BREEDING FOR BIOCHEMICAL QUALITY TRAITS OF PEARL MILLET FODDER - A REVIEW

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ABSTRACT

Pearl millet [Pennisetum glaucum (L.) R. Br.] is a dual-purpose crop. A number of biochemical characters viz., oxalic acid content, crude protein %, crude fiber %, mineral %, ash %, calcium %, sugar content, fat % etc., have been reported in this crop to cause a great variation in quality of fodder. Various studies revealed that both additive and non-additive components of variation were important for all the biochemical characters. Therefore, reciprocal recurrent selection appears to be the best approach for improvement of these biochemical quality traits of fodder in pearl millet. The improved populations developed through reciprocal recurrent selection may be exploited through development of composites and synthetics. The improved population may also be exploited by isolation of superior inbreds with high SCA for various biochemical parameters. These inbreds with high SCA may be used to develop hybrids.

Pearl millet [Pennisetum glaucum (L.) R. Br.] is a dual-purpose drought resistant fodder crop (Parveen et al., 1988), traditionally grown as a rain fed crop mostly under low fertility conditions. The green fodder of pearl millet is a valuable cattle feed on account of its high albuminoids and fat content. Green fodder of pearl millet is preferred over that of sorghum because its HCN content is low and it can be fed to cattle without harm at any stage of growth.

In the arid and semi-arid regions during summer months, particularly May to July, when the temperature is very high and humidity is extremely low bajra alone can be successfully grown owing to its drought resistance. Bajra has got prolific regeneration capacity therefore; a number of cuttings of green fodder can be taken throughout the year. Moreover, the green fodder of bajra also rates high quality wise as it possesses high concentrations of albuminoids, carbohydrates and fat and also it has easy digestibility.

In contrast to sorghum and other popular fodder of summer months, it can be fed to cattle at all stages of growth because it has very less HCN (Krishnaswamy and Raman, 1956).

Quality of the fodder is very important in deciding the value of the fodder. The quality of the fodder is determined by its protein content, sugar and mineral content with low content of oxalic acid and crude fiber content. For better palatability longer proportion of leaves to stem ratio with soft non-extruding internodes is also important.

Several investigators have determined the biochemical composition of fodder bajra with respect to calcium content, crude protein content, oxalic acid content, sugar content, fat content, crude fiber content etc. Some of the investigators have also determined the effect of growth stage of plant on biochemical composition, while some of these have studied the effect of environmental factors and levels of inputs on biochemical composition of bajra plant.

Composition of pearl millet fodder

Krishnaswamy (1962) studied the composition of pearl millet fodder and found 1.94 % albuminoids, 44.0 % carbohydrates, 1.3 % fat, 37.6 % crude fiber and 8.0 % ash in steam on the other hand; the green fodder at the milk stage contained 10.56 %

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albuminoids, 50.1 % carbohydrates, 2.1 % fat, 29.7 % crude fiber and 9.2 % ash of dry matter.

Athwal and Gupta (1966) studied the protein content in indigenous and exotic material and reported that the protein content ranged from 8.0 to 13.7 % in Indian varieties, 5.0 to 14.6 % in inbred lines in India, 8.0 to 13.0 % in African strains and 6.5 to 14.3 % in American inbreeds. Thus, protein content is almost similar in Indian, African and American pearl millet strains. Several investigators have worked out protein content besides other biochemical constituents in fodder bajra. For instance Singh et al. (1977) reported a range of crude protein content of whole plant from 9.8 to 12.4 %, while total cell wall constituents ranged from 66.2 to 73.5 % and the in-vitro dry matter digestibility from 52.6 to 59.9 %. Bailey et al. (1979) reported a wide range of protein content from 10.7 to 17.1 %. They also reported that the lysine was the most and in many cases the only, limiting amino acid. Varriano-Marston and Hoscney (1980) reported relatively narrow range for protein content (from 11.10 to 14.7%) and ash content (from 1.40 to 1.90 %). However, Makeri and Ugheruge (1992) reported wide range (from 14.10 to 20.30%) for crude protein content, while crude fiber content ranged from 28.00 to 30.8%.

Biochemical composition of pearl millet fodder with respect to crude protein, oxalic acid and sugar content as reported by various workers has been given below:

### Table 1. Biochemical composition of pearl millet fodder

<table>
<thead>
<tr>
<th>Crude protein content (%)</th>
<th>Calcium content (%)</th>
<th>Sugar content (%)</th>
<th>Oxalic acid content (%)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.851</td>
<td>0.3185</td>
<td>8.912</td>
<td>1.771</td>
<td>Singh (1991a)</td>
</tr>
<tr>
<td>6.855</td>
<td>0.3800</td>
<td>-</td>
<td>2.748</td>
<td>Singh (1991b)</td>
</tr>
<tr>
<td>9.650</td>
<td>0.3203</td>
<td>-</td>
<td>2.000</td>
<td>Kumawat (1993)</td>
</tr>
<tr>
<td>6.240</td>
<td>0.3907</td>
<td>-</td>
<td>2.890</td>
<td>Rathore (1993)</td>
</tr>
<tr>
<td>10.520</td>
<td>0.5700</td>
<td>-</td>
<td>1.980</td>
<td>Yadav (1994)</td>
</tr>
<tr>
<td>10.299</td>
<td>0.4070</td>
<td>-</td>
<td>1.119</td>
<td>Jain (1995)</td>
</tr>
<tr>
<td>5.523</td>
<td>0.4300</td>
<td>-</td>
<td>0.550</td>
<td>Yadav (1996)</td>
</tr>
<tr>
<td>9.314</td>
<td>0.4105</td>
<td>-</td>
<td>1.815</td>
<td>Dadhich (2001)</td>
</tr>
</tbody>
</table>

Athwal and Gupta (1966) reported that phosphorous content ranged from 1.0 to 2.8 %, calcium content ranged from 0.2 to 1.2% and ash content from 3 to 16%. Goswami et al. (1970) evaluated inbreeds for various biochemical characters and reported wide range of variability for various biochemical. The results have been presented in Table 2. They reported very wide ranged for crude protein, NFE and oxalic acid. They also reported highly significant variety x year variance for crude protein, ash, calcium, phosphorous and oxalic acid content. Gupta et al. (1982) reported significant variability for fat content and free fatty acids. Dadhich (2001) studied the various biochemical character of pearl millet fodder and found 1.51 % nitrogen, 0.24 % phosphorous, 29.03 % crude fiber content, 2.10 % ether extract, 10.86 % ash content and 48.68 % nitrogen free extract (NEF) of dry matter.

**Effect of growth stage on composition of pearl millet fodder:** Several investigators have determined the effect of growth stage on composition of pearl millet fodder.

Late maturing pearl millet varieties give a better leafier and are easier to manage, more persistent, higher in protein content and more digestible than early ones (Burton et al., 1968).
Table 2. Range for various biochemical characters in pearl millet inbreds

<table>
<thead>
<tr>
<th>Biochemical characters (as % of dry matter)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude protein*</td>
<td>6.75 - 13.68</td>
</tr>
<tr>
<td>Crude fat content</td>
<td>1.07 - 1.76</td>
</tr>
<tr>
<td>Crude fiber</td>
<td>27.22 - 34.80</td>
</tr>
<tr>
<td>NFE*</td>
<td>39.79 - 52.64</td>
</tr>
<tr>
<td>Total ash</td>
<td>6.39 - 13.15</td>
</tr>
<tr>
<td>Calcium</td>
<td>0.27 - 0.82</td>
</tr>
<tr>
<td>Phosphorous</td>
<td>0.44 - 0.82</td>
</tr>
<tr>
<td>Oxalic acid*</td>
<td>1.14 - 2.28</td>
</tr>
</tbody>
</table>

*Significantly varied with respect to inbreed.

Patel et al. (1958) and Patel and Shah (1959) observed that the fodder harvested after 2-3 months of growth was not nutritive as it contained low amount of protein ether extract and calcium with increase in the amount of crude fiber and nitrogen free extract. Boyle and Johnson (1968) reported 28 % crude protein content at early stage of growth, which decreased to 18 % at maturity. Hoveland et al. (1967) also reported a decrease in crude protein content in delayed harvest fodder whereas, lignin and crude fiber content were increased. It has been reported that as the growth proceeds, water-soluble carbohydrates increase, attain maximum value at flowering and there after decline to lower value at maturity (Bhatia et al., 1972). The cellulose, which is the main structural carbohydrate in pearl millet stem increase with the growth (Bhatia et al., 1972). Chawla and Gupta (1980) reported that the chemical variability in the leaves was better expressed than in the stem.

Yadav et al. (1991) reported that the protein content of the leaf and stem decreased with increasing growth stage, being highest at panicle initiation and lowest at maturity. Translocation efficiency (protein content at anthesis/maturity) averaged 0.43 for stem and 0.25 for the leaf. A similar report about crude protein content was reported by Gupta et al. (1995). They reported that pearl millet harvested at vegetative stage (45 days) had lower cell wall contents but higher rumen degradability of dry matter, crude protein and natural detergent fiber (NDF). The protein of forage harvested at 55 and 65 days after sowing was poorly degraded and digested. Dry matter digestibility decrease at maturity because fodder contained less amount of crude protein and mineral and higher content of lignin, whereas, the digestibility was higher at initial stage of maturity (Singh et al., 1974). Based on the digestion kinetic it has been concluded that harvesting bajra after 45 days of sowing gives most nutritious forage for ruminants (Gupta et al., 1995).

In pearl millet fodder about 1.18 % of nitrate nitrogen is found (Schneider and Clark, 1970). The amount of nitrate nitrogen increases with the application of higher levels of potassium along with magnesium and calcium content. Application of nitrogen increased crude protein, phosphorous, chloride, magnesium and potassium of leaf and starch, but decreased the calcium content (Shah and Mehta, 1960). Moreover, application of phosphorous increased crude protein, chloride, calcium and potassium contents of leaves but decreased the contents of sodium and magnesium (Shah and Mehta, 1960).

Plants of pearl millet are reported to contain oxalic acid (Goswami and Sidhu, 1967), which is considered to interfere with the calcium assimilation in the ruminants (Worden et al., 1954 and Brune, 1955). Oxalates occur as soluble salts of sodium and potassium or as insoluble salts of calcium. Some
plants species have soluble oxalates more than 10 %, such plants may be toxic to animals. Unfortunately, most oxalates containing plants are very palatable for the animals. The animals without any harmful effect exert insoluble oxalates in the diet. The soluble oxalates are degraded to carbonate and bicarbonate in the rumen and are liable to produce alkalosis and associated effects, if consumed in large quantities or over long period. In ruminants, the toxic dose varies with previous consumption of oxalates. Leaves less than 0.1 % of body weight are sufficient to produce symptoms in the starved animal, but such a level will not produce any effect in a well-fed animal. However, feeding forages containing more than 10 % oxalates is hazardous.

In pearl millet oxalic acid content range from 0.09 to 3.50 % (Athwal and Gupta, 1966). While content of 2.12 % oxalic acid in fodder bajra at pre flowering stage was reported by Parveen et al. (1988). They also observed that soaking of pearl millet fodder in water (1:10) for 30 minutes twice in succession reduced the oxalic acid content to 0.69 %. Contents of oxalates were present in high amount at the initial growth stage and later on declined with maturity of the plants (Goswami and Sidhu, 1967; Sharma et al., 1968 and Parveen et al., 1988). The reduction in the later stages may be due to the increased synthesis of cell wall polysaccharides, thus diluting the contents of oxalates in the total dry matter (Sharma et al., 1968).

Higher concentrations of oxalic acid and calcium content in leaves than in stems has been observed (Gupta and Batra, 1980 and Parveen et al., 1988). Sharma et al. 1968 and Kaur et al. (1970) also observed higher concentration of oxalates in the leaf than in the stem in the early stage of maturity and concluded that the oxalates are synthesized in the leaf and are then translocated to the stem. Bhatia (1973) also found that the leaf contains more oxalates than the stem but after 50 days of growth, the concentration becomes almost the same in both the tissues. In early stage of growth, leaf contains more free oxalates as compared to stem. Bound oxalates are less at early stage, increase with maturity and finally decrease.

Effects of biochemicals on digestion:
There are several studies in relation to the fate of the oxalates during digestion and complexion with other compounds during and after digestion. For instance Bhatia (1973) found that oxalates were not completely broken down in the rumen, and, thus, it is quite likely that some of them might be razzing out of the digestive tract as insert calcium oxalate, thus resulting in poisoning of oxalates due to decalcification. On the other hand Watts (1957) and Dodron (1959) reported that the oxalic acid interferes with the absorption of calcium, it occurs in plants as calcium oxalates (insoluble) and potassium oxalates (soluble). These investigators also observed that ruminants can consume large quantities of these salts without suffering any apparent ill effects of oxalate poisoning. The immunity to oxalates poisoning in the ruminants is due to the presence of microbial enzymes in the rumen, which can decompose oxalates.

Breeding for Quality Traits

Assessment of heritability and expected genetic advance is the foremost requirement in order to know about the possibility of improvement through selection and also to decide the selection criteria. Several investigators have estimated heritability for morphological characters but there are few reports with respect to biochemical characters. High heritability was reported by Gupta and Batra (1980) for the characters leaf oxalic acid, sodium and calcium content and for stem oxalic acid, sodium and calcium content. Das (1994) reported high heritability and high genetic advance for crude protein and calcium while
moderately high heritability and genetic advance for phosphorous content and oxalic acid. Longasundari and Khan (1996a) reported high narrow sense heritability for crude protein content, which indicates the major contribution of additive gene effects in the control of crude protein content. Calcium content also mainly under the control of additive gene effects. Thus, selection for these two characters i.e. protein content and calcium content will be effective. However, Goswami et al. (1970) reported highly significant inbred x year interaction variance for crude protein, total ash, calcium and phosphorous which indicated limited scope for selection of inbreds for these characters. They also reported that inbred x year interaction variance for oxalic acid was highly significant, therefore selection of inbred for low oxalic acid content seemed to be limited.

Hart (1967) reported significant positive correlation of dry matter digestibility and leafiness from root stage to maturity stage whereas significant negative correlation of dry matter digestibility with lignin content both in leaves and stem. Goswami et al. (1970) reported significant positive correlation of the character phosphorous content with crude protein content, crude fat content, crude fiber, ash content and calcium content. Ash content was positively correlated with calcium content and oxalic acid content. They also reported positive correlation of calcium content with oxalic acid and phosphorous content. Goswami et al. (1970) reported significant negative correlation between the character nitrogen free extract and crude protein, nitrogen free extract and ash content and between the characters NFE (Nitrogen Free Extract) and calcium content. Sehgal and Goswami (1969) reported that oxalic acid content had significant and positive correlation with protein and calcium content. Sehgal and Goswami (1971) reported that crude protein content had significant positively correlated with calcium content whereas it had significant negative correlation with crude fiber content. They also reported that total ash content had significant and positive correlation with calcium content whereas it had significant negative correlation with phosphorous content. Sidhu and Gupta (1974) reported that oxalic acid content had significant positive correlation with mineral content, stem thickness, leaf size and leaf length. Singh et al. (1987) reported significant negative correlation between protein concentration and protein quality.

Several attempts have been made to determine the genetic control of the biochemical components of pearl millet fodder. For protein content significant GCA and SCA variances were reported by several workers (Kumar et al., 1978; Yadav et al.; 1991 and Gill et al.; 1993). Predominance of GCA and variance over the SCA variance for protein content was reported by Devanand and Das (1997). There are also reported that protein content is predominantly controlled by non-additive gene effects (Harinarayana and Murthy, 1970; Ahmad and Murthy, 1972; Ahmad et al., 1972 and Dwivedi et al., 1978). However, predominance of both additive and non-additive gene effects was reported by Bhardwaj et al. (1984), Gupta and Sindhu (1984) and Satija and Thukrals (1985). Similarly, Longasundari and Khan (1996b) reported equal influence of additive and dominant genes in a partial diallele analysis. However Longasundari and Khan (1996a) in a study evaluated hybrids of indigenous sweet pearl millet genotypes and reported predominance of dominance gene action for crude protein content. Role of over dominance (Dwivedi et al., 1978) and that of interacting non allelic genes (Mahadevappa, 1967) was also noticed for the character protein content. Thus, these reports indicate that both additive and non additive gene effects were important in the inheritance of protein content and
therefore reciprocal recurrent selection appears to be the best approach for improvement of protein content in pearl millet and the populations developed through reciprocal recurrent selection may be utilized to develop hybrids.

Oxalic acid content was reported to be governed by dominance and epistasis (Gupta and Sidhu, 1984). Gill et al. (1993) also reported significance of SCA variance whereas non significance of GCA variance, which indicated the role of dominant genes. However, Devanand and Das (1997) predominance of GCA variance over SCA variance indicating predominance of additive gene action.

Calcium content was reported to be governed by dominance gene action (Gill et al., 1993) and also by epistatic gene interaction (Gupta and Sidhu, 1984). However, Devanand and Das (1997) reported higher SCA variance than GCA variance for calcium content indicating predominance of non­additive gene action.

Mineral content was reported to be governed by epistatic effects (Gupta and Sidhu, 1984). Bhardwaj et al. (1984) reported importance of both additive and non additive gene effects for total carotenoids and for the carotene. Deora (1989) reported significance GCA and SCA variance for crude fiber content. Heterosis has also been worked out for few biochemical components. Heterosis to the extent of 29.3 % for crude protein content and to the extent of 13.10 % for calcium content was reported by Devanand and Das (1996). They also reported negative heterosis to the extent of -27.9 % for oxalic acid content.


Sidhu and Gupta (1974) suggested breeding of hybrid having low oxalic acid, thin stem and long and narrow leaves. Critical analysis of heritability, genetic advance, correlation coefficient and gene effects it may be concluded that improvement in protein content and calcium content through reciprocal recurrent selection will be effective. Also reduction of oxalic acid by reciprocal recurrent selection for lower values of oxalic acid will be effective. Satija and Thukral (1985) and Thukral (1983) also suggested recurrent selection as the best method for developing low phytic acid.

CONCLUSION

The available reports so far, indicate that both additive and non-additive gene effects are important in the inheritance of protein content, oxalic acid content, total carotenoids and crude fiber content, while for calcium content dominance gene effects were important. Thus reciprocal recurrent selection appears to be the best approach for improved of these biochemical characters and for the development of improved population for these characters in pearl millet. These improved populations with higher levels of protein content, calcium content and mineral content and populations with lower oxalic acid may be further exploited through development of composites and synthetics.

The preponderance of additive gene effects can be comprehended if significantly high estimates of GCA are obtained, thus, suggesting the use of simple breeding procedures of improvement for concerned biochemical traits. The improved populations may also be exploited by isolation of superior inbreeds with high SCA for above mentioned.
biochemical parameters. These inbreds with high SCA may be used to developed hybrids.

REFERENCES