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Integrated Crop Management Strategy for Improved Chickpea Production and its Impact on the Livelihood of Farmers in Nepal

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Abstract

*Chickpea (*Cicer arietinum *L.) is traditionally an integral component of the rainfed rice-based cropping system of the Terai region of Nepal. However, in the last 20 years frequent crop failures due to out breaks of wilt (*Fusarium oxysporum *f.sp.* ciceris*), botrytis gray mold (*Botrytis cinerea*) and pod borer (*Helicoverpa armigera*) have made its cultivation unreliable and uneconomical. Surveys have shown that there is a substantial area of rainfed rice-fallow that could grow chickpea and generate additional income if farmers had access to a reliable production system for chickpea. To meet this need an integrated crop management (ICM) technology package was developed for Nepal. This comprised an improved cultivar Avarodhi (ICC 14344), rhizobial and fungicidal treatment of seeds prior to sowing; fertilizer application and need-based foliar applications of fungicides and insecticides to control BGM and pod borer, respectively. This technology package was evaluated and up-scaled through farmers' participatory on-farm research. Over 3000 farmers in 17 villages from 10 districts in the Terai (lowlands) of Nepal participated in conducting ICM validation trials. Severities of wilt, BGM and pod borer were significantly reduced and grain yields more than doubled in ICM plots compared with non-ICM plots in all the five years of study generating a substantial increase in income.*

Keywords: Botrytis gray mold, chickpea, Fusarium wilt, integrated crop management, pod borer, Nepal

Introduction

Chickpea (*Cicer arietinum* L.) is a high value food legume in Nepal and a major component of the largely vegetarian Nepalese diet, providing a versatile source of protein for the rural and urban poor. Though grain legumes are the essential components of the Nepalese diet, their consumption is only 9 kg per capita per annum, which is only 25% of the FAO recommendation. Area under chickpea cultivation has declined from 54,000 ha in 1981/82 to only 9560 ha in 2004 and productivity at 840 kg ha^{-1} remains low (MOAC, 2004). However, almost 370,000ha of rice fallow suitable for chickpea production has been recorded in Nepal (Subba Rao *et al.*, 2001). The reduction in area and the productivity is due to the yearly impact of several biotic and abiotic factors with diseases and insect pests the major constraint to yields (Pandey *et al.*, 2000). Fusarium wilt [FW, *Fusarium oxysporum* Schlecht. emend. Snyd. & Hans. f.sp. *ciceris* (Padwick) Matuo & Sato] and botrytis gray mold (BGM, *Botrytis cinerea* Pers. ex Fr.) are the main diseases and the pod borer [*Helicoverpa armigera* (Hubner)] is economically the most damaging insect pest (Karki *et al.*, 1993; Manandhar and Shakya, 1996) to chickpea. Wilt can kill the plants at all the growth stages and can cause severe losses in grain yield. BGM is the most important microbial constraint to chickpea production in Nepal and the wetter regions of India and Bangladesh (Pande *et al.*, 2005). The disease causes flower drop and damage to growing tips which can devastate the crop if weather conditions (cool and humid) are favorable to disease spread (Davidson *et al.*, 2004). The BGM epidemic in 1997/98 completely destroyed the chickpea crop in Nepal (Pandey *et al.*, 2000). Pod borer damages pods and foliage, buds and flowers to reduce yield up to 90% (Reed *et al.*, 1986).

Rice is the most important cereal in Nepal and is grown as rain-fed crop in the lowlands (Terai) during the monsoon. Up to late 1960s, grain legumes (especially chickpea) were grown profitably on residual soil moisture after rice harvest during the post-rainy season. After the introduction of input responsive wheat and rice cultivars, grain legumes such as chickpea were relegated to the less fertile rainfed marginal lands. Additionally frequent out break of diseases and insect pests devastated the crop and as a result, farmers became reluctant to grow legumes and large areas were left unsown after the rice harvest. Furthermore, due to continuous rice-wheat rotation, without a legume crop in the interval, soil fertility is under threat due to nitrogen exhaustion (Timsina and Connor, 2001).

Growing disease and insect resistant cultivars would be the best way to manage these biotic constraints. Though high levels of wilt resistance exist in chickpea, these varieties are highly susceptible to the two other major biotic constraints, BGM and pod borer. Adequate levels of resistance to BGM are not available in chickpea germplasm despite several breeding programs that have developed moderate levels (Pande *et al.*, 2002). Therefore, effective management of BGM needs to focus on judicious and effective application of the available chemical and agronomic practices in addition to host plant resistance (HPR). Several seed dressing and foliar fungicides have been found effective against BGM (Davidson *et al.*, 2004). Judicious use of chemical insecticides remain a generally effective tool for control of pod borer in India and Nepal (Singh *et al.*, 2000) though resistance to specific chemicals is a serious problem especially in or adjacent to cotton growing areas with a history of heavy insecticide use (Kranthi *et al.*, 2001, Ujagir, 2005). Switching to alternative resistance management approaches such as biopesticides may be required in these areas (Grzywacz *et al.*, 2005). Most critically, however, the adoption of integrated crop management (ICM) practices is limited by a lack of knowledge, experience and resources among the poorest farmers (Pande *et al.*, 1998). Nodulation was also found to be poor in traditional varieties limiting their capacity to fix atmospheric nitrogen (Pandey *et al.*, 2000).

To overcome these constraints and revive the cultivation of this highly valuable fallow crop, an economically viable and easily adaptable ICM technology was developed thus enabling poor farmers to obtain higher legume yields and greater net economic returns. This paper reports the farmer participatory evaluation of the ICM technology in Nepal from 1998/99 to 2002/03 post-rainy seasons and discusses the impact of the strategy on their livelihoods. Specific objectives of this study were (i) to understand farmers' perceptions about chickpea production constraints and their management (ii) to develop, evaluate and validate an ICM technology through a participatory approach, (iii) to promote and upscale ICM technology by involving large number of farmers in widespread areas and (iv) to evaluate the potential and economic impact of the technology on chickpea production and on farmers in Nepal.

Materials and methods

Identification of biotic constraints for chickpea production. Participatory rural appraisals (PRAs) were conducted to identify the production constraints of chickpea that prevailed in Nepal as perceived by farmers. During the formal survey, a multi-stage stratified random sampling technique was employed to select chickpea producers for identifying chickpea production constraints. Appraisals were carried out with 500 chickpea producers selected from 16 districts across the Terai on probability proportionate criteria across all the districts. The districts chosen were selected on the basis of the extent of chickpea production with villages being selected randomly from these districts and then individual farmers selected randomly from each selected village. Farmers were asked questions on general information about chickpea production, land use pattern, enterprise choice, economics of chickpea and other competitive crops, benefits and constraints of chickpea production and about their livelihoods.

Development of ICM technology. Lines for wilt resistance and BGM tolerance, Avarodhi (ICC 14344), a desi type were identified for inclusion in on-station ICM trials. Several fungicides were evaluated for seed treatment (Bavistin + Thiram or Bavistin) and foliar sprays (Bavistin and Dithane M 45) to mange BGM. Foliar application of the insecticide Endosulfan during flower and pod formation was used to control *H. armigera*. Farmers were advised to spray only when the insect threshold had been exceeded and indicated by the occurrence of at least one pod borer larva m^{-1} of crop in the field. Frequent surveying for pests was encouraged to ensure that outbreaks of pod borer could be detected when larvae were still young and susceptible to the chemical spray. Due to the limited availability the Nucleopolyhedrovirus (NPV) of *H. armigera,* it was not included in the ICM package. Boron deficiency, poor nodulation, and low fertility was overcome by the application of boric acid or borax, *Rhizobium* and DAP, respectively. Finally, wide line spacing with controlled DAP inputs was followed to reduce the development of dense canopies that encourage BGM.

All the above mentioned single factor management components were integrated into a multifactor ICM technology package. Therefore, the specific components of ICM technology were, the BGM tolerant and high-yielding cultivar ICC 14344 (Avarodhi), wider row spacing (60 X 10 cm), seed treatment with Benlate + Thiram (1:1) @ 2.5 g kg^{-1} seed, need based foliar application of Bavistin (2 g L^{-1}

water) to control BGM, need based applications of endosulfan to manage pod borer, application of *Rhizobium* inoculum @ 210 g ha^{-1} to improve nodulation and soil application of di-ammonium phosphate @ 100 kg ha^{-1} to overcome poor soil fertility. The non-ICM technology was normal farmer practice and comprised of local seed and none of the inputs of ICM.

On-farm validation of ICM technology. Following the successful development and validation of the ICM technology package in several on-station trials the ICM was evaluated through farmers' participatory on-farm research in Nepal and compared with non-ICM technology (farmers' practice). The farmers' participatory on-farm research was conducted in collaboration with the Nepal Agricultural Research Council (NARC) to help embed the technologies into the national system for agricultural extension. Regional Agricultural Research Stations (RARS) located in Khajura (Banke) in western Nepal and Tarahara (Sunsari) in eastern Nepal, National Grain Legumes Research Program (NGLRP), Rampur (Chitwan) in central Nepal, National Oil Seeds Research Program (NORP), Nawalpur (Sarlahi), in central Nepal facilitated on-farm studies.

Selection of villages and farmers. Seventeen villages from 10 districts (Banke, Bardia, Nawalparasi, Chitwan, Sarlahi, Mohattari, Saptari, Sirha, Sunsari and Morang) were selected based on the total cropped area under chickpea cultivation in rice fallows in the Terai region for on-farm trials between 1998/99 to 2002/03. These selected villages were representative of the districts in topography but accessible enough to allow monitoring of the trials (Table 1).

Field schools and farmers' training. Field schools for ICM training were conducted four times a year in each village to explain the value and application of each ICM component to farmers before planting and the others at 30 to 40, 60 to 70 and 90 to 100 days after sowing during the crop season. In the first school before planting, farmers were asked to share their experiences and perceptions about the chickpea production constraints and discussed how ICM components would address each of the production constraints raised during the discussions. In the subsequent classes the symptoms of wilt, BGM and different instars of pod borer larvae were explained in reference to relative pesticide susceptibility and age. They were also told about favourable weather conditions for the development of these pests and the most effective management options and the crop stages at which these could be best used. These classes formed the basis for identification of emergence of any additional location-specific constraint and also assessment of farmers' perceptions of ICM. Most critically it was the farmers who, in each case, applied the technologies themselves. Brochures with colour photographs of the important biotic and abiotic constraints and their control measures were produced in Nepalese and distributed to all farmers associated with the participatory trials and elsewhere among farmers in Nepal.

Table 1. Number of ICM and non-ICM trials in different villages in Nepal from 1998/99 to 2002/03

Year	Number of trials	Number of villages	Districts
1998	110	5	Bardia, Banke, Nawalparasi, Sirha
1999	503	7	Bardia, Banke, Nawalparasi, Sirha, Sarlai, Moattari
2000	875	9	Bardia, Banke, Nawalparasi, Sirha, Sarlai, Saptari, Moattari, Sunsari
2001	504*	13	Bardia, Banke, Nawalparasi, Sirha, Sarlai, Moattari, Sunsari, Saptari
2002	1111*	11	Bardia, Banke, Sirha, Sarlai, Moattari, Sunsari, Morang, Saptari, Chitwan

*Implementation of trials affected by civil war

Experimental design, data collection and analysis. The trial was planted in a strip plot design with each individual field plot (approximately 3 x 10 m) representing one replication. Each crop was sown according to the usual tillage practice after rice. Sowings were done only in the presence of a NARC and/or project scientist. Data on the severity of wilt, BGM, percentage of pod damage by pod borer and grain yield were recorded in three 1 x 1 m pre-demarcated quadrants in all the plots in each year. Wilt and BGM were recorded on 1-9 rating scale (where 1= no disease and 9 = >80% defoliation of leaves, flower and pod infection and complete drying of stem) using standard methodology (Nene *et al.*, 1981). Percentage of pod damage was recorded by evaluating the proportion of damaged pods on a sample of randomly selected plants in each plot (Shahzad and Shah, 2003). Data were analyzed using restricted maximum likelihood (REML) analysis (Patterson and Thompson, 1971) assuming cultivar and treatment effects as fixed. Costs and benefits were calculated using the mean cost of inputs and mean grain yield across all the trials in each district in each year. Mean cost of inputs and mean market price of chickpea grain across the five years were taken for cost-benefit analysis.

Results and discussion

This paper describes an ICM technology package that can lead to substantial improvements in the chickpea production on winter rice fallows in Nepal. The work demonstrates that while individual targeting of technologies can have significant impacts on chickpea yields in rice fallows in South Asia (Musa *et al.*, 2001), to ensure a sustainable and substantial improvement in yields farmers require an integrated suite of technologies that address all the major constraints. Our results show that the frequent and often severe incidence of diseases and insect pests that have devastated the chickpea crop in Nepal and have led to the precipitate decline recorded in chickpea fallow cropping can be controlled and managed through adoption of an effective ICM strategy. The results we have presented indicate that even when relying on pesticides and fungicides, if managed correctly, input levels can be maintained at low levels that are affordable and as environmentally benign as possible while making substantial improvements to productivity and securing a crop where previously farmers ran the very real risk of complete crop loss.

Biotic constraints

The mean incidence of wilt across locations and years was significantly ($P < 0.005$) lower in ICM plots than in non-ICM plots (Figure 1). Wilt incidence in ICM plots varied from a yearly mean of 1.8 in 1998-99 to 2.1 in 2002-03 as compared to 4.6 in 1998-99 to 5.3 in 2002-03 in non-ICM plots (1-9 rating scale). Similarly, mean BGM severity was also significantly ($P < 0.005$) lower in ICM treatments than local cultivar of non-ICM treatment in all the years and the severity was lower in both ICM and non-ICM treatments in all the locations during first three years (1998/99 to 2000/01) than last two years (2001/02 and 2002/03). Incidence of BGM was greater in non-ICM plots in 2001-02 and 2002-03 due to the cool and humid weather conducive for disease development (Figure 2).

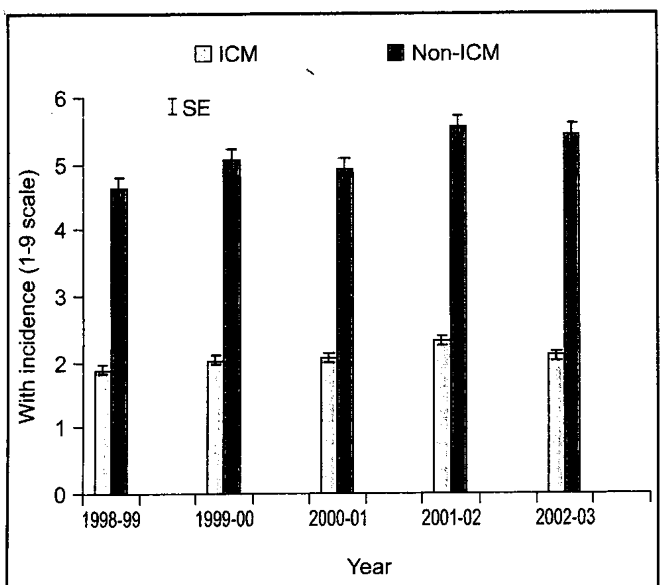

Figure 1. Incidence of wilt in chickpea farmer participatory ICM and non-ICM trials in Nepal from 1998/99 to 2002/03

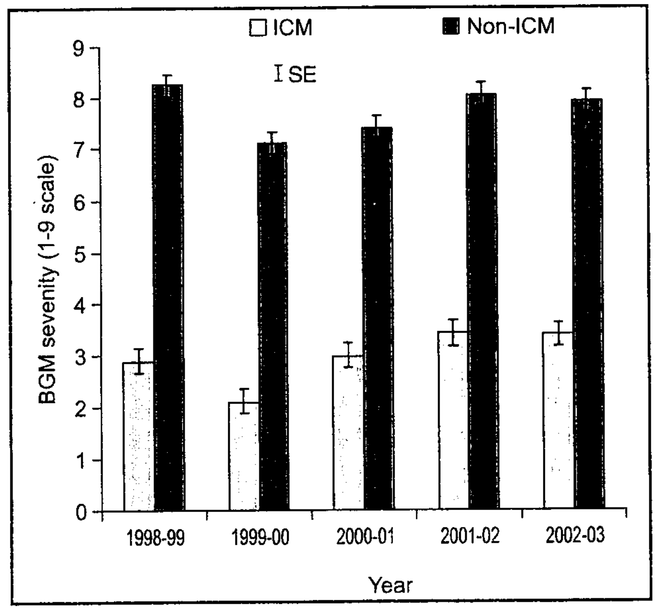

Figure 2. Severity of Botrytis gray mold in farmer participatory ICM and non- ICM trials from 1998/99 to 2002/03, Nepal

In our initial studies we observed that farmers were aware that the persistence of cool and wet weather and some light rain during winter resulted in rotting of branches and was a major factor in poor yields in chickpea. This rotting of branches was due to BGM (Bakr *et al.*, 1997; Pande *et al.*, 1998). In the present study, the incidence of BGM was lower in ICM plots than in non-ICM plots in all locations and in all the years. Similarly wilt was significantly lower in ICM plots than in non-ICM plots across all the villages in all years. Thus, we conclude that both the seed treatment with Benlate and Thiram (Haware *et al.*, 1978) as well as the inherent resistance to wilt in our improved variety were responsible for disease management. BGM can be managed by fungicidal control measures combined with cultivation practices such as correct plant spacing and controlled fertilizer inputs to reduce excessive foliar growth that inhibits flowering as shown by both on-station and on-farm experiments in Bangladesh and Nepal (Karki *et al.*, 1993; Bakr *et al.*, 1997; Pande *et al.*, 1998).

The pod borer damage recorded in ICM plots was also significantly lower ($P < 0.005$) than non-ICM treatment in all the seasons studied. Pod borer damage in all ICM plots varied from a yearly mean of 2.8 % in 1998 to a mean of 8.6% in 2001 season, while in non ICM plots damage was always much higher with mean damage over all sites lowest in 1998 with 40% mean damage to a high of 54% in 2002

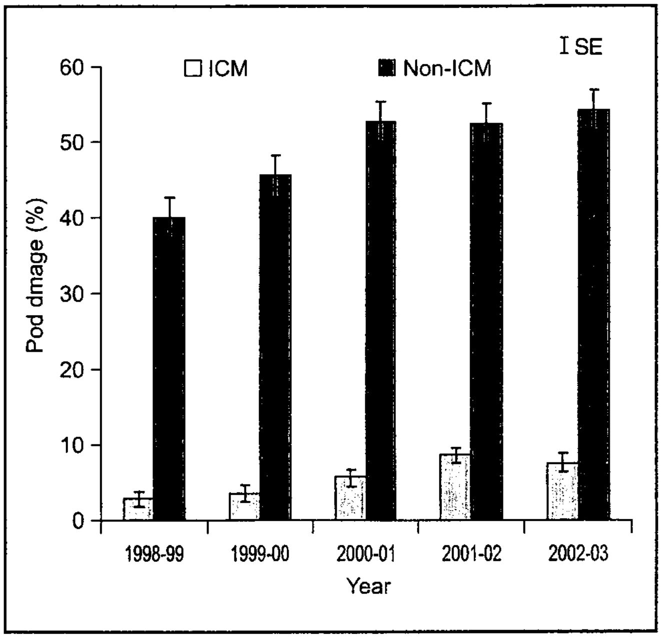

Figure 3. Per cent pod borer damage in farmer participatory ICM and non-ICM trials in Nepal from 1998/99 to 2002/03

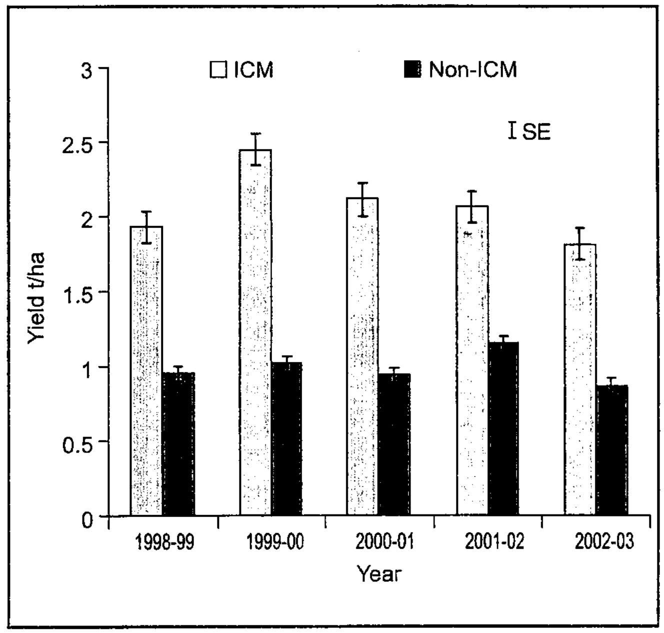

Figure 4. Grain yield (t ha^{-1}) in chickpea on-farm ICM and non-ICM trials from 1998/99 to 2002/03, Nepal

season (Figure 3). High levels of damage to pods as seen in the non-ICM plots are invariably accompanied by later reductions of yield. Furthermore, the damage to pods would have been more profound since these plants were already damaged by BGM and wilt.

The incidence of the pod borer was also significantly lower in ICM plots than in non-ICM plots in all locations and the incidence recorded in non–ICM plots was similar to that reported from other chickpea production areas of South Asia (Rahman, 1990). The success of chemical control of pod borer is dependent on the timely application of insecticide once larvae are identified in the field. Existing farmer practice was characterized by an absence of pest scouting and as a result many insecticide applications were previously made at the wrong time or too late to control the larvae and failed to produce effective pest control. Hence, a major focus was on farmer training in timely scouting of pod borer.

Yield

As expected, yields and net economic returns were higher from ICM treatments than from non-ICM treatment with net returns around two times greater. Significantly higher yields (2.07 t ha^{-1}) were recorded over all years and locations in ICM plots as compared to the mean yield in non-ICM plots (0.98 Kg ha^{-1}). This represents a substantial and highly significant yield increase of 121% (P <0.005) (Figure 4).

Similar results were obtained from farmers participatory on-farm groundnut integrated disease management (IDM) experiments involving moderate levels of HPR and need-based use of fungicides for management of foliar diseases (Pande *et al.,* 2001). This increase in net income is highly significant in improving livelihoods of resource poor farmers in Nepal. In the socio-economic surveys conducted in selected villages in Nepal in 2003-04, we observed a significant improvement in livelihoods among the farmers who had adopted the ICM technology (Pande *et al.*, 2003).

Economic benefits of ICM technology

otal cost of inputs was NRs 14380 ha^{-1} [1 NRs (Nepali rupees) = ~ 0.0153 US $] in ICM and NRs 6870 in non-ICM treatments. Chickpea grains were sold @ NRs 28000 t^{-1}. Total cost of inputs was deducted from total gross income, which was obtained by selling total chickpea grains to get net income. A net profit of NRs 35454, 54860, 46846, 46983, 32990 from ICM, and 22250, 24050, 20165, 20883 and 10311 from non-ICM treatment was obtained respectively from 1998/99 to 2002/03 post rainy seasons (Figure 5). Thus while per cent increase in net income in ICM treatment over non-ICM treatment was 59, 128, 132, 125 and 220 %, respectively from 1998/199 to 2002/03 seasons, in all seasons and locations a substantive and significant increase in profitability with the ICM system was recorded. Looking at the higher returns almost all the participating farmers expressed their preference for the ICM practices.

Adoption and scale-up of ICM technology

Adoption of ICM technology increased in the targeted villages and also spread vary rapidly to nearby villages

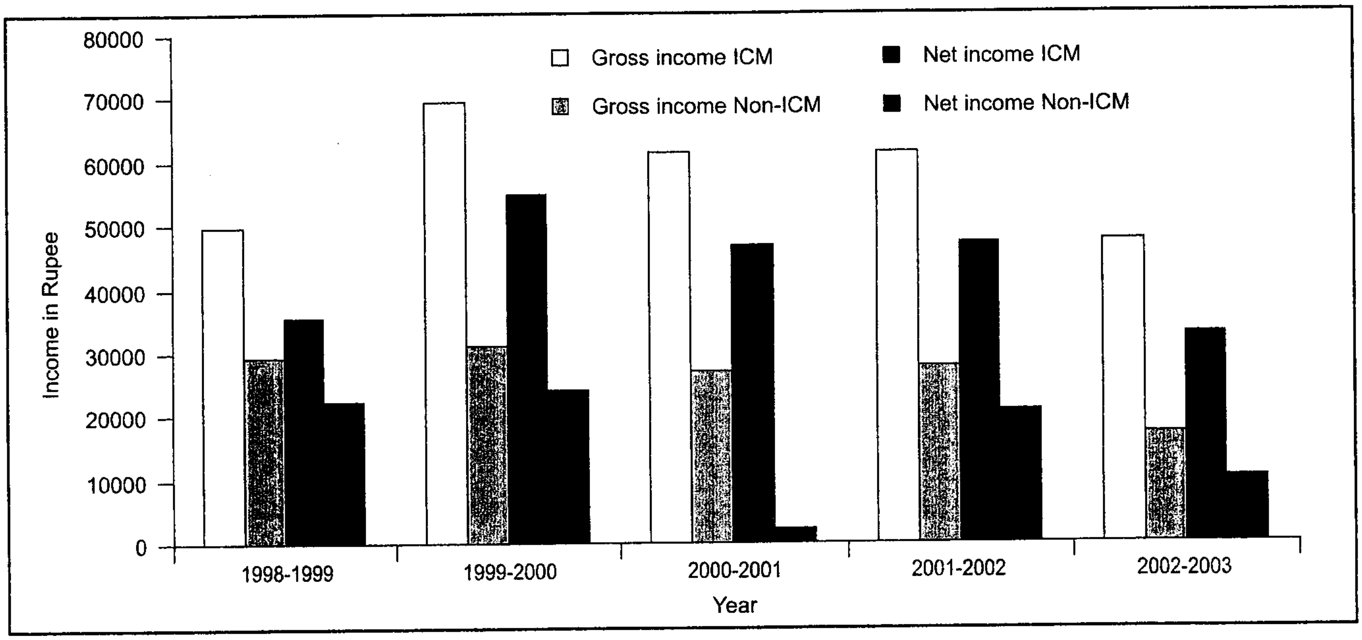

Figure 5. Mean gross and net income in NRs from ICM and non-ICM farmer participatory trials from 1998-99 to 2002-03, Nepal

because of the high economic returns and owing to local mechanisms of dissemination such as farmer meetings, through local NGOs conducting independent projects on chickpea production and wide distribution of printed ICM technology information sheets. In the 1998/99 season, ICM technology was initiated in 110 farmers' fields. Neighboring farmers in all these villages were observing the trials and by the end of 2002/03, 11000 farmers were reported to be following the ICM technology described here (Figure 6).

The ICM technology presented here provides a major tool for reversing the decline in chickpea production in Nepal and neighboring countries. The technology has gained the confidence of the farmers which is why the adoption of this technology increased every year. Reduction in numbers of farmers in 2001-02 was due to disruption consequent upon the civil war in Nepal during this period. The promotion of chickpea ICM on a national scale has the potential to bring back into profitable cultivation a substantial area of fallow

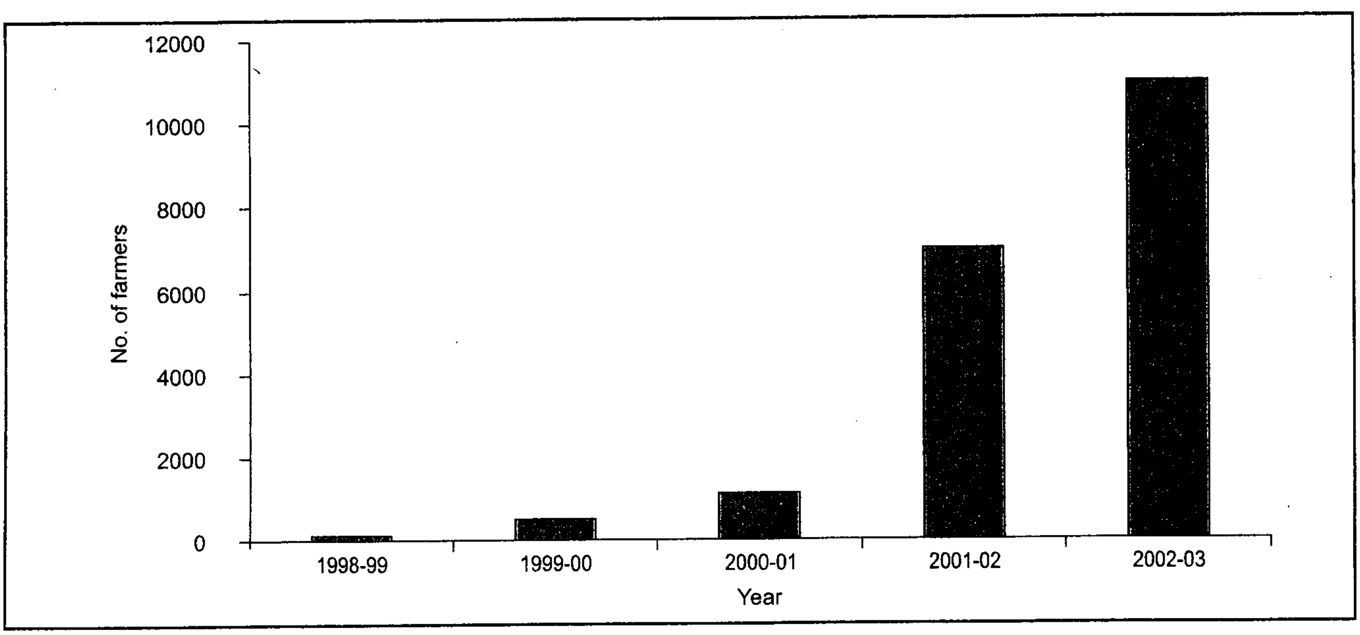

Figure 6. Adoption and scale-up of chickpea integrated pest management technology from 1998-99 to 2002-03 post rainy season, Nepal

land and give poor rural households a significant additional source of income and high protein food thus contributing to the achievement of the millennium development goals of poverty alleviation and malnutrition management. However, ultimately countrywide adoption requires the government in Nepal to make chickpea crop improvement a national priority and can be implemented using a low cost (~\$2.20 farmer^{-1}) mini-kit suitable for production on the traditional Nepalese agricultural unit area of 1 katha (333m^2) (Table 2). Technology support requires subsidies for equipment and the technologies themselves as well as the development of alternatives to the chemicals such as NPV. The mechanisms for funding are now in place in Nepal from regular agricultural budgets. The activities of extension providers such as NGOs, SMEs and community based groups could be financed through the District Agricultural Development Funds of the Agricultural Perspective Plan Support Programme (Stevenson *et al.*, 2005). These funds are designed to strengthen decentralized service delivery, streamline agricultural interventions in remote areas, promote public-private partnerships and provide opportunities for grass-root line agencies to change their role from implementers to facilitators.

Chickpea is also a very important legume crop in north-eastern parts of India and Bangladesh. Production constraints in these two countries are similar to those in Nepal. Therefore, the ICM technology described in this paper could be extended to large areas of India and Bangladesh, where similar cropping systems and conditions prevail.

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Table 2. Mini-kit components for up-scaling with costs per *Katha* (333 m^2)

ICM input	Cost (NRs)[a]
Seed - Avarodhi (1.5 Kg)	45
Rhizobium treatment (7 g)	10
Fertilizer (DAP) (3.3 Kg)	40
Fungicide for BGM (Bavistin)	25
Endosulfan for pod borer	35
Heavy duty plastic bag storage for seed storage after harvest	10
Information leaflet & ICM application guidelines	15
Total	180

[a]1 NRs = approximately 0.0125 US\$

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