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GENETIC IMPROVEMENT AND MANAGEMENT OF QUALITY IN CROP PLANTS*

V. P. GUPTA

Punjab Agricultural University, Ludhiana 141004

Quality in verbatum means degree of excellence and is, therefore, a relative term and its improvement is more challenging than of any other trait. Definition of quality varies according to our needs from the viewpoint of seed, crop growth, crop product, post-harvest technology, consumer preferences, cooking quality, keeping quality, transportability etc.

The problem of quality improvement is as much of management as of breeding. The methods of breeding may be the same as conventional ones but require a proper understanding of nature of gene control, availability of germplasm, monitoring and manipulation of growth rhythm, developmental patterns and biochemical and physiological processes etc.

General nutritional goals include improvement of palatability, acceptability, better chemical composition, and energy yield along with high yield. High yield should not be compromised with quality. Also, breeding for quality should safeguard economic interests of the consumer and producer.

Quality characters may be classified as:

1. Organolaptic features like taste, smell, aroma.
2. Chemical composition and nutritive value like protein content, amino acid composition, fatty acid composition and antiquality factors.
3. Morphological features, such as, seed size, seed color.
4. Biological, such as, biological value, protein efficiency ratio, body weight gain etc.

Objectives in quality improvement may be to breed for:

1. Better chemical composition
2. Quality of protein, oil etc.

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3. Reduction of antiquality factors

4. Exploitation of genetic variability

5. Genetic manipulation of growth rhythm

6. Genetic manipulation of biosynthesis of chemical components

The morphological features are the easiest to use. Even a common man can make use of them. However, a grower's criteria for quality seeds are different than those of the consumer.

Seed type has been observed to be related with protein quality in sorghum. The opaque types are superior to translucent ones for protein and lysine content and leucine/lysine ratio. In maize, yellow seeded types are superior to white seeded and bold seeded are superior to small seeded types for green fodder yield, dry matter yield, crude protein percent, and crude protein yield.

Seed colour has been related with tannins in sorghum. Dark brown seeds have the highest tannin content, followed by dull brown, reddish brown, and brick red seeds. Tannins interfere with bioavailability of nutrients. Polyphenols generally inhibit the hydrolytic enzymes. Tannins impart bird resistance and prevent preharvest germination by retarding metabolic processes.

The white grained pearl millet has more carotenoids. Crude protein, though slightly on higher side, yet shows a large range of variation as in the slaty coloured and grey types. Also, there is no difference in cooking quality.

In maize, brown midrib is associated with lower lignin content and greater digestibility of cellulose and hemicellulose. In tomato, thick skin is desirable for quality, keeping quality, transportation and longevity. However, varieties with such features do not necessarily satisfy the needs of the industry. Also the table purpose preferences are different than those of the technologist or the grower.

Breeding for uniformity of morphological traits does not necessarily ensure uniformity of quality traits. In muskmelon, besides uniformity of fruit size, color and shape and stripe appearance, the sweetness due to sugar content is highly variable. In such cases, the intravarietal and even intraplant variation must be studied to work out the repeatability of a trait and a realistic basis of its genetic improvement.

Sometimes proper management of the plant can help to ensure uniformity of quality. For example in grapes, uniformity of maturity, bold berry size and sugar content can be ensured by proper cutting, management and trimming of the inflorescence.

The development of new genotypes purely from quality point of view is often possible. In Indian mustard, table purpose *saag* types have been developed which are herbaceous, more leafy with delayed main shoot development.

Breeding for long narrow leaves has proved useful in the improvement of quality in terms of high protein content and low oxalic acid content in Napier–Bajra hybrids and the new pearl millet fodder types. The broad leaves have larger stomata and hence there is more accumulation of oxalates in them. The narrow leaves have smaller stomata but their photosynthetic efficiency is not affected as there is more number of stomata. The voluntary intake of these new types has been improved on account of nonhairiness, thin stems, and better palatability. Voluntary intake and digestibility are the major factors influencing animal production. The quality parameters in forage production are energy content, digestibility, intake and utilization; toxic and harmful constituents; and essential elements such as proteins and minerals. The nature of their gene control varies in different plant parts as in leaves and stems. Their expression is also influenced by environment differentially in different plant parts.

In almost all cereal grains, lysine, tryptophan and threonine are the limiting amino acids. However, a wide range of genetic variation occurs and can be exploited. In pearl millet, tryptophan is higher than in other cereal grains. However, it has high phytic acid content. Phytic acid occurs in seed coat and germ. It forms insoluble compounds with several minerals, leading to mineral deficiency. It also affects digestibility and availability of nutrients. The nature of gene control varies with the experimental material.

The amino acid availability and protein digestibility increases on cooking, especially in pulses. Sulphur content in plants is correlated with S-amino acids which, in turn, are positively correlated with biological value of the protein. Nitrogen application may increase yield and protein content, but at higher doses there is increase in nonessential amino acids with a general decrease in essential amino acids. Low lysine leads to impaired utilization of proteins, resulting in inadequate support for growth and maintenance of human body.

The quality of human diet can be improved by feeding on cereal + legume mixtures. The response is genotype specific and is more sharp in the course grain poor quality cereals. Similarly, the animal feed value of forages can be improved by mixed cropping and feeding of legume + grass mixtures. For this, one needs to develop appropriate genotypes that respond better to mixed cropping systems and fit well in the relay cropping schemes. It is equally important to monitor the growth rhythm of the plant type. There is often decline in desirable components and increase in undesirable components with the advancement of growth. There is also tissue-specific effect of season on the growth rhythm and biochemical profile of a plant type. Such effects, however, are genotype-specific and involve a large component of genotype x environment effects over growth stages. Similar pattern of genotype-specific variation is observed during grain filling stages. An analysis of the pattern of variation and nature of gene effects could help in manipulating grain quality.

Study of the biochemical profile at various growth stages in some crop plants has helped in the identification of critical stages for genetic manipulation, biochemical parameters leading to changes in plant behaviour, and inherent potential of the plant genotypes. The nature of gene effects may vary differentially at different developmental stages. However, in biochemical genetic studies involving enzymes as parameters, it is the activity of an enzyme which is of prime importance. Over and above this, the balance of enzymes matters more than an enzyme alone. Therefore, overall biochemical profile as observed for several enzymes is a better criterion for the study of plant behaviour as shown by our studies in several crops like pearl millet, wheat, groundnut, gram, mungbean, lentil, Indian mustard etc.

Studies in these crops revealed that most of the antiquality factors develop at later stages of grain development while most of the desirable components are accumulated by the stage through 2/3 or 3/4 of the usual span of grain development. Thus, longer span of maturity is not desirable, especially when it does not add to the yield potential after a particular stage. However, the nature of gene effects varies over the developmental stages and there is genotype-specific response for the rate of biosynthesis of the chemical constituents. Certain biochemical, genetic parameters, and expression of certain enzymes during different phases of growth could be correlated with the post-harvest quality parameters. Manipulation of the enzyme profile, especially at grain developmental stages of the genotypes, could therefore help in identification of genotypes with better quality. Even the combining ability behaviour of the quality traits could be correlated with that for enzyme activity as shown by our studies in Indian mustard.

The environmental stress may also affect the accumulation rate of chemical constituents. Such a response, however, is crop- and genotype-specific. Our studies with several crops have shown that in crops like cereals, the stress heavily curtails yield but grain quality may not be affected. However, in some *Brassica* species both yield and quality parameters are affected. Desirable fatty acids decrease while undesirable ones increase under stress with genotype-specific response. In groundnut, quality varies within and between taxonomic groups. Environmental stress reduces oil content but increases protein per cent. Crude protein content in mungbean decreases under all stresses while that of lentil and gram increases under water stress. In lentil, methionine and tryptophan increase under moisture stress. Also the phytohemaglutinins are more but the behaviour of genotypes for this antiquality factor is unpredictable over environments. The protein fractions in gram showed highly significant genotypic differences for water- soluble, salt-soluble, and alkali-soluble fractions with highly significant genotype x environment interactions. There were higher genotypic differences for water soluble fractions with less effect of environment. The genotypic effects on the salt-soluble protein fractions were also very high but there was variable response of genotypes to environmental variation.

The maternal effects may also play an important role in expression of some quality parameters. In pearl millet, the inheritance of free fatty acid content is governed by maternal effects. The nature of gene effects also varies for different fatty acids in pearl millet. In groundnut, while crude protein and oil content were governed by additive gene effects, the nonadditive gene effects were predominant for individual fatty acid content.

What then should be the breeding objectives and plans for genetic improvement of quality? The breeding methods would basically remain the same as for other traits but the objective is more complicated as one has to manage the whole plant. Although ample variation exists for many nutritional characteristics, yet the ease of their manipulation in a breeding programme and eventual incorporation into an improved variety will depend on the type of genetic control and the amount and type of genetic variation. Genetic correlations between desirable and undesirable characters may also become important limitations in a breeding programme.

The effect of span of maturity and late harvest has invariably been found to be adverse for various quality parameters in different crops. In pearl millet, the longer span of maturity increases the phytic acid content and is also negatively correlated with protein content. Also the span of earing is related with increase in free fatty acids which are released on grinding and cause rancidity. Late harvest of maize ears reduces the digestibility of organic matter, crude protein, fat, crude fibre, and nitrogen-free extract; the effects are genotype- and season- specific. Similarly, late harvest reduces the maize stover quality due to reduction in digestibility of organic matter, crude protein, fat, crude fibre and nitrogen-free extract. The effects are again genotype- and season-specific. In case of Indian mustard, the erucic acid content increases by chain alongation at later stages of grain development, at a time when more than 90% of the lipids would have been accumulated. Here again, breeding for shorter span of maturity will be desirable.

It would also be desirable to select for genotypes with better response to environmental changes and to pinpoint the factors that really influence quality. For example, sulphur content in Indian mustard retards the rate of erucic acid synthesis but it increases the rate of glucosinolate accumulation and total content in the developing seeds.

Liquid culture of detached ears of cereals, use of radioisotope techniques, and manipulation of amino nitrogen and soluble carbohydrates in the sap entering the grains have shown that protein synthesis in cereals can be increased at the cost of starch accumulation without affecting grain weight. This means there is scope of creating genetic variability for efficient biosynthesis of desirable chemical constituents.

Manipulation of growth rhythm and hence quality in Napier–Bajra hybrids has been achieved through selection for a novel regeneration habit.

In the Indian mustard, lines with shorter span of maturity but prolific bearing have been identified and could be used to widen the scope for improvement of quality.

EPILOGUE

It is difficult to define quality as a single term. In verbatim it means degree of excellence but a measure of excellence will depend on our requirement. Methods for genetic improvement of quality traits, however, are in no way different than the usual procedures followed for conventional genetic improvement. Depending on the genetic material at hand and the nature of genic control for a particular trait, one may resort to selection, mutation, hybridization, interspecific hybridization or polyploidy. The quality traits may also be correlated favourably with morphological features or the plant behaviour. These favourable correlations could be exploited with tremendous success.

For the genetic improvement of chemical traits we must first study the nutritive value and define parameters to be analysed or manipulated. This should follow the study and evaluation of the germplasm, genetic analyses, and development of suitable selection criteria. The quality traits are generally influenced by the physiology of growth and development of the organism. It is, therefore, imperative to monitor the growth rhythm and also pinpoint specific parameters to be manipulated by monitoring the growth rhythm. For example, forage quality could be improved by manipulating the growth habit and development of a fodder plant. In grain crops, the present emphasis is on monitoring the biochemical processes in the developing grains with a hope to modify the developmental processes in a desirable direction, namely, improvement of quality without affecting yield.