. of primary branches per plant, SBR: No. of secondary branches per plant, NOP: No. of nodules per plant, ENO: No. of effective nodules per plant, ENOPPL: No. of effective nodules per plant, FW: Fresh, weight of nodules in g per plant and Sc: Seed color

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