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Review Article

BREEDING FOR QUALITY IMPROVEMENT IN SMALL MILLETS: A REVIEW

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Abstract- Small millets widely known as 'nutricereals' consist a number of distinct species of small-seeded grasses that are grown for grain purpose, each with their own unique traits and very good nutritional value. The most economically significant of these at present is finger millet, but the other small millets like little millet, barnyard millet, proso millet, foxtail millet, and kodo millet are also have their own importance to the tribal farmers who grow them.
Key words- Millets, Plant breeding

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Introduction

Little millet was domesticated in the Eastern Ghats of India occupying a major portion of diet amongst the tribal people and spread to Sri Lanka, Nepal, and Myanmar. While, proso millet is a short-season crop cultivated in drier regions of Asia, Africa, Europe, Australia, and North America. Also, barnyard millet is the fastest growing among the millets with a harvesting period of 6 weeks (for food as well as fodder) and kodo millet is native to the tropical and sub-tropical regions of South America and domesticated in India 3,000 years ago. The hill millets are grown over an area of around 1.88 million hectares in India of which little millet accounts for 29 % of area and of the 1/3rd of the production of the small millets. Finger millet grains contain higher levels of minerals like Ca, Mg, and K. It also has high levels of amino acids like methionine, lysine and tryptophan, and polyphenols. Barnyard millet grains possess other functional constituents' *viz*., γ-amino butyric acid (GABA) and β-glucan, used as antioxidants and in reducing blood lipid levels. With lowest carbohydrate content among the millets, barnyard millet is recommended as an ideal food for type II diabetics. Kodo millet is best owed with high magnesium content (1.1 g/kg dry matter). In addition, it is rich in vitamin B, minerals like potassium, phosphorus, iron, zinc and magnesium. Therefore, it can address nutritional sensitive agriculture, which aims at nutritional enhancement to combat the present scenario of micronutrient malnutrition [1]. It is a good source of protein, very rich in carbohydrate, fat, minerals and vitamins and should be considered as essential food for nutritional security.

Review of Literature

Plant breeding can increase nutrient levels in small millets and other staple crops to target levels required for improving human nutrition, without compromising yield or farmer-preferred agronomic traits. The crop development process entails screening germplasm for available genetic diversity, pre breeding parental genotypes, developing and testing micronutrient-dense germplasm, conducting genetic studies, and developing molecular markers to lower the costs and quicken the pace of breeding.

Finger millet

Mallana and Rajeshekara (1969) made an attempt to develop protein rich white and high yielding variety of finger millet and they succeeded in developing a variety named Hamsa [2].

Hamsa has characteristics like high yielding, high protein content, dwarf habit and early maturity. The proximate composition of Hamsa is *viz*. moisture 6.10 percent, protein 9.1 percent, total ash 2.46 percent and fibre 4.34 percent. Calcium 323 mg per 100 g, phosphorus 236 mg per 100 g and iron 7.6 mg per 100 g. Kempanna and Kavallappa (1968) chemically analyzed grains of nineteen finger millet genotypes for crude protein, crude fat, calcium, phosphorus and total ash contents [3]. There seemed to have been a recognizable variation among genotypes in respect of most of the nutrient elements. Variation in relation to protein and fat were statistically significant which revealed the presence of wide diversity between the genotypes and selection for these traits could be effective in improving the quality traits in the genotypes. Deosthale *et al*. (1970) analysed 20 varieties of finger millet, grown at four different locations and found that protein content varied from 5.6 to 11.6 percent [4]. In thirteen of these varieties the range of inorganic nutrients were calcium 253 to 666 mg per 100 g, phosphorus 204 to 330 mg per 100 g and iron 1.3 to 17.6 mg per 100 g. There was significant negative correlation between protein and lysine contents. Indira and Naik (1971) estimated the chemical constituents, protein fractions and amino acid composition in five varieties of finger millet [5]. The protein and fat contents ranged from 6.23 to 9.52 percent and 1.44 to 2.5 percent, respectively. Whereas calcium, phosphorus and Iron varied from 252-272 mg per 100 g; 242-284 mg per 100 g and 11 -18 mg per 100 g, respectively. Shadekshara Swamy (1971) analysed 15 varieties of ragi grown under identical conditions [6]. The results showed that range of crude protein content was 4.71 percent in poorna to 9.88 percent in Hamsa. The range of phosphorus, Iron and calcium content in IE-28, ROH2 and H-22 were 0.2268 to 0.470 percent; 0.0025 to 0.0199 percent and 0.2301 to 0.6902 percent, respectively. They also showed that there was no relationship between the mineral element and ash content. Mahudeswaran et al. (1972) found that the protein content of five white varieties of finger millet ranged from 8.06 to 11.73 percent and that of brown strain was 7.47 percent [7]. The variety EC 854 (white) was rich in protein (11.73 %) as well as calcium and phosphorus when compared to other strains. Begum and Lingaiah (1976) determined the protein efficiency of 'Hamsa' finger millet variety [8]. The values for biological value, percent digestibility and net protein utilization were 89, 94 and 84 percent, respectively. They showed that the nutritive value of Hamsa ragi protein is better than that of brown ragi varieties. Pore and Margar (1977) examined protein content of 36 varieties of finger millet which ranged from 5.8 to 12.8 percent while, fat content

from 1.3 to 2.7 percent, carbohydrates content from 81.3 to 89.4 percent, ash content 2.1 to 3.7 percent, calcium content 261 to 520 mg per 100 g, phosphorus content 116 to 404 mg per 100 g and iron content from 3.4 to 19.0 mg per 100 g [9]. Suguna (1984) conducted study in some finger millet varieties and revealed that considerable varietal differences were observed for the nutrients estimated in Finger millet varieties [10]. Range of crude protein content was 6.37 % in Indaf-1 to 8.76 in Indaf-11. The Variation in the ash content among the different varieties was from 2.1 in Indaf-3 to 2.71 in Indaf-5. The range of calcium, total phosphorus content were 283.56 to 388.43 mg and 198.02 to 271.12 mg per 100 g, respectively. Variety Indaf-1 was rich in calcium as compared to other varieties. It revealed the presence of wide variability between the genotypes and selection for these traits could be effective in improving the quality traits in the genotypes. Venkanna *et al*. (1987) analyzed protein and chemical composition content in six varieties of finger millet [11]. It does not showed variation in ash and nitrogen content. The concentrations of phosphorus, calcium and copper were more in VZM-1 than the other hybrids. VR 250-6 showed highest content of iron. Protein content varied from 8.0 in Godavari to 12.1 % in C-157. It revealed the presence of wide variability between the genotypes and selection for these traits could be effective in improving the quality traits in the genotypes. Barbeau and Hilu (1993) analyzed two wild and eight domesticated cultivars of finger millet to determine their proximate composition and calcium, iron and amino acid content. Wide variation was observed in the protein (7.5 to 11.7%), calcium (376 to 515 mg/100g) and iron (3.7 to 6.8 mg/100g) content of the wild and domesticated cultivars [12]. Maloo *et al*. (1998) evaluated finger millet genotypes for quality traits for three years. Analysis of variance showed that, genotypes differed significantly [13]. Range of seed protein varied from 6.37 to 13.00 %, calcium content varied from 286-507 mg per 100 g and seed iron varied from 3.12 to 5.10 %. They suggested that, these quality traits were largely governed by additive gene effects that in turn could be improved by selection. Sankara *et al.* (1998) studied 36 genotypes of finger millet for varying seed colours revealed a wide range of protein and calcium contents. White seeded genotypes had higher protein contents, while brown seeded genotypes had a wide range of values. High heritability coupled with high genetic advance indicate their governance by additive gene action. Hence, crossing followed by selection is effective breeding strategy to improve these traits. Based on genetic diversity and performance, the genotypes MS 1168, MS 174 and MS 2869 were found to be suitable for use as parents in hybridization programme for improving protein and calcium respectively. Vadivoo *et al.* (1998) analysis of 36 genotypes of finger millet with varying seed colours and founded that white seeded genotypes had higher protein content, while brown seeded types had a wide range of values [14]. Brown seeded genotypes GE 2500 had the highest protein content. Ravindran (2003) conducted a study on millets for proximate composition, mineral composition, and phytate and oxalate contents [15]. The average protein content of common millet, finger millet and foxtail millet were 14·4, 9·8 and 15·9%, respectively. Satish *et al*. (2003) analyzed chemical composition and protein content in 40 finger millet accessions. Accession IE 3135 showed highest content of calcium [16]. Protein content ranged from 6.80 to 11.36 % with a mean of 9.10 percent. Accession IE 2235 recorded highest protein content (11.36%) and it was lowest in IE 3135 (6.80%).It revealed the presence of wide variability among the genotypes and selection for these traits could be effective in improving the quality traits in the genotypes. Shashi *et al*. (2007) observed nutritive value of finger millet in different genotypes [17]. They found calcium was in the range of 264-365 mg/100g, magnesium 66-130 mg/100g, iron 3.60-7.31 mg/100g, sodium 0.60-0.95 mg/100g and potassium 294-1160 mg/100g. Whereas bio accessibility of iron was more in ML- 426 and ML-322 (12.01 and 12.06, respectively) and also they contain less tannins and phytates (0.30% and 0.34 mg/100g, respectively). An antinutritional factor like phytate content was more in ML-197 (320 mg/g) and least in ML-365 (246mg/g). The highest tannin content was found in ML-197 (0.54%) and least was found in ML-365(0.20%). The bioaccessibility of iron appears to be associated with the high composition of antinutrients like phytates and tannins. The bioaccessibility of iron in ML-197 is very less due to the presence of more tannins and phytates. Shimelis and Mulugeta (2009) studied on three improved finger millet varieties (Tadesse, Padet, Boneya) and six local varieties [18]. The local varieties included were labeled PBR (pawe brown) 1,PBR 2 and PBR 3,PBL (pawe black) 1,PBL 2 & PBL 3,and analyzed for chemical composition. The protein content is higher in boneya (10.50g/100g) followed by padet (9.86g/g) and the PBL 1 had lowest content. Moisture was highest in PBL 3 and lowest in boneya. Ash was higher in PBL 2 and 3 while lowest in boneya. Panwar Preety *et al*. (2010) studied 52 genotypes of the finger millet to find out polymorphism using 18 RAPD, 10 SSR and 10 pair of cytochrome P450 gene base markers which shows 49.4%, 50.2% and 58.7% polymorphism respectively [19]. The dendrogram developed by RAPD, SSR and cytochrome P450 gene based primers analyses revealed that the genotypes are grouped in different clusters according to high calcium (300–450 mg/100 g), medium calcium (200–300 mg/100 g) and low calcium (100–200 mg/100 g). The first cluster had genotypes containing low calcium (100–200mg/100g). Second cluster included genotypes containing high calcium (300–450mg/100 g). Third cluster included genotypes containing medium calcium (200–300 mg/ 100g). Mantel test employed for detection of goodness of fit established cophenetic correlation values above 0.95 for all the three marker systems. Comparison of RAPD, SSR and cytochrome P450 gene based markers, in terms of the quality of data output, indicated that SSRs and cyt P450 gene based markers are particularly promising for the analysis of plant genome diversity. Priyadarshini *et al*. (2011) examined twenty-one hybrids along with seven parents of finger millet for genetic variability and revealed protein content ranged from 7.37 to 11.97 % [20]. High heritability along with moderate genetic advance (% of mean) observed for seed protein content indicated involvement of additive gene action for these traits and phenotypic selection based on this trait in the segregating generations would likely to be effective. Singh and Srivastava (2006) examined the chemical composition of finger millet varieties and revealed that total carbohydrate content of finger millet has been reported to be in the range of 72 to 79.5 percent [21]. Finger millet has nearly 7% protein but large variations in protein content from 5.6 to 12.70 percent was reported that total ash content is higher in finger millet than in commonly consumed cereal grains. The ash content has been found to be nearly 1.7 to 4.13 percent in finger millet. Upadhyaya, *et al.* (2011) evaluated of finger millet core germplasm for grain nutrients and agronomic traits revealed a substantial genetic variability for grain Fe, Zn, calcium (Ca) and protein contents [22]. The accessions rich in nutrient contents were identified and their agronomic diversity assessed. Kumar *et al.* (2012) examined fifty two genotypes of finger millet collected from Uttarakhand hills were subjected to simple sequence repeat (SSR), random amplified polymorphic DNA (RAPD)-PCR and protein profiling analysis to investigate the variation in protein content [23]. Khouloudbachar *et al*. (2013) worked on mineral and fibre characterizations performed for 30 samples collected from four oases of Gabes in finger millet [24]. For each sample 11 nutrients (Na, K, P, Ca, Mg and N), the crude protein, the neutral detergent fibre, the acid detergent fibre, the crude fibre and ash contents, were studied. Results of minerals analysis showed that calcium and magnesium were the most concentrated nutrients. (189.93 1272.36 mg/100g and 84.71 567.45 mg/100g respectively), followed by potassium (11.24 284.7 mg/100g), sodium (13.73 42.47 mg/100g) and phosphorus (2.208 11.033 mg/100g). Acid detergent fibre, neutral detergent fibre, crude fibre and ash average contents of the accessions were respectively higher than 30.58, 12.65, 4.01 and 3.2 percent of dry matter. Savitha *et al.* (2013) studied ten parents and twenty one hybrid combinations [25]. Found that line GPU 48 have high GCA effect for protein content, tester PR 202 showed high GCA effects for iron content. However, hybrids OEB 259 x K 7, CO(Ra) x K 7, hybrid RAU 8 x PR 202, GPU 28 x PR 202, VR 708 x KM 525, hybrids GPU 28 x K 7, VR 708 x PR 202, GPU 48 x PR 202 shows high sca effects for grain protein, iron (mg/100g) and zinc content (mg/100g) respectively. Hybrids CO(Ra)14 x K 7, CO(Ra) 14 x PR 202 CO (Ra) 14 x KM 252, Hybrids GPU 28 x PR 202 VR 708 x KM 252 RAU 8 x PR 202, Hybrids OEB 259 x KM 252 VR 708 x PR 202 RAU 8x KM252 shows high standard heterosis for protein, iron (mg/100g) and zinc (mg/100g) respectively. Hybrids CO (Ra) 14 x PR 202, CO(Ra) 14 x KM 525 and CO(Ra) 14 x KM 252 were found to be significant for all the three types of heterosis for grain protein content. Hybrid VR 708 x KM 252 were found to be significant for all the three types of heterosis for iron content. Hence, these results will be very helpful for quality improvement through heterosis breeding. Nirgudi *et al.* (2014) developed 36 EST-SSR primers for the opaque2 modifiers and 20

anchored-SSR primers for calcium transporters and calmodulin for analysis of the genetic diversity of 103 finger millet genotypes for grain protein and calcium contents [26]. The opaque2 modifiers specific EST-SSRs could able to differentiate the finger millet genotypes into high, medium and low protein containing genotypes. However, calcium dependent candidate gene based EST-SSRs could broadly differentiate the genotypes based on the calcium content with a few exceptions. A significant negative correlation between calcium and protein content was observed. The present study resulted in identification of highly polymorphic primers (FMO2E30, FMO2E33, FMO2-18 and FMO2-14) based on the parameters such as percentage of polymorphism, PIC values, gene diversity and number of alleles. Das *et al*. (2017) studied 48 germplasm lines of finger millet and found that calcium content of the genotypes ranged from 188.66mg/100 g of grain to 324.33 mg/100 g of grain with an average value of 235.34 mg/100g [27].The genotypic coefficients of variability were moderate and high for protein (16.4) and calcium (31.21), respectively. Protein content, calcium content and grain yield have shown high heritability viz., 99.47, 97.74 and 75.50, respectively. Genetic advance as percentage of mean was also high for these three characteristics, protein, calcium and grain yield/plot. Devaliya *et al*. (2017) examined 68 genotypes of finger millet for character association studies, which revealed that, grain yield per plant had highly positive and significant association with protein content at both genotypic and phenotypic levels [28]. Protein content had highly significant positive correlation with days to 50 % flowering, days to maturity, number of productive tillers per plant, straw yield per plant, iron content and main ear head length at genotypic level. Which indicated that protein content can by improve by selecting these positively associated traits. Devaliya et al. (2018) examined 68 genotypes of finger millet and the data were recorded on 13 quantitative traits to assess the magnitude of genetic variability, heritability and genetic advance for yield and yield contributing traits [29]. High estimates of genotypic and phenotypic variance were observed for iron content. Phenotypic coefficients of variability were greater than genotypic coefficients of variability for all the traits studied which is indicated possibilities of improvement in this trait.

Little millet

Nirmalakumari *et al*. (2006) develop samai culture TNAU 91 from the cross between CO_2 x MS-1684 which is superior to the standard varieties CO_3, paiyur 2, and OLM 203 (National check) in standard trials, multilocation trials, AICRP trials, adaptive research trials and on farm trials in relation to grain yield and quality characters like cruse protein, potassium (%), b-carotene (µg/g), colour and appearance, flavor, texture, taste, fodder crude protein (%), crude fat (%) and crude ash (%). Nambi *et al*. (2012) reported that among the 18 accessions of little millet which were analyzed, maximum proximate content of moisture (MSSRF BD2), protein (MSSRF BD2), carbohydrate (MSSRF BD11), total ash (MSSRF BD9),.fibre (MSSRF BD18), fat (MSSRF BD12), and energy (MSSRF BD12), were listed. High mineral content of calcium (MSSRF BD8), iron (MSSRF BD1), magnesium (MSSRF BD14), phosphorus, (MSSRF BD14), potassium (MSSRF BD15) and zinc (MSSRF BD6) were observed [30]. Roopa et al. (2013) found that local little millet had higher moisture (11.43%) and fat (4.97%), while variety Sukshema possessed higher protein (8.96%), carbohydrate (70.47%), starch (59.19%) and zinc (2.03mg per 100g) [31]. Functional properties indicated that the water (0.88g per g) and oil (0.66g per g) absorption capacity and swelling power (7.73g per g) were higher and least gelation capacity was lower (9.07%) in Sukshema. Nazneen *et al*. (2013) reported that little millet whole grains contains, zinc, copper, manganese and iron contents ranged from 0.24to 0.50 mg per 100g, 0.24 to 0.58 mg per 100g, 0.08to 0.16 mg per 100g and 1.28 to 3.05 mg per 100g, respectively [32]. The antioxidant activity in whole millet grain ranged from 19.06 to 24.33 percent in millets. Selvi *et al*. (2015) examined 30 germplasm of the little millet and the results revealed that zinc, iron and calcium contents in grains of little millet genotypes differed significantly. The zinc content was varied from 2.04 to 8.00 mg/ g with a mean of 5.23 mg/g. Wide variation in iron content was observed and it ranged from 1.49 to 23.38 mg/g with a mean of 4.95 mg per g. The grain calcium content ranged from 1.14 to 13.15 mg/ g with a mean of 3.90 mg per g. Zinc, iron and calcium rich genotypes *viz*., TNPsu 25, TNPsu 23, TNPsu 22 and TNPsu 141 could be involved in hybridization with agronomically superior breeding lines to combine grain nutrients (zinc, iron and calcium) and grain yield. Which revealed the presence of wide diversity between the genotypes and selection for these traits could be effective in improving the quality traits in the genotypes.

Foxtail millet

The varieties were classified into high, moderate, and low iron content categories. High genetic variability for grain Fe content can use for further crop improvement programme. Nirmalakumari *et al*. (2006) develop tanai culture TNAU 196 (foxtail millet) which is a derivative of the cross involving CO 5 and ISE 248 which shows higher yield potential and good grain quality with higher protein content of 13.62 percent calcium content of 0.35 percent than the variety CO 6 in which protein and calcium contents were 11.62 percent and 0.33 percent respectively. Kamara *et al*. (2009) examined the chemical composition and physicochemical properties of two varieties defatted foxtail millet flour grown in China [33]. Balasubramanian and Viswanathan (2010) studied the physical qualitative properties including 1000 kernel weight, bulk density, true density, porosity, angle of repose, coefficient of static friction, coefficient of internal friction and grain hardness were determined for foxtail millet, little millet, kodo millet, common millet, barnyard millet and finger millet in the moisture content range of 11.1 to 25 percent db [34]. Thousand kernel weight increased from 2.3 to 6.1 g and angle of repose increased from 25.0 to 38.2°. Bulk density decreased from 868.1 to 477.1 kg/m3 and true density from 1988.7 to 884.4 kg/m3 for all minor millets when observed in the moisture range of 11.1 to 25 percent. Porosity decreased from 63.7 to 32.5 percent. Mohamed Lamine Bangoura *et al*. (2011) investigated the extraction and fractionation of insoluble fibres from two varieties of foxtail millets [35]. Choudhury Pranati Das and Basanti Baroova (2011) estimated crude fat and crude fibre contents of foxtail millet [36]. Wang *et al*. (2011) successfully transform the foxtail millet cv. Jigu 11 with lysine-rich protein encoding gene 'SBgLR'. They carried out PCR and western blot analyses of SBgLR transgenic foxtail millet plants. PCR analysis of genomic DNA to detect the presence of the SBgLR gene. Lane 1, molecular weight marker; lane 2, positive control; lanes 3 to 8, plants showing amplification of the predicted 280 bpSBgLR-specific sequence; lane 9, non-transformed plants. While in western blot analysis of SBgLR protein expression in transgenic foxtail millet, probed with SBgLR antibody at 1:1000. Lanes 1 to 6, 50 µg protein from T0 transgenic foxtail millet mature seeds; lane 7, 50 µg protein from non-transformed foxtail millet mature seeds.

Barnyard Millet

Jun Young Kim *et al*. (2011) studied 13 barnyard millet genotypes and reported that IT 153600 exhibited the highest total protein (14.75±1.7%) [37]. Barbeau and Hilu, (1995) examined two wild and eight domesticated cultivars of finger millet and reported that wide variations were observed in the protein (mean values ranged from 7.5 to 11.7%). Singh *et al*. (2010) studied the qualitative properties like geometric mean diameter, specificity, grain surface area, 1000 grain mass, dynamic angle of repose, coefficient of internal friction, true density, terminal velocity, coefficient of static friction at different surfaces.

Proso millet

Dikshit and Natarajan (2013) evaluated 44 proso millet genotypes for variability and correlation study [38]. DIVA-GIS grid maps generated for the germplasm accessions indicated that high variability for protein content, inflorescence length and days to maturity found in proso millet germplasm collected from the Southern region of Ratnagiri district of Maharashtra. On the basis of this it can be concluded that we can improve protein content by selecting it's positively associated traits.

Application of review: In the era of quality foods materials in Agriculture the information on nutricereals for quality improvement in small millets is very much essential and applicable for qualitative improvement in small millets crops [39-43].

Review Category: Nutricereals

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