Participatory Crop Improvement for Maize-Millet Intercropping in the mid-hills of the Himalayan Region

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Participatory Crop Improvement for Maize-Millet Intercropping in the mid-hills of the Himalayan Region

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EXECUTIVE SUMMARY

Maize is the staple crop for around 10 million people in the mid-hills of Nepal, where most families are in food deficit because maize yields are low and have remained stagnant for decades. The project achieved 30% yield increase over local varieties, in on-farm trials run and evaluated by farmers themselves and has initiated follow-on work to scale up the use of participatory approaches nationally.

Although new varieties previously released have had higher yield potential than local cultivars, they have not been adopted by hill farmers because they were not compatible with the farming system. Maize is generally relay cropped with millet on crop terraces that are often affected by the presence of fodder trees. The trees reduce crop yield by altering the microclimate, affecting pest and disease incidence, and competing directly with the crop for light, water and nutrients.

Farmers have sophisticated understanding of tree-crop interactions, and recognise local crop varieties that are tolerant of competition from trees and that are compatible with their integrated farming system. Farmers' knowledge about maize cultivation was systematically documented and then used to drive crop improvement, guiding modification and release of germplasm for testing by farmers and initiating change in agronomic recommendations. The knowledge base created during the project remains an enduring resource for agricultural improvement in the hills.

Farmers' knowledge was verified in agronomic and physiological characterisation of the environment in which maize is grown, including the climate, soil and farmer decisions that define the context in which the maize crop has to perform. Local and introduced varieties were compared with respect to key traits that confer advantage in this environment, revealing on the one hand, deeper rooting of local over previously introduced varieties, indicating potential gains from combining traits through breeding, but no significant differences in photosynthetic light response.

High yielding germplasm was obtained from CIMMYT, modified on-station in relation to farmers' preferences and then tested for local suitability by farmers themselves in participatory varietal selection (PVS) trials involving over a hundred farmers across five villages. This resulted in farmers adopting new varieties with greater yield potential, stress tolerance and other system compatibility benefits (such as stay green characteristics that improve the use of crop residues as animal fodder), improving average annual grain yields over traditional varieties by 28%, 16% and 32% in 1999, 2000 and 2001 respectively.

The project harnessed the local knowledge of farmers, and their criteria for varietal selection, to incorporate system compatible traits from local maize with the higher yield potential of introduced germplasm in participatory plant breeding (PPB). Four PPB composites were created by crossing local and introduced germplasm. High yielding germplasm from yellow grained varieties was incorporated in a new white grained composite, important because white grain colour is a prerequisite for adoption. The best of these are now being tested by farmers in continued PVS and a project aimed at defining the requirements for scaling up the use of participatory crop improvement methods nationally through collaboration amongst government bodies and NGOs has been initiated.

1. BACKGROUND

The background to this research involves definition of the researchable constraint, low maize yields caused by low adoption of new maize varieties with demonstrably higher yield potential because they are not compatible with the complex farming system in the hills. This research project set out to develop and apply participatory crop improvement methods that could simultaneously achieve higher yield and system compatibility by allowing farmers to judge new germplasm in on-farm trials that they ran themselves. In this section the problem is set out, followed by brief summaries of previous research on the farming systems of the mid hills, participatory crop improvement and acquisition of local knowledge.

The problem

The key developmental problem addressed by this research was food deficit and low income of hill farmers in the Himalayan region where maize is the most important rain-fed crop. This affects around 10 million people living in ruaral households in the mid-hills of Nepal where over 50% of the population live in the hills and more than 60% of these people live below the poverty line, maize is grown on about 0.8 M ha (almost 40% of the total cultivated area of the country) and 80% of this occurs on terraced hill land, producing over 1.3 Mt a^{-1} (MoA, 1995). In the eastern hills almost 70% of farm households are in food deficit for some of the year (30% for at least half the year and 10% are in deficit all year round). Maize yields averaged just over 1.5 t ha^{-1} in hill regions at the start of the project (CBS, 1995), they have not increased significantly over the last two decades and were less than half of what was regularly achieved with improved varieties on outreach research sites (Palikhe, 1996).

The project was developed locally by Mr T.P. Tiwari at the Nepal Agricultural Reasearch Council (NARC) Agricultural Research Station at Pakhribas (ARSP) in response to the failure of conventional crop improvement methods to impact rural livelihoods, despite a demonstrable potential for higher yields from hill maize. ARSP had the remit for agricultural research in the eastern mid-hills of Nepal and the project was approved nationally both by the bilateral DFID, Hill Agricultural Research Programme (HARP), who provided local funding, and the national Hill Maize Research Project (HRMP) run by NARC in collaboration with the International Maize and Wheat Improvement Centre (CIMMYT). Farmer surveys at ARSP had indicated that the reasons for low maize yields included:the low genetic potential of the material planted, losses due to disease, and competition from fodder trees grown on crop terrace risers.- farmers estimated that yield loss attributable to trees varied from 30 - 70% depending on tree density and the size of the crop terrace (Fretwell, 1998). The majority of terraces on upper slope, rain-fed (*bari*) land where maize is grown were affected by trees. Carter and Gilmour (1989) documented a steady increase in tree cover on farm land at a landscape level over the last quarter of a century throughout the mid-hills of Nepal. Detailed data at a farm level from the eastern mid-hills (Thapa, 1994) showed that all farmers owned some *bari* land and that 85% of them had fodder trees on the crop terrace risers. Impact studies in the ARSP command area suggested that, while over 40% of farmers had received and planted new seed derived from conventional breeding programmes, only about 6% of the area planted was actually of new varieties, despite their higher yield potential, because the new varieties were not system compatible (Chemjong et al., 1995).

ARSP thus identified a need to develop a participatory approach to crop improvement with farmers involved in the selection of germplasm in their typical on-farm contexts, in order to produce adoptable varieties that while higher yielding were also system compatible. The need for such an approach was corroborated by the CGIAR system wide programme on participatory research and gender analysis who identified participatory breeding of hill maize in Nepal as a priority (Ashby, 1998). The resultant methodology and germplasm have a wide applicability for hillside systems in the Himalayan region including parts of India and Bhutan.

The farming system

Farming systems in the mid-hills of Nepal are complex and involve integration of crops, animals and trees (Figure 1). Animals are vital in supplying draught power for cultivation and manure to maintain soil fertility. As access to degrading common property forest resources has declined over the last decade or so, the number of fodder trees on farms has increased to maintain a supply of vital winter (dry season) fodder to sustain animal populations (Carter and Gilmour, 1989). Trees are particularly incorporated on the upper slope, rain-fed land (*bari*), and within this on crop terrace risers where they compete with crops for light, water and nutrients and modify the microclimate (affecting the environment for pest and pathogen spread) and the erosive potential of raindrops (Thapa et al., 1995; Joshi and Devkota, 1996).

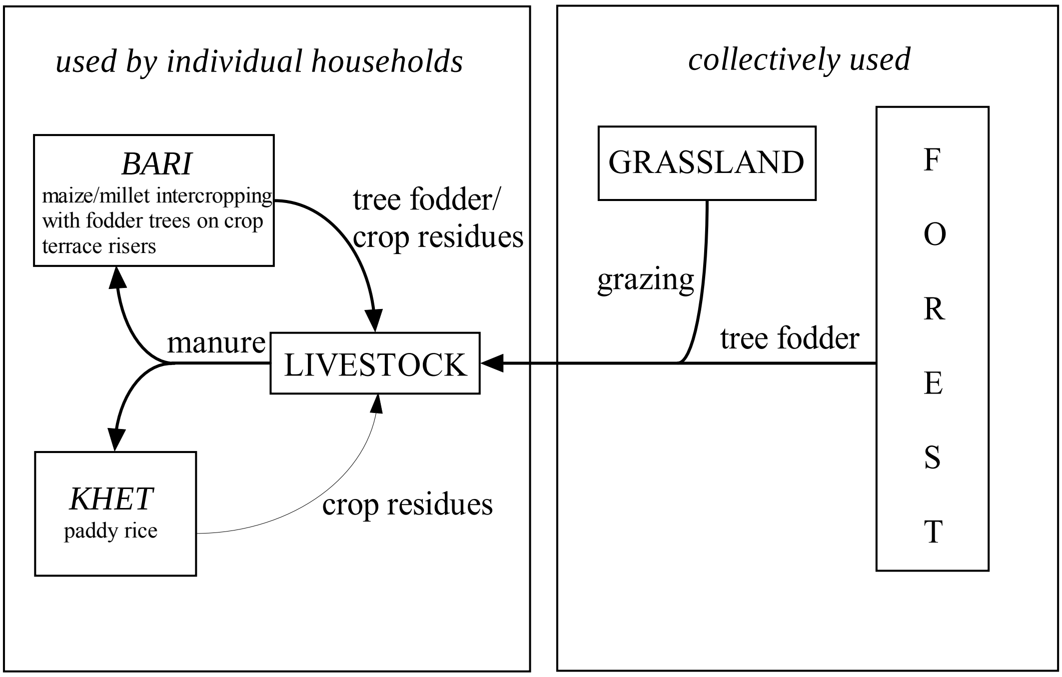

Figure 1.1 Land use diagram for typical farming systems in the mid-hills of Nepal, showing the integrative role of livestock. Upper slope rain-fed land is locally known as *bari*, lower slope, irrigated land is locally known as *khet*. Source: adapted from Sinclair, 1999.

The predominant cropping pattern on *bari* land is maize relay cropped with millet. Maize yields are low and have been almost stagnant for the past two decades. Reasons for low yields include:

- the low genetic potential of the material planted,
- losses due to disease, particularly leaf blight (*Helminthosporium turcicum*) and ear rot (*Fusarium moniliformi*) - average yield loss from leaf blight alone is 10%, but was up to 40% in some areas surveyed. Tolerance for both diseases can be selected for. Tight husks, for example, confer tolerance to ear rot,
- declining soil fertility, this was addressed in a contemporaneous NRSP hillsides project involving agricultural research stations at Lumle and Pakhribas managed by Prof. Peter Gregory at Reading, and
- competition from fodder trees grown on crop terrace risers - farmers themselves estimate that yield loss attributable to trees varies from 30 - 70% depending on tree density and the size of the crop terrace (Fretwell, 1998).

Maize research was initiated for the Eastern hills at ARSP in the mid 1970's, and a shuttle breeding programme, nationally co-ordinated in Rampur in the Terai has been operational since the early 1980s. This has involved adaptive selection of germplasm in co-operation with CIMMYT. Several new varieties have been released, with Manakamana 1 (first released in 1986) by far the most widespread in the mid-hills. These varieties are selected on-station in full sunlight without the influence of trees.

Impact studies in the ARSP command area suggest that, while over 40% of farmers have received and planted new seed, only about 6% of the area planted is actually of new varieties, despite their higher yield potential. This is because of a lack of overall system compatibility of new varieties. Farmers, for example, recognise a number of associative attributes of local maize varieties which they value, notably shade tolerance, which improves their suitability for integration with trees (Thapa, 1994). There is also evidence that farmers more often save seed from their previous crop (selecting well formed grains from bulked shelled seed after harvest, so that the plant phenotype from which seed was taken is not known) than purchase seed, resulting in rapid genetic erosion of new varieties as a result of open pollination.

Participatory approaches to plant breeding

Elsewhere in Nepal and in India, participatory crop improvement (both varietal selection and breeding) with rice and maize has resulted in use of a wider germplasm base by farmers than conventional breeding approaches and has proved successful in improving adoption rates of higher yielding varieties (Witcombe et al, 1996; Joshi and Witcombe, 1996; Sthapit et al, 1996). In the present context, where relay cropping of open-pollinated maize with millet and integration with trees is widespread, the challenge to produce higher yielding varieties that retain system compatibility is greater and an approach that combined participatory varietal selection to produce an appropriate local composite for subsequent breeding with a consultative approach based on rigorous evaluation of local knowledge was used.

The need for participatory approaches in plant breeding arises from farmer's criteria for selection often not matching those of plant breeders (Kamara et al. 1996). A participatory varietal selection study by Lumle Agricultural Research Centre showed differential adoption of maize varieties in different seasons (Kadayat 1996). Virk et al. (1996) showed gains from farmer participation in plant breeding through analysis of data from various crops across India. Participatory plant breeding (PPB) is a logical next step after participatory varietal selection (PVS). PPB is used when suitable cultivars can not be identified through PVS with existing germplasm (Joshi and Witcombe 1998). PPB builds on the results of PVS by using farmer-preferred varieties as parents in breeding programme. Methods appropriate to both self- and cross-pollinating crops have been described by Witcombe et al. (1996). They advocate creation of broad based populations (composites) with the third or fourth random mating generations given to farmers for mass selection which has been successfully practised in a maize breeding programme in Gujarat (India). Composite varieties produced from this programme, e.g. GDRM 186, GDRM 187 are performing extremely well in trials, and are highly acceptable to farmers (Joshi and Witcombe 1998). Some of these were at a pre-release stage in Gujarat when the present research began in Nepal. Virk and his associates (unpublished) have followed both short term and long term strategies for PPB in maize in Bihar. The strategy in the long term is similar to that followed by Joshi and Witcombe (1998) but in the short term inter-varietal hybrids between farmer-preferred varieties were developed.

Formal approaches to knowledge acquisition

Previous collaborative research involving ARSP and Bangor, funded by the DFID forestry research programme (projects R4731 and R6322) in the eastern mid hills of Nepal had revealed that farmers at village level had sophisticated knowledge of tree crop interactions (Thapa et al., 1995) and tree fodder value (Thapa et al., 1997) and that they recognised local crop varieties that they thought were shade tolerant. In a survey of farmers in Solma village development committee (n=40) people identified five local cultivars of maize (large and small leaved, large and small white grained and kali) which they distinguished from introduced varieties (Thapa, 1994). Of these, they identified two as tolerant of shade, two as intolerant of shade and prone to lodging and one as moderately tolerant. Varieties were described in terms of height and stem thickness or strength. They also distinguished three local varieties of millet described in similar terms with different shade tolerance.

Comparable agroecological knowledge has since been found in contrasting communities across the eastern mid-hills (Joshi and Sinclair, 1997) commensurate with using an evaluation of local knowledge to drive research at an institutional level (Walker et al., 1997; Joshi and Sinclair, 1998). Methods for knowledge acquisition from farmers including elicitation and explicit representation (AKT - the agroforestry knowledge toolkit) have been developed (Sinclair and Walker, 1998; Walker and Sinclair, 1998) together with appropriate software packages for knowledge acquisition (Walker et al., 1995) and subsequent use in research planning (Kendon et al., 1995; Randell and Sinclair, 1997; Joshi and Sinclair , 1998a). The software and methodology were developed at ARSP and are presently in use there resulting in a profound impact on research priorities and planning (Joshi and Sinclair 1998b).

2. PROJECT PURPOSE

The purpose of the project was to sustainably increase yields from systems on sloping lands by minimising production losses.

The project has contributed to this purpose by incorporating attributes for higher yield and pest and disease resistance from introduced germplasm into locally acceptable maize varieties in Nepal that are system compatible and so are adopted by farmers. The results are widely applicable in the Himalayan region and have been locally, regionally and internationally disseminated.

The project entailed firstly developing and applying participatory crop improvement methods for hill maize, thereby demonstrating that yield improvements in farmers' conditions could be achieved. Yield improvements of around 30% were demonstrated through PVS using introduced germplasm from CIMMYT, modified on-station according to farmers articulated preferences, and then evaluated with a range of other material by farmers themselves in participatory varietal selection (PVS) trials. Two new varieties have so far been adopted by participating farmers, one because it was high yielding and another, for a different niche within the system, because it was very early maturing.

Analysis of local knowledge and characterisation of the agronomic environment in which maize was grown facilitated definition of combinations of key traits required for hill maize to have high yield potential and system compatibility. Physiological contrast of local and introduced varieties identified some advantageous traits in local varieties, such as white grain colour and deeper rooting, that could usefully be combined with the higher yield potential of introduced germplasm through participatory breeding, as well as less plastic traits, such as photosynthetic light response, which did not vary significantly amongst varieties. This has led to the design and implementation of a participatory plant breeding programme from which new germplasm has emerged for entry into continued PVS. Four composites have so far been created, two that have already begun to be tested on-farm, including a white grained variety incorporating high yielding attributes from an initially yellow parent (PM-7) that was highly ranked by farmers in PVS trials in 2001. PPB will continue to provide new material for testing in PVS trials.

Open pollination of maize makes it a challenging crop for participatory improvement. This places a higher importance on acquiring farmers' knowledge and perceptions so that demonstrably better germplasm can be identified through prescreening on-station, so that what is released to farmers is more likely to out perform local varieties. In addition to promoting use of seed of new varieties with high yield potential in farmers' conditions, the project also identified the need to teach farmers how to maintain the genetic quality of farm saved seed. Traditionally farmers select seed from stored cobs or grains shortly before it is required when it is no longer possible to assess many plant attributes. By encouraging farmers to select next year's seed progressively from better plants in the current year's field, and to control pollen flow through detasseling, genetic improvements can be maintained for several years, reducing the frequency that new seed needs to be purchased.

The project outputs, demonstrate the potential for substantial and sustained maize yield increase through participatory crop improvement at a village level. The next challenge is to scale this up to national coverage, which will require institutional change and integration across governmental and NGO sectors, necessitating adaptation of participatory methods to suit the opportunities and constraints faced by different institutions. A project has been initiated to identify both the institutional requirements and the resources needed to achieve this.

The potential pay off from national adoption of participatory methods for crop improvement appear large - immediate increase in staple crop production of around 30% from PVS relevant to the livelihoods of around 10 million people, with subsequent sustained yield improvements from new varieties developed through PPB that could be expected to exceed projected increases in demand for maize in Nepal (Paudyal *et al*., 2001). Furthermore, new varieties are a key technology because increased yield achieved through their adoption can lead to re-investment in various components of the integrated farming system, leading to further enhancement of rural livelihoods.

3. RESEARCH ACTIVITIES

The research activities were carried out by the Nepali researcher (Mr T.P. Tiwari) based at the NARC Agricultural Research Station, Pakhribas while he was registered as a postgraduate student at the University of Wales, Bangor, supervised by the principal investigators from SAFS (Drs Sinclair and Brook) and Dr Virk in CAZS. Dr Tiwari successfully defended his thesis in October 2001 and was awarded a PhD. Local funding was provided by the DFID Hill Agricultural Research Programme (HARP).

1. Definition of system requirements and acquisition of farmer knowledge and perceptions

1.1 Local knowledge about the maize cultivation, maize varieties and their physiological attributes was acquired from farmers using the AKT knowledge-based systems methodology. This involved semi-structured interview of a small purposive sample of farmers in three villages (Patle, Marga and Fakchamara) in the eastern mid-hills (fully described in Annex 1), from which an explicit knowledge base was created on computer (Annex 2). The knowledge of key informants was later verified in relation to a larger sample of farmers during PVS trials (Annex 5) and in relation to scientific measurements of plant attributes (Annexes 3 and 4). Methodological enhancements developed during the project included the use of pictorial representations of crop traits on cards to elicit preferences and priorities of non-literate farmers (Figure 3.1) and the use of group discussions to arrive at consensus with respect to ranking of selection criteria. A number of people in NARC and the NGO sector were exposed to and received training in knowledge based systems methods during the course of the project in a series of knowledge acquisition workshops held in Nepal.

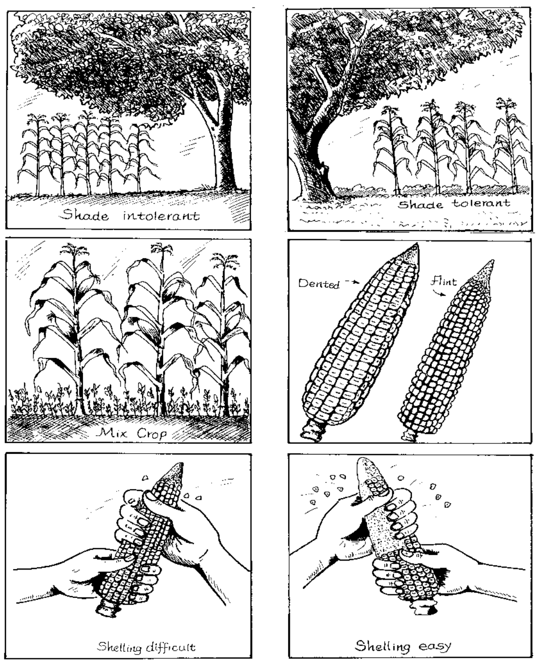

Figure 3.1 Example of pictorial cards used to elicit selection criteria for maize varieties from non-literate farmers.

1.2 The influence of trees on crop terrace risers was measured in typical farm conditions by using portable micrometeorological sensors including photosynthetically active radiation (PAR) above and below the maize crop using a Sunscan portable canopy analyser (Delta-T Devices, Cambridge), the red-far red ratio incident to the maize crop with an SKR 110 ratio sensor, (Skye Instruments, Llandrindod Wells), plant temperature using an IT-340 infra red thermometer (Horiba Ltd, Kyoto) and humidity using a portable whirling hygrometer (Casella Ltd). These intensive measurements were made throughout the crop growing season in 1999 in a series of quadrats set out across sample east and south east facing crop terraces on 10 farms in Patle and Marga (Figure 3.2) from which corresponding crop production measurements were also taken. A more extensive agronomic survey was also conducted across 50 farms in Patle, Marga and Fakchamara in the same year. In this survey the agronomic practices used by farmers were recorded in detail (e.g. amounts of seed, compost and ferilizer used) together with crop performance. Areas influenced by tree shade and open areas away from trees were demarcated so that the effect of trees on agronomic practice and crop performance could be ascertained. Full details are given in Annex 3.

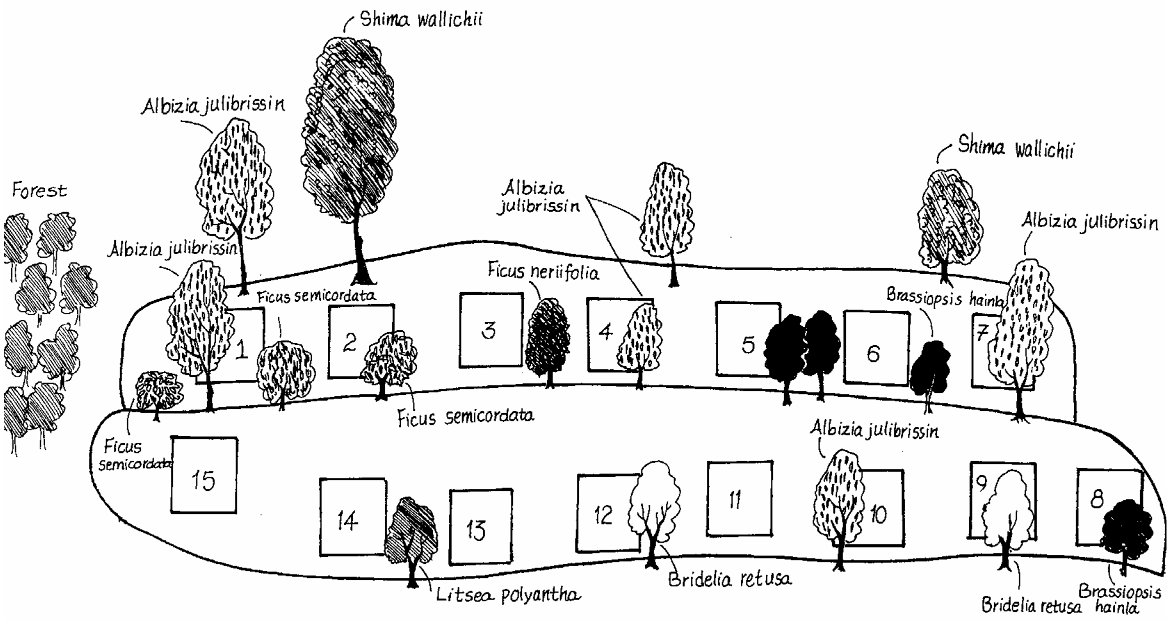

Figure 3.2. A typical *bari* terrace system used to record micro-environmental parameters. This comprises two contiguous terraces. There were another nine farmers' fields of similar type on which similar observations were made. Numbers in squares are quadrat labels, each quadrat was 9 m^2 in size.

2. Acquisition and consolidation of appropriate germplasm

2.1 Local germplasm with attributes preferred by farmers was acquired through farmer survey and described and documented as perceived by farmers themselves. Four local varieties were acquired in this way from different locations: Muga, Madi, Fakchamara and Marga.

2.2 Introduced germplasm with appropriate attributes was also acquired from CIMMYT and some varieties were prescreened and modified on-station according to articulated farmer preferences before being evaluated in participatory varietal selection trials from 1999 to 2001 together with newly bred composites emerging from the participatory breeding programme (Table 3.1, see also 2.3 and 4 below and Annex 5).

Table 3.1. Varieties offered to participating farmers.

Variety	Description	Grain type	Release status
Population-22	White and large grain, lodging and turcicum blight tolerant. Maturity comparable with local	Semi-flint. Work is going on to select flinted type.	Pre-release for mid hills.
Manakamana-1	White grain and large grain, tolerant to lodging. Early maturity.	Semi-flint.	Released for mid hills.
BA-93-2126#2	White grain, earlier than local in maturity and lodging and *turcicum* blight tolerant.	Flint	Pre-release for mid hills.
Arun-1	White grain, early maturity and lodging tolerant.	Flint	New for mid hills
PM-1	White grain, medium maturity.	Flint. Selection for better plant type is continuing.	Newly bred composite
PM-3	White grain and medium maturity.	Flint. Selection for better plant type is continuing.	Newly bred composite
PM-7	White grain, bred from yellow parent	Flint. Selection for better plant type is continuing.	Newly bred composite

Demonstration trials (with all varieties grown at one location) were conducted in five villages while single variety paired comparison trials (where one farmer compares a single variety with his or her local landrace) were conducted in three villages (Table 3.2).

Table 3.2 PVS trials and their methods of evaluation.

Design of trials	Description and management	Method of evaluation	Number of meetings	Sites
All variety, single replicate trials (Demonstration)	All varieties grown together with local varieties, under farmers' management	Focus group discussion (FGD), farm visit, yield measured	Several meetings with individual farmers. Two phases in several small groups	4-5 farmers at each of five sites: Marga, Patle, Fakchamara M/dhunga and Tankhuwa
Single variety trials - paired comparison (FAMPAR)	One new variety grown side by side with local variety, under farmers' management	FGD, household questionnaires, farm visits, yield measurements	Several meetings with individual farmers. Two phases in several small groups	20-25 farmers at each of three sites: Marga, Patle & Fakchamara

2.3 Local germplasm was combined in a composite (PM-1) and then a further series of composites produced that incorporated introduced germplasm with the local material (PM-3, PM-5 and PM-7 - see Table 3.3). This was achieved using a shuttle breeding strategy, with crops grown in the terai in the winter to increase the number of generations possible leading to rapid production of stable composites. Several composites were maintained as new germplasm was identified and incorporated in an ongoing refinement process.

Table 3.3. Participatory maize breeding schedule

	1st year, Season 1 (March, 1999 hills) Season-2 (September, 1999 Terai)		**2nd year (2000)**	**3rd year (2001)**
PM-3 a. Composite parents Population-22 Muga local F/mara local b.Composite Manakamana-1 Marga local, F/mara local c. Composite Arun-1, Madi local Marga local	Sowing time of parental varieties adjusted according to maturity class. Purposive randomisation was done to equalise chances of random mating. 50% plants detasseled and selections made among them only. Good maize growers invited twice during the field selection. Lab selection for healthy, white flinted grains. The same procedures were followed for b and c composites	Broad-based composite Composites (a, b and c) grown together to prepare a broad-based composite (named PM 3). Sown by purposive randomisation to equalise chances of random mating at NMRP, Rampur during winter. Other techniques not changed.	Upgrading continued at station. Good maize growers invited for field selection. Laboratory selection by the good maize growers was planned but could not materialise. FAMPAR trials. Seed increase in farmers' fields.	Upgrading continued. FAMPAR trials. Co-ordinated multilocation trials (CVTs). Disease nurseries. Seed increase in farmers' fields.
PM-1 Parents All 4 above locals	ditto	ditto and the name given is PM-1	ditto	ditto
PM- 5 Parents All FAMPAR varieties	Best ears from over 70 farmers' fields of FAMPAR varieties selected by farmers themselves. Shelled seeds were mixed and sown as a composite.	Seed of different varieties mixed in equal proportion and sown as a composite. Good maize growers invited to select in the field. 50% of plants detasseled for random mating.	Bulk sowing. Random mating as a composite. FAMPAR trials.	Upgrading continued (PM 5). FAMPAR trials. Co-ordinated multilocation trials. Seed increase in farmers' fields.
PM-7 Pool-21 yellow (Female) Arun-1, Madi local Manakamana-1 Population-22 (four male)	Female parent sown in alternate rows with four varieties. All female and undesirable and diseased plants from male rows detasseled. Good maize growers invited for field selections. Deep yellow and white seeds and other diseased grains discarded. Only pale yellow seeds (being hybrids) from yellow female parent continued.	Pale yellow seeds sown at Rampur as C_1. 50% plants detasseled. Field selection. Lab selection: White seeds separated as C_2 to continue. Other colours discarded.	Random mating from white seed (PM 7). Good maize growers invited for plant selection. FAMPAR trials.	Upgrading continued. FAMPAR trials. Co-ordinated multilocation trials. Seed increase in farmers' fields.

3. Evaluation of germplasm response to shade and biotic stresses

3.1 Variation in physiological responses to shade in several local varieties was measured in controlled environments using walk in Fisons growth cabinets in Bangor in 1999. Photosynthetic light response was measured using a portable Infra Red Gas Analyser (IRGA) and combined with growth analysis.

3.2 Physiological responses of local and introduced germplasm to shade and biotic stresses were evaluated in two field experiments at ARSP in 2000, one with artificial shade and the other with natural shade. The artificial shade experiment (Figure 3.3) allowed precise determination of above and below ground physiological response to a uniform reduction in PAR and was associated with an MSc project (Paul Wagstaff) that facilitated measurement of root length in addition to micrometeorological measurements as described in 1.2 above, combined with periodic measurements of assimilation using a portable IRGA. The natural shade involved use of crop terraces with and without fodder trees at ARSP to create shaded and non-shaded conditions typical of those quantified in the characterisation phase (see 1.2 above).

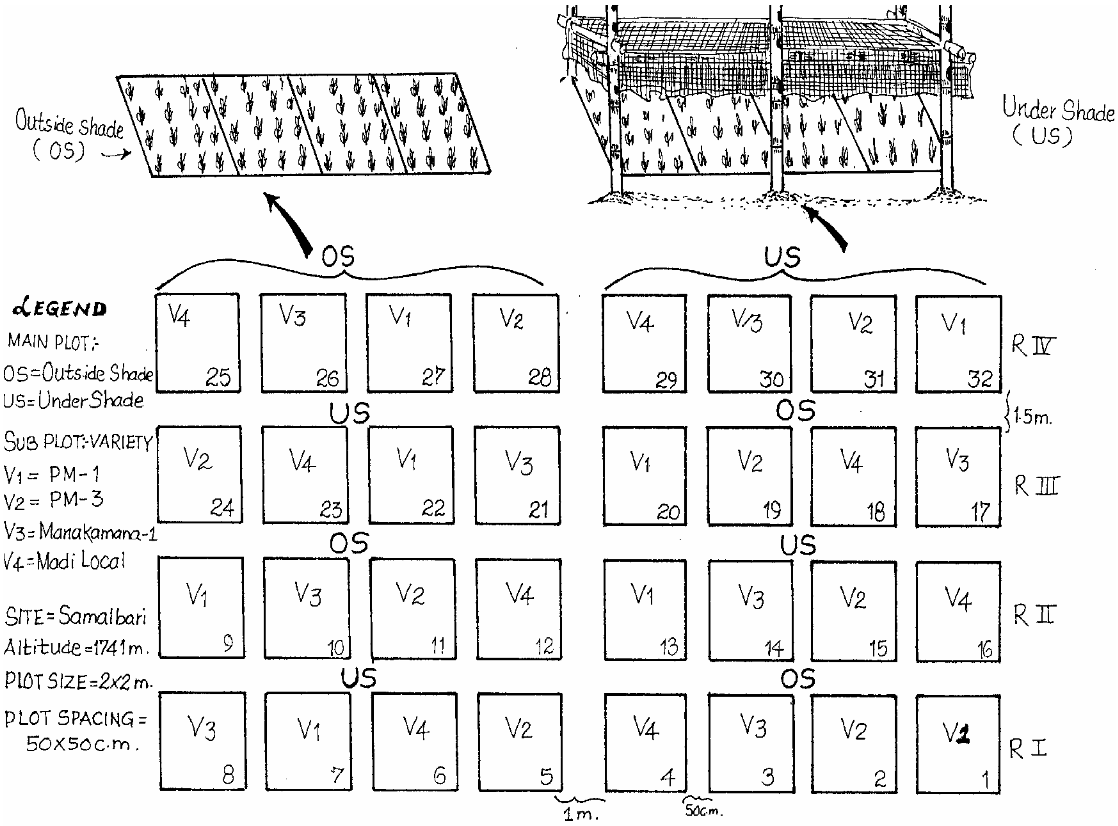

Figure 3.3 Field plan of split plot artificial shade experiment, with shading as main effect and variety as the sub plot effect. Shade was provided by green loose woven polypropylene netting draped over bamboo frames (Annex 4).

4. Design of participatory breeding programme

4.1 The participatory varietal selection and experimental trials of local and introduced germplasm were analysed and interpreted in the light of the agronomic characterisation and local knowledge with regard to the design of a continued, system compatible breeding programme (Annex 5). Considerations included revision of agronomic recommendations as well as identification, multiplication and dissemination of better varieties.

4.2 The results referred to in 4.1 above were incorporated in an implementable strategy for participatory crop improvement for the mid hills more generally (Annex 5) and are now the subject of wider application in a follow on phase aimed at scaling up to a national level.

4.3 A national workshop was held in Dhulikhel near Kathmandu on September 10th, 2001 at which the results of the project were presented and discussed (Table 3.4).

Table 3.4 Evaluation workshop programme.

Time	Activity	Presenter	Institutions
10:00-10:30	Registration		
10:30–10:40	Welcome to Participants	Dr K. D. Joshi	CIMMYT
10:40-10:55	Introduction	Dr F L Sinclair	SAFS, UWB
10.55–11:15	Role of DFID-PSP research in Nepal	Dr Dave Harris	CAZS, UWB
11:15- 11:45	Characterisation of bari land maize/millet systems	TP Tiwari	HARP / ARSP
11:45-12:45	Discussion on characterisation of farmer environments	Plenary	All participants
12.45-14.00	Lunch		
14:00-14:30	LI-BIRD experience in Participatory approaches	D. Poudel	LIBIRD
14:30-14.40	Discussion	Plenary	
14:40-15:20	Findings of participatory research (PPB and PVS) and data analysis procedures.	TP Tiwari/ Dr DS Virk	HARP / ARSP CAZS,UW
15:20-15:40	Discussion	Plenary	
15.40-16.00	Tea break		
16:00-17:00	How should participatory approaches to crop improvement of hill maize be taken forward in Nepal? • linkages • integration of conventional and participatory methods • modification of the variety testing and release system • community seed supply system • what are the next steps? (what should be done by whom and with what resources?).	Breakout group discussions	All participants
17:00-17:45	Summary of group discussions	Plenary	All
17:45-18:00	Chairman's closing remarks	Director, Crops and Horticulture	NARC

The workshop was attended by 31 key people from the governmental and NGO sectors concerned with hill maize research and extension in Nepal and India (Table 3.5).

Table 3.5 Evaluation workshop participants.

Name	Institution	Designation
David Harris	DFID, Plant Sciences Research Programme	Manager
DS Pathik	Nepal Agricultural Research Council (NARC)	Director, Crops and Horticulture
TP Pokhrel	National Wheat Research Programme	Wheat Coordinator
PL Karna	Agricultural Research Station (ARS), Pakhribas	Station Chief
KB Koirala	ARS, Dailekh	Maize Breeder
BP Tripathi	ARS, Lumle	Senior Soil Scientist
DP Sherchan	Local Initiatives for Biodiversity Research and Development (LIBIRD)	Senior Soil Scientist
D Poudel	LIBIRD	Plant Breeder
S Gyanwali	LIBIRD	Plant Breeder
SP Chand	DFID Seed Sector Support Project, , Nepal	Area Coordinator
RB Katuwal	ARS, Pakhribas	Outreach Agronomist
Pratap Shrestha	LIBIRD	Socio-economist
TP Tiwari	HARP / ARS, Pakhribas	Research Fellow
Yadvinder Singh	Punjab Agricultural University, India	Professor
Resham Gautam	LIBIRD	Plant Breeder
Sharmila Sunuwar	LIBIRD	Plant Breeder
K Adhikari	National Maize Research Programme, Rampur (NARC)	Maize Coordinator
Amit Pryadarshi	ABD, Khumaltar	Maize Officer
KD Joshi	CIMMYT	Programme Coordinator
NP Rajbhandari	CIMMYT	
Joel Ransom	CIMMYT	Head of Hill Maize Research Programme
Sudarshan Mathema	DFID, Hill Agricultural Research Project, Nepal	Manager
Shiva S Shrestha	Department of Agriculture (DoA)	Director, Extension and Planning
GP Pandey	DoA	Director, Crops
MN Shrestha	DoA	Seed Specialist
Bhola M Basnet	NARC	Chief, Publications
PB Baruwal	ARS, Pakhribas	Technician
BB Tamang	LIBIRD	Technician
FL Sinclair	SAFS, University of Wales, Bangor (UWB)	Senior Lecturer
DS Virk	CAZS, UWB	Senior Research Fellow
PP Khatiwada	ARS, Pakhribas	Senior Scientist

The results were also presented by invitation at an international symposium on hill maize research organised by the CIMMYT/NARC Hill Maize Research Programme held in Kathmandu in December 2001. This comprised two presentations, one on charaterisation and physiological responses (presented by FL Sinclair) and one on participatory varietal selection and breeding (presented by TP Tiwari).

4. OUTPUTS

1. System compatibility for maize genotypes quantified and described.

The local knowledge base generated during the project (Annex 2), revealed sophisticated understanding of maize cultivation practices by farmers and was verified with respect to contrasting physiology amongst varieties through scientific experimentation (Annex 4) and in relation to its representativeness of what is known by the farming community in the eastern mid-hills of Nepal through continued survey in the course of the PVS trials (Annex 5).

Farmers recognised a number of different local maize varieties (Figure 4.1) for which they had detailed descriptions of in terms of traits that conferred advantages according to the niche within the farming system that each variety was used for.

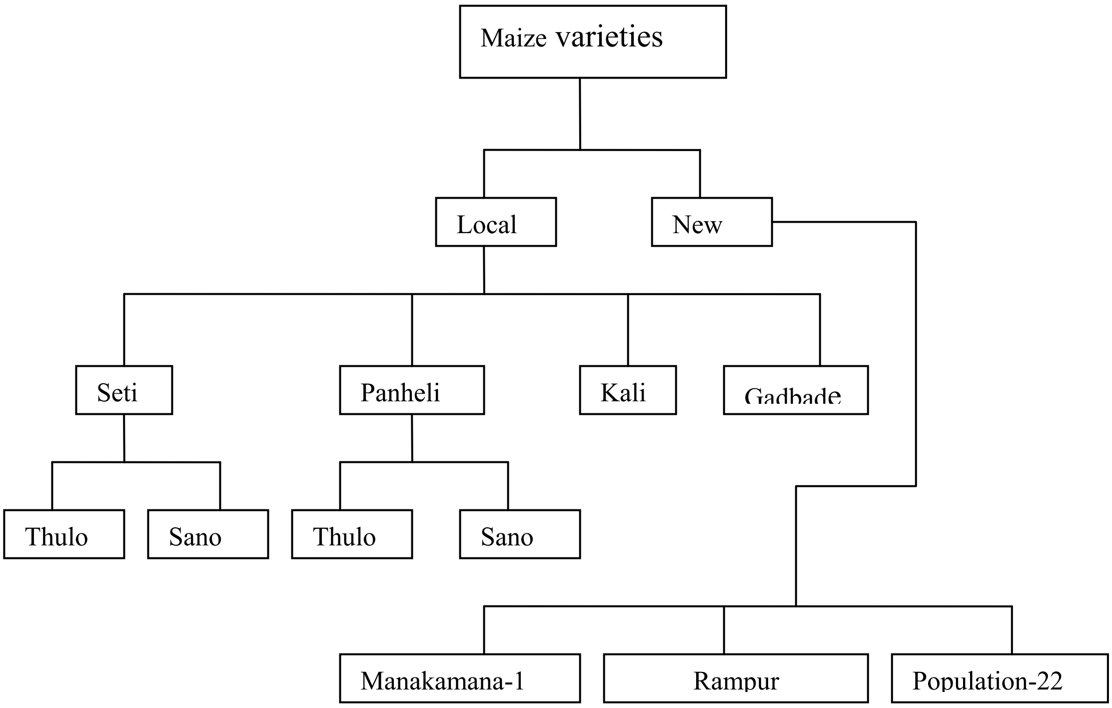

Figure 4.1. Names of common maize varieties grown by farmers at Marga, Patle and Fakchamara and their hierarchical relation to one another. Thulo means 'large', 'sano' means small, 'seti' means white, 'gadbade' means mixed coloured, 'panheli' means yellow and 'kali' means black.

Farmers also understood a number of ecological processes in some mechanistic detail and the impacts of their actions upon them, including detailed understanding of tree-crop interactions and appreciation of the development of weevil infestation in stored grain (Figure 4.2).

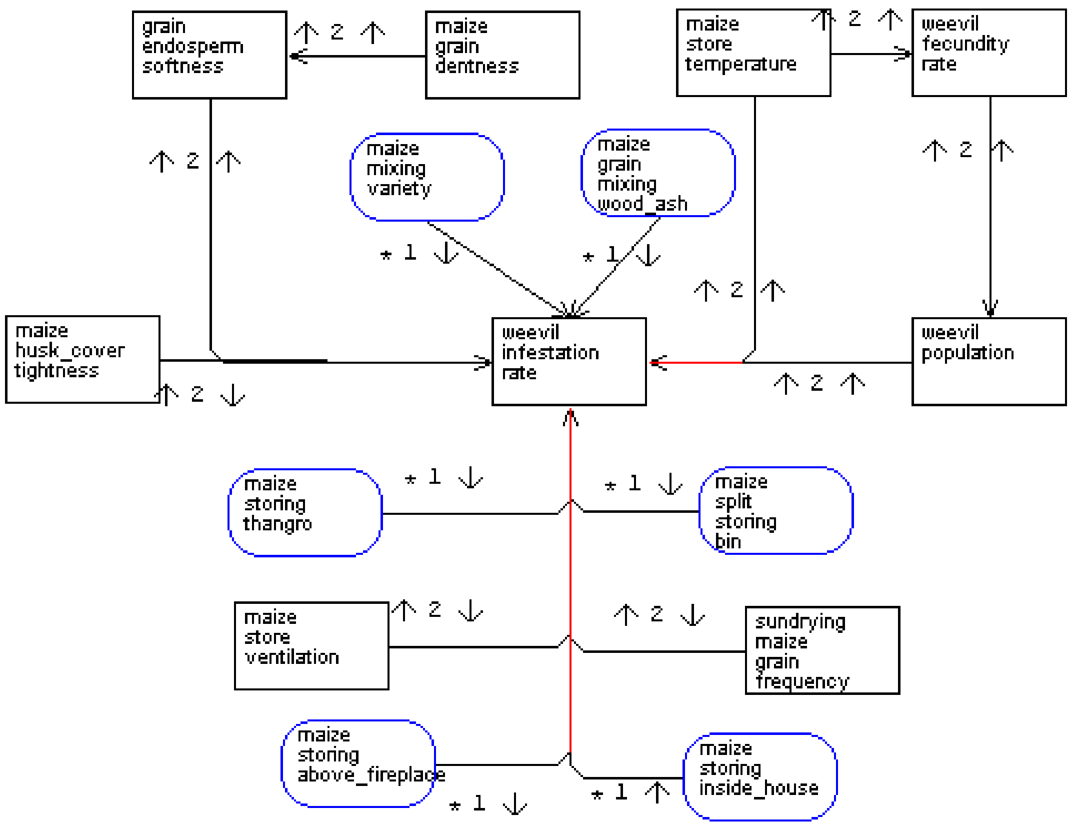

Figure 4.2. A systematic representation of farmers' causal knowledge of how different factors affect weevil infestation rate. Nodes with right angled corners represent attributes of components of the agroecosystem, those with rounded corners represent actions taken by people. The links between the nodes represent causal flow from one node to the other. The small arrows signify the direction of change of values of the causal attribute and the affected attribute (↑ for increase, ↓ for decrease). The numeral '2' signifies symmetry of causation (an ↑ in a causing a ↓ in b is equivalent to a ↓ in a causing an ↑ in b) and the numeral 1 that causation is not so reversible, a * symbol occurs where the node itself has a direct effect rather than the effect being caused by the node increasing or decreasing.

Revelations about local practice and its rationality has led to revision of agronomic recommendations (such as the use of higher seed rates) as well as informing the plant breeding strategy. The knowledge base remains an enduring resource for agricultural improvement in the hills.

Characterisation of the climatic and agronomic context in which farmers grow hill maize (Annex 3) revealed a complex and heterogeneous environment, dominated by variation in farmer practice and low light levels (Figure 4.3). Note the difference between light at 30 days and other measurements later in the year in Figure 4, showing the impact of cloud that creates low and largely diffuse light conditions for most of the growing season.

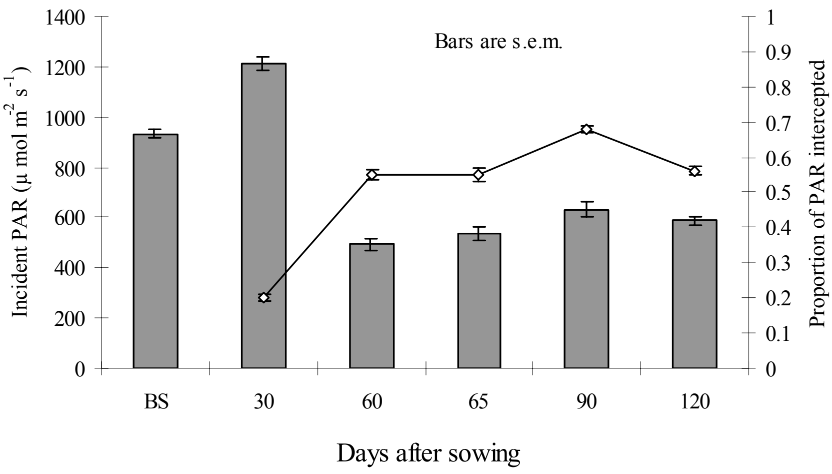

Figure 4.3 Incident PAR to open grown maize (bars) and the fraction of this intercepted by the crop (points).

During most of the growing season incident light levels were low (400-600 u mol m^2 s^{-1}), and so well below the light saturation point for maize (Figure 4.4) which would mean that even small reductions in incident light through tree shading could be expected to have a large impact on productivity.

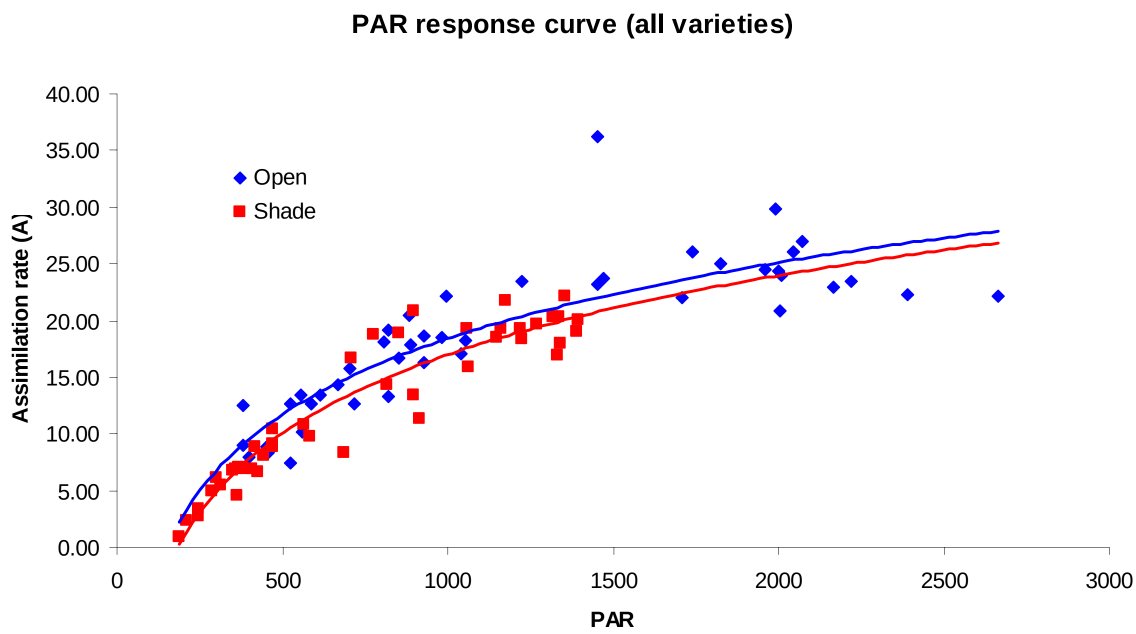

Figure 4.4 Light response curves for different Nepalese maize varieties grown in differences due either to variety or shade.

The actual presence of fodder trees on crop terrace risers reduced maize yield by from 14 to 47% in different villages with an overall mean reduction of 36% (Figure 4.5).

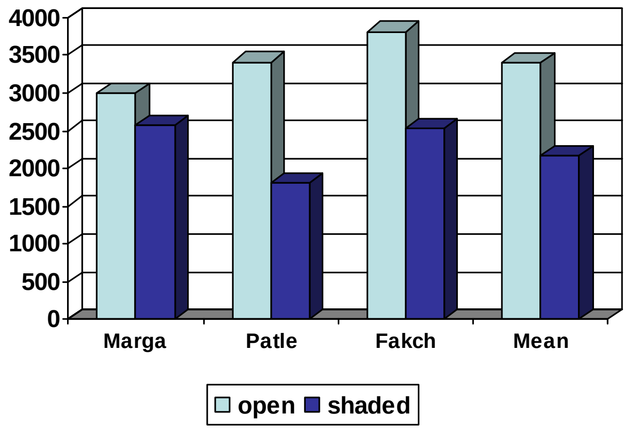

Figure 4.5 Maize productivity (kg ha^{-1}) for maize grown in the open and on terraces influenced by the presence of fodder trees.

Very high initial plant populations were progressively reduced to a low final density at harvest (Figure 4.6). Seed rate varied from 29 to 111 kg ha^{-1} across all farms and was, on average from 155-220% above the national recommendation of 20 kg ha^{-1} at the three sites but as a result of thinning during the season, final populations were from 28 to 45% below that recommended. There were significantly lower populations under shade, but only from 30 days after sowing because of more lodging and higher incidence of barren plants which farmers then removed during thinning.

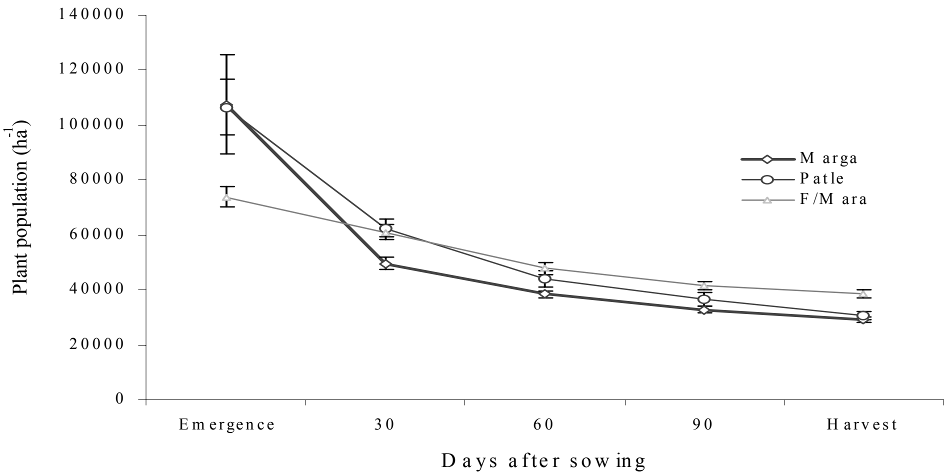

Figure 4.6 Mean plant populations (+/- standard error) for farmers maize crops from emergence to harvest in three locations in the eastern mid-hills.

Reasons for high seed rates that were heavily thinned revealed that the major reason was use of thinned maize as fodder. Mitigating risk from low germination, weather, pest and diseases, birds eating broadcast seed and lodging were also mentioned. There was generally a high level of agreement amongst farmers regarding the importance of these reasons, although more variability in farmers responses at Marga than at Patle, and some differences in rankings amongst sites; for example weather and lodging were ranked more important at Marga than Patle.

Eighteen local criteria for selecting maize varieties were articulated by farmers, including many traits that conferred system compatibility. These could be assigned to two broad groups of: essential attributes (e.g. large, white, flint grain type) that farmers would not compromise and desirable attributes (e.g. short to medium time to maturation) where their preference operated on a continuous scale (shorter duration was better but could be traded off against other attributes).

2. Appropriate local and introduced germplasm evaluated and adaptively selected for system compatibility.

Six new varieties were evaluated by farmers in Dhankuta and Terathum districts, against their local germplasm, in single variety paired comparison trials (Annex 5).

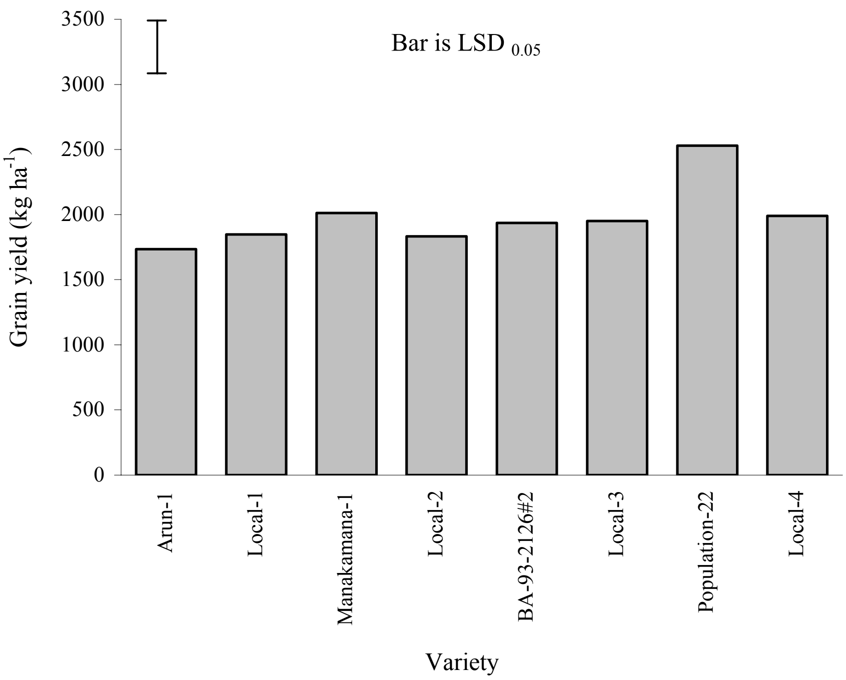

Figure 4.7. Farmers' observed mean grain yield of FAMPAR varieties compared with their respective local varieties in 1999.

Population 22, which comprises germplasm introduced from CIMMYT and then modified on-station to meet requirements articulated by farmers, produced 28%, 16% and 32% higher yields than the local varieties that farmers compared them with in 1999, 2000 and 2001 respectively while improving a range of other traits that farmers valued. Results of grain yield from farmer trials in 1999 are shown in Figure 4.7 by way of example, full details of yields are presented in Annex 5.

Farmers' overall evaluations of varieties tested in 2000 are shown in Table 4.1 these comprise a summary of detailed assessment of individual traits in a series of evaluations. Figure 4.8, by way of example, shows farmers evaluation of pre-harvest traits for the varieties tested in 2000. Full details of pre and post harvest evaluations are presented in Annex 5.

Table 4.1. Ranking of maize varieties at different sites scored by different groups of farmers in 2000.

Sites	Marga		Patle		Fakchamara		Score	
Var.\Group	♂	♀	♂	♀	Both	Both	Total	Rank
Pop-22	1	1	1	1	2	1	7	1
Mana-1	2	2	2	2	1	2	11	2
Arun-1	3	4	4	3	4	4	22	3
PM-3	4	3	6	4	3	3	23	4
Locals	3	5	3	4	5	3	23	4
PM-1	5	6	5	5	5	5	31	5

The initial network of participatory trials has led to farmers becoming more active in selecting preferred germplasm on the basis of pre and post harvest traits and in multiplying seed of the varieties that they prefer (so far the high yielding Population 22 and a lower yielding but early maturing variety Arun-1 have been adopted by farmers for different niches within their farming system).

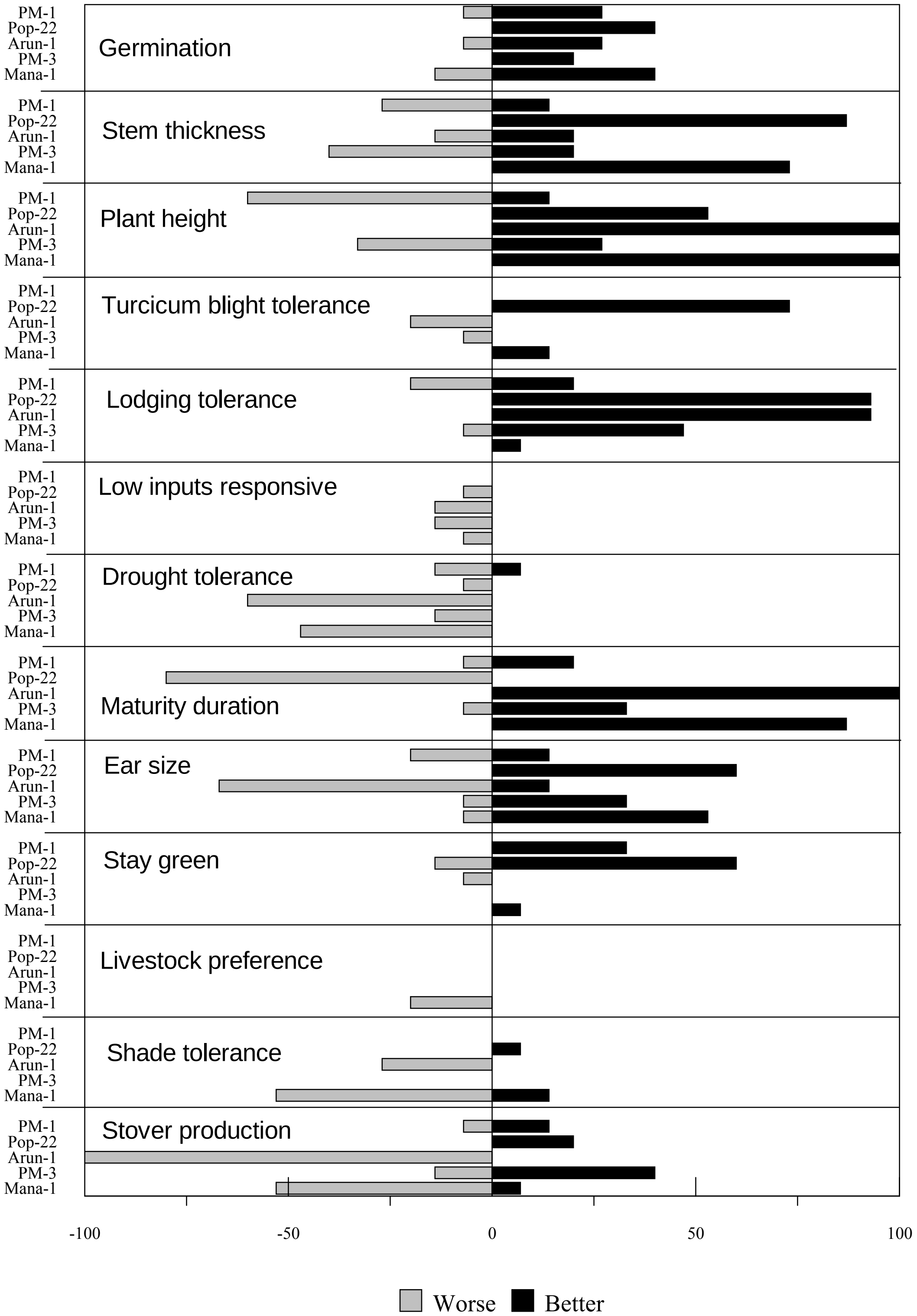

Figure 4.8 Farmers' evaluation of preharvest traits in relation to whether they are worse or better than the local variety being grown in 2000.

3. Physiological adaptation to locally operative stresses in local and introduced germplasm evaluated.

The adaptation of local and introduced maize to shade was assessed in a series of controlled environment and field experiments. Leaf photosynthetic responses did not vary significantly amongst varieties (see Figure 4.4 above) but productivity was proportionately reduced by shade (Figure 4.9), confirming results from agronomic characterisation in farmers' fields and providing parameters that allow reductions in productivity due to tree shade to be modelled.

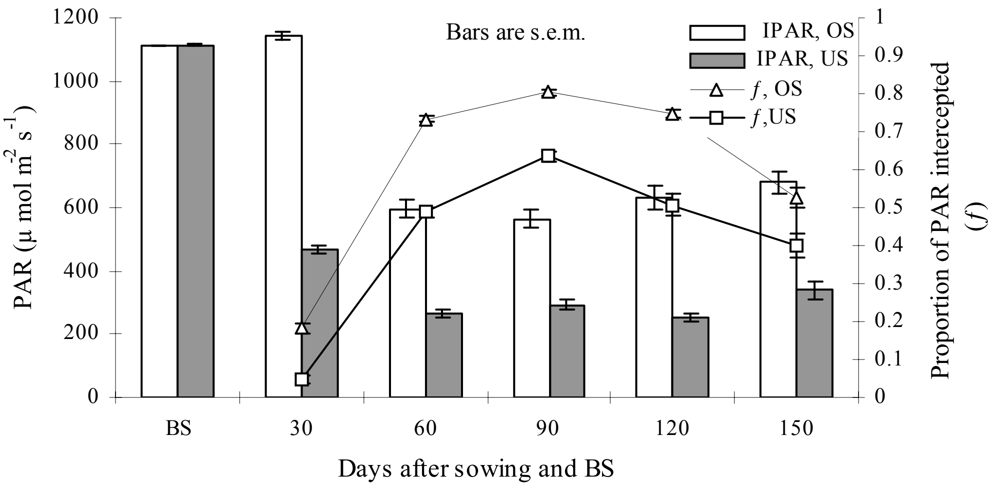

Figure 4.9 Light incident (bars) and intercepted (points) by maize in open (white bars, diamonds) and shaded (dark bars, squares) plots in an on-station experiment. Productivity was reduced proportionately to light intercepted.

While there were no differences in photosynthetic responses amongst varieties, the most widely released new variety Manakamana-1 had a lower root length and shallower root system under shade than local varieties (Figure 4.10). This confirms farmer's local knowledge that introduced varieties have smaller root systems than local varieties. This is an important constraint since deeper roots may confer tolerance to periodic water shortage and larger root systems may confer resistance to lodging, which is an essential local selection criterion for maize. Appropriate root development in shaded conditions is thus a key trait for new maize varieties grown in association with fodder trees.

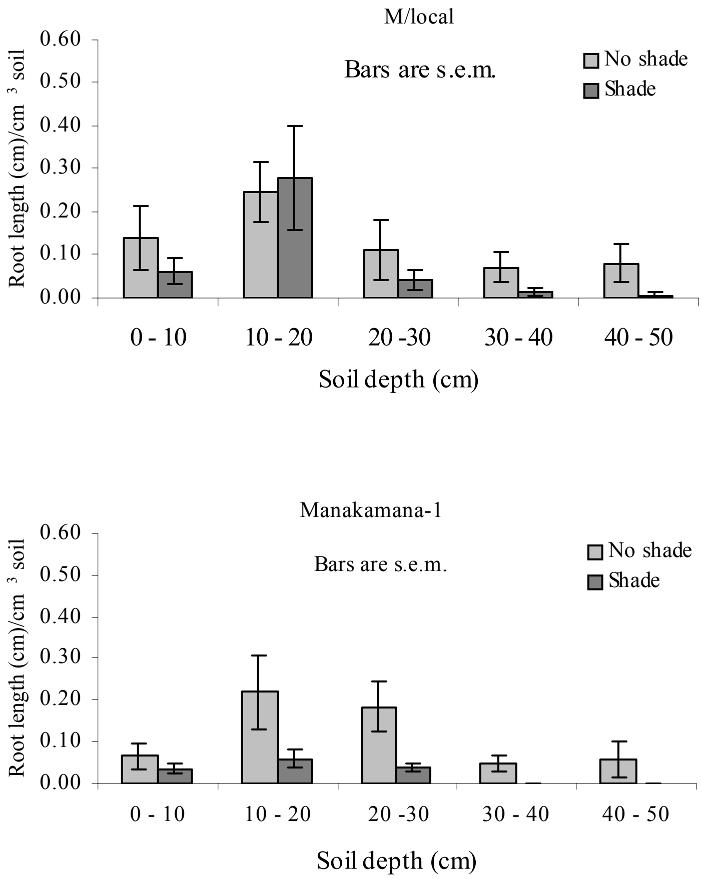

Figure 4.10. Mean relative root density (RLD) at 68 days after sowing at different soil depths.

4. Participatory crop breeding programme for mid-hills designed.

A participatory crop breeding programme has been designed for hill maize in Nepal and begun to be implemented (Annex 5). Four PPB composites have already been created by crossing local and introduced germplasm, two of which have been initially evaluated in on farm trials (see Table 3.3). High yielding germplasm from yellow grained varieties has been successfully incorporated in a new white grained composite PM-7, by crossing with the yellow variety and then selecting back for white grain colour, which is important because this is an essential farmer selection criterion for maize for home consumption in the eastern mid-hills. A follow up project to determine requirements for scaling up participatory crop improvement nationally in Nepal and seek resources to achieve this emerged from the evaluation workshop and is now in progress with a range of governmental and NGO collaborators.

5. Contribution of Outputs

The outputs of the project have exceeded expectations. In addition to designing a participatory plant breeding programme for hill maize, significant progress has been made in implementing it and immediate gains from participatory varietal selection with introduced germplasm, modified on-station to meet farmers articulated preferences, has produced consistent yield improvements of around 30% in addition to meeting other farmer criteria. Limitations to crop yield imposed by the low light environment and farmer practices are also now better understood and incorporated in extension recommendations and research planning.

While the project has demonstrated that substantial yield improvements and adoption of new varieties by farmers is possible through the use of participatory crop improvement for hill maize, the challenge remains to scale this up from success in a few villages in two districts to cover the potential extrapolation domain for the technology across the mid-hills of Nepal.

During the evaluation workshop it became clear that institutional change would be required to achieve this including:

- better integration of research and extension, and amongst the government and NGO sectors,
- decentralisation of the research and extension system with more pull from farmers within districts (through, for example farmer preferences driving PVS) rather than push from the centre, and
- liberalisation of the seed certification and supply system (so that farmers can choose what germplasm to grow where rather than being told which varieties to grow in what circumstances).

Furthermore, it was clear that different organisations in the chain from research on new varieties to supplying farmers with seed, such as research stations, the government extension system and NGOs, have different constraints and modes of operation that will require participatory crop improvement methods to be tailored to their circumstances.

A follow-on bridging project has been proposed (concept note in Annex 6) to address these institutional requirements and seek resources to scale up participatory crop improvement nationally in Nepal and disseminate the results regionally. This process has already begun with Dr Tiwari now associated with the CIMMYT / NARC Hill Maize Research Programme and collaborating with the Department of Agriculture and NGOs in five hill districts to implement participatory crop improvement for hill maize. This will be piloted in the bridging phase and then hopefully rolled out across hill districts if resources are obtained to do so during the bridging phase.

Varieties showing substantial yield improvements have already been identified for the eastern, central and western mid-hills appropriate for around 1.5 million households affecting the livelihoods of around 7.6 million people. One variety suitable for this regional coverage will be released during the bridging phase in 2002 and it is estimated to have reached 800 households (affecting around 4 000 people) by 2003 through seed multiplication by collaborating organisations (see Annex 6). Similar gains could subsequently be extended to the mid and far western hills where the agroecological conditions are different by action of the target institutions (who are collaborators in the bridging phase project) implementing the anticipated national scaling up of PVS (for which resources will be sought as part of the bridging phase). The ultimate beneficiaries of the research, if it leads to the anticipated national scaling up, could be up to 10 million people in rural households in the midhills of Nepal. This would require the follow-on national scaling up (2003-2008) to be implemented and be successful in making new varieties available to farmers. Substantial and immediate yield increases of the staple food crop in food deficit households (in the order of 30%) could be expected through PVS with subsequent increases as new varieties are released from PPB that could be expected to keep maize production ahead of rising demand.

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REFERENCES

Ashby, J. 1998. Preselected projects for system wide programme on participatory methods. CIAT, Cali, Colombia.

Carter, J. and D. Gilmour (1989). *Tree crop increase on private farm land in central Nepal*. Mountain Research and Development 9 (4):381-391.

CBS 1995. Agricultural Statistics of Nepal 1994/95. National Planning commission Secretariat, Thapathali, Kathmandu, Nepal.

Chemjong, P.B. et al., 1995. The impact of PAC research in the eastern hills of Nepal: farmer adoption of nine agricultural technologies, Dhankuta, Nepal.

Fretwell, T. 1998. Farmer knowledge about maize cultivation in the eastern mid-hills of Nepal. MSc thesis, School of Agricultural and Forest Sciences, University of Wales, Bangor.

Joshi, L. and Devkota, N. 1996. *Effect of* Ficus auriculata *on maize and millet crops at mid altitude* bari. PAC, Working Paper 153. Pakhribas Agricultural Centre, Dhankuta, Nepal.

Joshi, L. and Sinclair, F.L. 1998a. *The use of automated reasoning in planning research and extension.* School of Agricultural and Forest Sciences, University of Wales, Bangor, 51 pp.

Joshi, L. and Sinclair, F.L. 1998b. *Impact of using a knowledge based systems approach*. School of Agricultural and Forest Sciences, University of Wales, Bangor, 44 pp.

Joshi, L. and Sinclair, F.L. 1997. Knowledge acquisition from multiple communities. School of Agricultural and Forest Sciences, University of Wales, Bangor, 34 pp.

Joshi, L. and Witcombe, J.R. 1996. Farmer participatory crop improvement. II. Farmer participatory varietal selection in India. *Experimental Agriculture* **32**:461-477.

Joshi, A. and Witcombe, J.R. 1998. Farmer participatory approaches for varietal improvement. *In:* J.R. Witcombe, D.S. Virk and J. Farrington (eds). *Seeds of Choice-Making the most of new varieties for small farmers*. Oxford & IBH Publ. Co. New Delhi. Pp 171-189.

Kadayat, K.B. 1996. Outreach research report on maize, 1994/95: Nitrogen top-dressing in spring maize and participatory variety selection on maize. Working paper Lumle Regional Agricultural Research Centre, 1997, No. 97-9, pp 27.

Kamara, A., Defoer, T., Groote, H. de and De Groote, H. 1996. Selection of new varieties through participatory research, the case of corn in South Mali. *Tropicultura* 14(3): 100-1005.

Kendon, G., Walker, D.H., Robertson, D., Haggith, M., Sinclair, F.L. and Muetzelfeldt, R.I. (1995) Supporting customised reasoning in the agroforestry domain. *New Review of Applied Expert Systems* **1**: 179-192.

MoA, 1995. *Nepal Agriculture Perspective Plant (Final Report) Main Document.* Agricultural Project Service Centre, Kethmandu and Jon Mellor Associates, Inc. Washington, D.C. June 1995.

Palikhe, M. 1996. *National Maize Research Programme: Maize Co-ordinator's Report for 1995.* Paper presented at the 19th Summer Crops Workshop held at RARS, Parwanipur from February 27-29 1996.

Paudyal, K.R., Ransom, J.K., Rajbhandari, N.P., Adhikari, K., Gerpacio, R.V. and Pingali, P.L. (2001) *Maize in Nepal: Production Systems, Constraints and Priorities for Research*. NARC and CIMMYT, Kathmandu.

Randell, D.A. and Sinclair, F.L., 1997. *WinAKT Version 1.00 software description and user notes*. School of Agricultural and Forest Sciences, University of Wales, Bangor, 25 pp.

Sinclair, F.L. 1999. A general classification of agroforestry practice. *Agroforestry Systems* **46**: 161-180.

Sinclair, F.L. and Walker D.H. 1998. Qualitative knowledge about complex agroecosystems. Part 1: a natural language approach to representation. *Agricultural Systems* **56**: 341-363.

Sthapit, B.R., Joshi, K.D. and Witcombe, J.R. 1996. Farmer participatory crop improvement. III. Participatory plant breeding, a case study for rice in Nepal. *Expl. Agric*. 32:479-496.

Thapa, B. 1994. Farmers' ecological knowledge about the management and use of farmland tree fodder resources in the mid-hills of eastern Nepal. PhD thesis, School of Agricultural and Forest Sciences, University of Wales, Bangor, 271 pp.

Thapa, B., Walker, D.H. and Sinclair, F.L. 1997. Indigenous knowledge of the feeding value of tree fodder. *Animal Feed Science and Technology* **67**: 97-114.

Thapa, B., Sinclair, F.L., and Walker, D.H. 1995. Incorporation of indigenous knowledge and perspectives in agroforestry development. Part Two: Case-study on the impact of explicit representation of farmers' knowledge. *Agroforestry Systems* **30**: 249 - 261

Virk, D.S. 1998. Visit report, 5-15 July 1998. KRIBHCO Indo-British Rainfed Farming Project (East). *Unpublished.*

Virk, D.S., Bhasker Raj, A.G. and Witcombe, J.R. 1996. The need of farmer participation in crop improvement in India. *Crop Improvement 23 (special)*: 178-193.

Walker, D.H., Sinclair, F.L., Joshi, L. and Ambrose, B. 1997. Prospects for the use of corporate knowledge bases in the generation, management and communication of knowledge at a frontline agricultural research centre. *Agricultural Systems* **54**: 291-312.

Walker, D.H. and Sinclair, F.L. 1998. Qualitative knowledge about complex agroecosystems. Part 2: formal representation. *Agricultural Systems* **56**: 365-386.

Witcombe, J.R., Joshi, A., Joshi, K.D. and Sthapit, B.R. 1996. Farmer participatory crop improvement. I. Varietal selection and breeding methods and their impact on biodiversity. *Expl. Agric*. 32:445-460.