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Biochemical profiling of protein and fiber in f_4 population of red sorghum (*Sorghum bicolor* (L.) Moench) genotypes

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Abstract
Sorghum is a cereal crop that can grow in diverse environments and has many nutritional benefits. Analysing the protein and fiber content of the sorghum genotypes can help breeders to develop improved varieties with improved nutritional quality. This study was conducted to evaluate the yield contributing traits and to profile the protein and fiber content of three red sorghum crosses *viz.*, Paiyur 2 X PYR RS.16.07, Paiyur 2 X Kottathur local-5, Paiyur 2 X Ammapatti local-1 along with their parents. In this study, the Kjeldahl method was employed to analyse the total crude protein content whereas, the crude fiber was estimated using the standard procedure. Results indicated that the parent Kottathur local 5 and its cross Paiyur 2 X Kottathur local-5 had a significant protein as well as fiber content in comparison with that of other parents and their crosses. It was followed by the cross Paiyur 2 X Ammapatti local-1which had the next best protein and fiber content. All the crosses were high-yielding in nature. As a whole, the cross Paiyur 2 X Kottathur local-5 surpassed all other crosses and parents in terms of seed yield, protein and fiber content.

Keywords: Red sorghum population, high yielding, nutritional benefits, protein & fiber

Introduction
Sorghum is an important crop grown in many countries. It is used for food, animal feed, building material, and fuel for cooking, especially in dryland areas. Sorghum is also a gluten-free cereal that is significant in the present day scenario where the occurrence of Celiac Disease (CD), an immunological response to gluten intolerance, is on the rise. Plant based protein sources like sorghum are high in fiber, vitamins and antioxidants that promote bone, heart and immune health. Regular consumption of sorghum grains provides numerous health benefits including preventing cancer due to the rare antioxidants present in the bran layer of the grains. Sorghum is also rich in vitamin B and minerals magnesium, potassium, phosphorus, iron, and zinc. One of the important aspects of sorghum quality is its protein and fiber content which affect its digestibility and functionality. Sorghum is an important source of plant based protein, containing 10.62 g/100 g. 1 cup (192 gram) serving of cooked whole grain sorghum contains 22 grams of protein. Protein provides the building blocks for bone, muscle, skin, and enzyme development. Certain sorghum varieties have substantial antioxidant properties due to phytochemical compounds including condensed tannins and anthocyanins mainly located in the bran fraction. There are different methods for analysing the protein content of sorghum, such as Kjeldahl, Dumas, and near-infrared spectroscopy (NIRS).

Fiber is abundant in sorghum and can aid digestion, cholesterol reduction, and blood sugar control. The amount of fiber in half a cup of uncooked sorghum (100 gm) is 7 gm or roughly 28% of the adult daily value. The fiber content in sorghum is two to three folds than that of other cereals like rice, quinoa and oats. Maintaining a healthy digestive tract and gut demands fiber. By giving the stool more volume and softness, fiber can help avoid constipation, diarrhoea, and other digestive problems. In addition to boosting immunity and contentment, fiber may nourish the good bacteria in the stomach. By lowering the absorption of cholesterol and glucose in blood, fiber can also reduce the risk of obesity, diabetes, and heart disease. This study was conducted to analyse the protein and fiber content of the red sorghum crosses and parents to identify the better genotypes with high nutritional content for further exploitation.

Materials and Methods

The plant material used in this study was comprised of the F_4 generation red sorghum inter-specific crosses *viz*., Cross I- Paiyur 2 X PYR RS.16.07, Cross II- Paiyur 2 X Kottathur local-5, Cross III- Paiyur 2 X Ammapatti local-1. At the Agricultural College and Research Institute in Madurai, the F_4 populations of each cross were evaluated in RBD with 2 replications. Each entry was raised in 4 rows which are 6m in length, with a row-to-row spacing of 45 cm and plant-to-plant spacing of 15 cm. All the crosses were evaluated for six quantitative traits *viz.*, days to maturity, days to fifty percent flowering, panicle weight, number of primary branches, test weight and seed yield.

The protein content of the selected entries were estimated using the Kjeldahl method and the procedure suggested by Sadasivam (1996) [13] was used to analyse the fiber content of sorghum genotypes. Three different red sorghum crosses *viz*., Paiyur 2 X PYR RS.16.07, Paiyur 2 X Kottathur local-5, Paiyur 2 X Ammapatti local-1 in F_4 generation were subjected for the estimation of protein and fiber levels.

Protein estimation: The Kjeldahl method consists of three steps: digestion, distillation, and titration. First, the sorghum samples were digested with concentrated sulfuric acid to convert the organic nitrogen into ammonium sulfate. Then the digested samples were distilled with sodium hydroxide to release ammonia gas, which was then captured by a boric acid solution. Finally, the boric acid solution was titrated with a standard acid solution to measure the amount of ammonia and the endpoint was indicated by the appearance of brick red color. The protein content of each sorghum sample was obtained by multiplying the nitrogen content by a conversion factor of 6.25.

Fiber estimation: In a beaker, 200 ml of 1.25% sulphuric acid was added to the ground seed sample, which was then heated for 30 minutes. The contents were filtered through muslin cloth and rinsed in distilled water until the washing was no longer acidic. Once again, the residue was heated for 30 minutes with sodium hydroxide solution at 1.25%. Following that, the sample was rinsed with 50 ml of distilled water and filtered through muslin cloth. The residues were weighed and dried in a silica crucible at 130 °C for 2-4 hours. After drying, the weight was recorded. From the initial and final weights of the residue, the percentage of weight reduction attributable to fiber content was estimated.

Results and Discussion

In crop plants early maturing lines are more suitable for adverse climatic conditions than medium and late maturing varieties. On analyzing the quantitative traits days to maturity and days to fifty percent flowering, it was evident that the cross Paiyur 2 X PYR RS.16.07 was early maturing in nature followed by the cross Paiyur 2 X Ammapatti local-1, whereas the cross Paiyur 2 X Kottathur local-5 was late maturing. Even though the cross Paiyur 2 X Kottathur local-5 appeared to be late maturing in nature, it outperformed other crosses in seed yield.

All the three crosses surpassed the check variety Paiyur 2 in terms of seed yield.

Aminon *et al.*, (2015) [3] also selected three sorghum genotypes *viz.*, A41, A14 and A7 which were early maturing (59 to 66 days to 50% maturity) and high yielding (4.85 to 7.85 t/ha) in nature. Seed yield was an important trait based on which determines the usefulness of a genotype.

High seed yield was the primary breeding objective for most of the breeding experiments.

The parents of the three red sorghum crosses involved in this experiment *viz.*, PYR 2, PYR.16.07, Kottathur local 5 and Ammapatti local 1 were appraised to have a mean yield of 22.96,19.06, 25.19 and 23.61 g/plant and the three red sorghum crosses had a mean yield of 25.97, 27.94 and 26.92 g/plant. The parent Kottathur local-5 recorded the highest seed yield among the parents. The Parents Kottahur local-5 and Ammapatti local-1 recorded higher seed yield than the check variety (PYR 2). All three crosses outperformed their parents and check in terms of seed yield. Cross II registered for the highest yield in comparison with its parents and other crosses. Enyew *et al.* (2021) [4] Aslo identified five superior genotypes *viz.*, G148, G123, G110, G203 and G73 for high grain yield with farmer preferred traits from three hundred twenty sorghum landraces.

The parents of the three red sorghum crosses involved in this study *viz.*, PYR 2, PYR.16.07, Kottathur local 5 and Ammapatti local 1 were appraised to have a protein content of 10.30%, 11.64%, 17.40% and 9.70% respectively. The parent Kottathur local 5 recorded high protein content in comparison with all other parents. The three red sorghum crosses *viz*., Paiyur 2 X PYR RS.16.07, Paiyur 2 X Kottathur local-5, Paiyur 2 X Ammapatti local-1 had a protein content of 12.24%, 13.72% and 11.38% respectively. Cross II registered the highest protein content among the three crosses. The results concluded that all the crosses outperformed the check variety (PYR 2) in terms of crude protein content. The level of protein recorded in this study was in accordance with the results observed by Mohapatra *et al.* (2021) [8], Kaplan *et al.* (2020) [7], Tasie and Gebreyes (2020) [12], Rocchetti *et al.* (2020) [11], Abdelhalim *et al.* (2019) [1], Ahmad *et al.* (2018) [2], Gassem and Osman (2003) [6] and Njuguna *et al.*(2018) [10] in sorghum.

Similarly, the parents of the three red sorghum cross PYR 2, PYR.16.07, Kottathur local 5 and Ammapatti local 1 recorded a fiber content of 1.74%, 2.49 %, 2.68% and 2.61% respectively. Results evidenced that the parent Kottathur local 5 had the highest fiber content among all other parents. Meanwhile, the three red sorghum crosses were observed with a fiber content of 2.18%, 2.34% and 2.14%. Among the three crosses Cross II recorded for the highest fiber content. Comparable to that of yield and protein content, all the crosses outperformed the check variety (PYR 2). Gassem and Osman (2003) [6]; Tasie and Gebreyes (2020) [12] recorded similar fiber levels in sorghum.

Table 1: Estimated protein content and yield of red sorghum parents and their F_4 crosses.

Sl. No	Parents/cross	Protein content (%)	Fiber Content (%)	Yield (g/plant)
1	PYR 2	10.3	1.74	22.96
2	PYR.RS.16.07	11.64	2.49	19.06
3	Kottathur Local- 5	17.4	2.68	25.19
4	Ammapatti local-1	9.7	2.61	23.61
5	Paiyur 2 X PYR RS.16.07	12.24	2.18	25.97
6	Paiyur 2 X Kottathur local-5	13.72	2.34	27.94
7	Paiyur 2 X Ammapatti local-1	11.38	2.14	26.92

Table 2: Evaluation of yield attributing characters yield attributing characters in F_4 population of red sorghum genotypes

Genotypes	DM	DFPF	PW	NPB	TW	SPY
Paiyur 2	101	63	30.73	30.03	20.16	22.96
PYR.RS.16.07	95	59	26.35	28.40	21.30	19.06
Kottathur Local- 5	108	70	34.1	19.80	24.80	25.19
Ammapatti local-1	105	64	27.06	34.02	15.80	23.61
Paiyur 2 X PYR RS.16.07	96.3	64	32.4	32.1	20.44	25.97
Paiyur 2 X Kottathur local-5	105.3	66	34.88	34.7	18.55	27.94
Paiyur 2 X Ammapatti local-1	98.55	65	31.71	36.1	20.68	26.92

DM- days to maturity (days), DFPF- days to fifty percent flowering (days), PW- panicle weight (gm), NPB- number of primary branches, TW- test weight (gm) & SPY- single plant yield (gm)

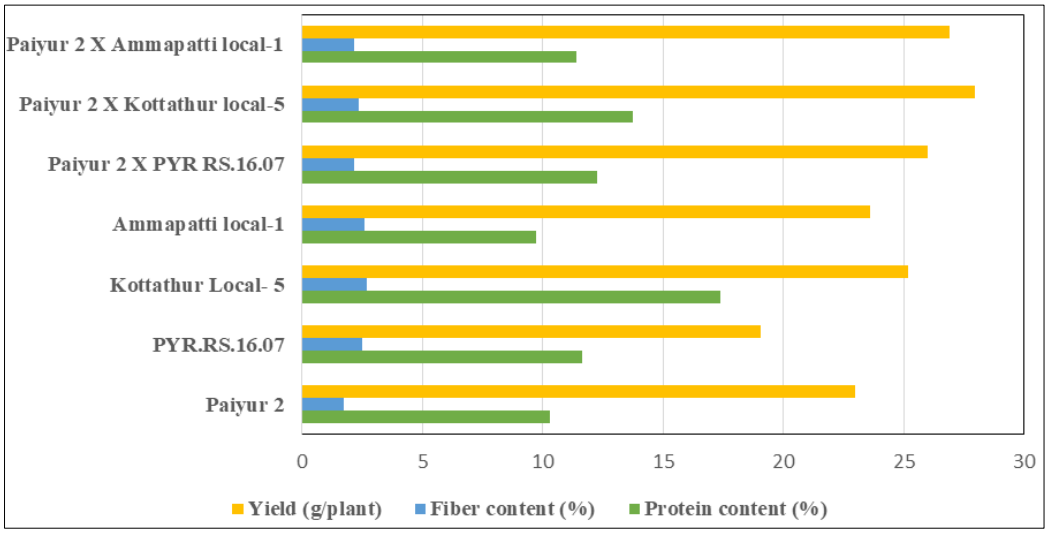

Fig 1: Seed yield, protein and fiber content of F_4 population red sorghum genotypes and their parents.

Conclusion

From the results, it was concluded that the parent Kottathur local 5 a late maturing red sorghum genotype which recorded for high protein and fiber content, could be effectively utilised in crossing program to develop new high yielding sorghum lines with high protein and fiber content. The other parent Ammapatti local 1 could also be utilized in the breeding program to derive sorghum lines with improved nutritional quality since it was an early maturing genotype with good quantites of protein and fiber. The cross II- Paiyur 2 X Kottathur local-5 outperformed the check variety (PYR 2) and other crosses in terms of yield, protein and fiber content. It also excelled all the parents and crosses with respect to seed yield. The homogenous progenies of Cross II and Cross III with high yielding potential and notable levels of protein and fiber levels could be selected and forwarded for further evaluation in yield trails. Further, the nutritional content of Cross II could be improved based on the selection through pedigree method of breeding in advanced generations. Also, the early maturing Cross III- Paiyur 2 X Ammapatti local-1 accounted good levels of protein and fiber content with remarkable yield potential. Hence, the cross Paiyur 2 X Ammapatti local-1could be developed into an early maturing high yielding red sorghum variety with higher levels protein and fiber.

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