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Kirsten vom Brocke: "Effects of farmers' seed management on performance, adaptation and genetic diversity of pearl millet {Pennisetum glaucum [L.j R.Br.) populations in Rajasthan", Dissertation an der Universität Hohenheim 2001

Summary

Background

Pearl millet {Pennisetum glaucum [L.J R.Br.) is the staple food and fodder crop of Rajasthan in northwest India, where it is grown on 4-6 million ha annually. Depending on distribution and amount of rainfall, average productivity of the crop can vary considerably from year to year. This especially applies to the dry western part of Rajasthan. This region which borders the Thar Desert, often has less than 250mm annual rainfall, resulting in average yield levels frequently below 100 kg/ha. Rajasthan farmers must exploit various management strategies in order to meet their environmental, socio-economic and quality needs. They claim that while modem varieties (MVs) may yield more with favourable rainfall, they perform poorly compared to traditional landraces during times of drought. MVs are also perceived to be inferior in stover production and deficient in nutritional value. Notwithstanding the perceived risks of MVs under harsh climatic conditions, farmers are still attracted to the possibilities of higher yield potential under favourable conditions. But in order to avoid crop failure in the event of drought, the farmers often only mix small quantities of modem variety seed into their own adapted landrace seed grain. Furthermore, some farmers select for preferred panicles in their diversified crop as a way of eliminating the negative effects of the MVs.

Focus of research

The present thesis was initiated as part of a project designed to investigate diversity and productivity of farmers' pearl millet genetic resources in Rajasthan as well as farmers' specific needs and preferences. The project also focused on participative strategies of germplasm enhancement and genetic resource conservation- A special feature of the project was that an agricultural social scientist (A. Christinck) and a population geneticist (K. vom Brocke) worked side by side. ICRISAT and its national partner institutions in Rajasthan collaborated on the project together with the University of Hohenheim in Germany, with further informal support provided by local Indian NGOs. The project was funded by the German Ministry for Economic Cooperation and Development (BMZ) with administrative support from the German Society for Technical Cooperation (GTZ).

Aim of the project

The main aim was to establish a basis for participatory plant breeding so that breeders can develop improved cultivars that are locally acceptable. This involved finding strategies for improving the dissemination of such germplasm, as well as exploring the possibilities of in situ maintenance of traditional cultivars - with the active involvement of farmers. The objectives of the submitted thesis were to quantify the effects of farmers' pearl millet seed management practices in Rajasthan in regard to: (1) adaptation and performance under various drought stress conditions; (2) morphological and agronomic variation between and within farmers' populations; and (3) molecular diversity in traditional pearl millet landraces.

Methods

For the first objective, a field experiment was conducted in five environments (site/season combinations) between 1997-1999 at experimental stations in western Rajasthan. The experiment comprised 48 pearl millet grain stocks (food grain samples as well as seed grain samples) from farmers and 33 modem varieties. The farmer grain stocks had evolved through different seed management practices e.g. various levels of MV introgression and different seed selection methods. Farmers use certain traits when describing the productivity and adaptability of a plant, and these traits were observed in the trials.

Different statistical applications were used to quantify the effects of the different seed management strategies. These applications included: principal component analysis, pattern analysis for graphical representation of the genotype x environment interactions, analysis of variances (AMOVAs), and multiple comparisons of entry means.

In order to analyses morphological and agronomic variation, three of the aforementioned 48 farmer grain stocks were chosen as base populations for the second experiment. One population represented a typical landrace (population RR) and the two other populations comprised grain stocks that had been modified through MV introgression via the farmers (populations DR and SB). The experiment was conducted in the form of progeny trials comprising 100 full-sib families from each of the three base populations.

To calculate quantitative genetic parameters, variance components were calculated according to the experimental design. Parameters included coefficients of error variation (CV), broad-sense heritability (h2), expected response to selection G(y) and population means.

To characterise genetic diversity, an AFLP-(amplified fragment length polymorphism) marker study was carried out. The AFLP study comprised individuals from 27 farmer landrace populations, 14 from western and 12 from eastern Rajasthan, each comprising 19-30 random panicles collected from fields or threshing grounds. The collection and characterisation of samples was carried out by the social scientist using an approach that actively involved farmers. Additionally, 12 control cultivars were integrated into the study. These cultivars consisted of open-pollinated MVs, composites, hybrids, and African landraces.

AFLP bands were scored for presence (1) or absence (0) of bands for all 39 pearl millet cultivars. Shannon's information index (H) and AMOVA (Analysis of Molecular Variance) was used to calculate and describe marker-based diversity and partitioning of diversity.

Cluster analysis was used to estimate Genetic distances among populations. In order to visualise the degree of gene flow between populations, the logarithms of inferred gene flow were plotted against the logarithms of the geographical distance.

Results and conclusion

The first experiment saw three favourable seasons and two seasons with low rainfall. The second experiment saw drought stress during all seasons. This resulted in considerable differences among environmental means. Grain yield for the two experiments ranged from 55g m'2 under drought stress to 272g m'2 under favourable conditions.

In the first experiment, farmer grain stocks differed significantly for all traits except grain yield. Significant genotype x environment interactions were observed for most of the traits. Nodal tillering, number of productive tillers, as well as a diversity score showed a positive phenotypic relationship with grain yield (r=0.3-0.9) under low rainfall conditions; whereas stem diameter, leave width, panicle girth, and grain weight were negatively associated (r=0.2-0.7) with grain yield under the same conditions. The relationships were reverse under favourable conditions. These results confirm that morphological and agronomic traits used by farmers to describe the adaptation and performance of pearl millet cultivars are indeed effective.

Principal coordinate analysis and pattern analysis confirmed the existence of groups corresponding to seed management practices. Entries representing typical landraces (LR) and grain stocks with only occasional introgression of MVs (IG1) remained distinct from grain stocks with frequent introgression of MVs (IG2). Most of the LR and IG1 entries showed specific adaptation to low-rainfall conditions, whereas IG2 entries indicated a wider adaptation.

Under favourable conditions, farmer grain stocks with regular MV introgression combined with mass panicle selection showed similar productivity levels as modem varieties. Under lessening rainfall, pure landraces showed, in tendency, higher grain yields. Introgression of MV germplasm into group IG1 was not sufficient enough to surpass the LR performance level, indicating that occasional introgression of modem varieties does not offer significant advancement in regard to adaptation and productivity. Stover yield performance was, higher for farmer grain stocks in all cases - up to 24% in the group LR under low rainfall.

Significant changes in plant-type characteristics were associated with the amount of introgression of modem varieties. Stem diameter, panicle girth, leaf width, and phenotypic diversity all increased, whereas nodal tillering decreased. Results further showed that farmer panicle selection (IG2) reduced nodal tillering and significantly increased panicle girth and grain weight. Introgression of modem varieties combined with mass panicle selection thus can be seen as an effective method for improving grain yield.

In the second experiment, the typical landrace RR produced the significant highest population mean for nodal tillering and number of productive tillers compared to both modified landrace populations (DR, SB). Population DR achieved the highest stover yield. Estimates of genetic variances were highly significant (P=0.01) for all traits in each of the three populations. Heritability estimates (based on entry means) ranged between 0.75 and 0.92 for morphological traits, and between 0.53 to 0.94 for yield traits and flowering. Both modified populations (DR and SB) generally had somewhat higher estimates. Across environments, genetic gains for grain yield were 1.6% for RR and 2.2% for DR and SB each. Under severe drought stress estimates were more than twice as high.

The degree of polymorphism in the 27 farmer landrace populations and 12 control cultivars ranged between 69% and 92%. According to Shannon's information index, diversity in Rajasthan landrace populations were 9% to 14% higher than in composite-based modem varieties. Most of the variation (>80%) found in the analysed material was attributable to within-population diversity.

According to farmers, the same pearl millet landrace type grows across all of western Rajasthan. In eastern Rajasthan, on the other hand, fanners distinguish between several different morphological landraces that are commonly named after their village of origin. Landrace populations collected from different villages in western Rajasthan showed no significant genetic distances. In eastern Rajasthan the variation between landrace groups with different names was three times higher than the variation between landraces within the 'name groups'. In western Rajasthan, gene flow inferred from genetic distances was generally greater than 25 migrants per generation. Gene flow between eastern Rajasthan landraces was considerably smaller. The different diversity patterns and levels of gene flow in western and eastern Rajasthan reflect the different seed management practices and seed systems.

The submitted thesis shows that those plant traits fanners use in describing performance, adaptation and diversity are highly effective in the targeted environments. In order to define effective selection criteria, as well as breeding goals that can meet the farmers' needs and preferences, the farmers themselves should be integrated in the selection process. Through their own management practices, farmers are able to enhance the yield potential of their populations and increase the potential for genetic gains in important traits. Farmer seed management should therefore be viewed as a valuable breeding activity. Farmers can provide the ideal starting material for variety development programs.

The population genetic study confirmed that farmers' seed management actually influences and modifies the pattern of genetic diversity, as well as the genetic structure of pearl millet landraces in Rajasthan. In respect to the different seed systems, different conservation strategies need to be developed for western and eastern Rajasthan. In western Rajasthan, emphasis needs to be placed on the maintenance of a high degree of intra-population diversity and improved means of disseminating pure landrace seed. In eastern Rajasthan, farmers are interested in the improvement, maintenance and propagation of single 'village' landraces of specific ideotypes.

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