Chapter VIII

Discussion, Summary and Recommendations

8.1 Discussion

The discussions that follow are drawn and analysed from the field survey findings and then every effort is made to relate these results with earlier works, so that the outcomes of the research are fully justified and credible.

8.1.1 Bio-physical environment

Rice blast was recorded as early as 1637 and the malady was attributed to the application of manure in presence of a warm, moist wind (Ou, 1985). This piece of earliest known evidence implied by biophysical elements directed many workers on rice to an extensive research on its epidemiology. The numerous studies on blast ascribe the epidemic to climate (Suzuki, 1975), varietal susceptibility and crop management practices (Ou, 1985). Despite this, farmers have been growing susceptible local varieties, due to their better eating quality inherently demanded by consumers (Naito, 1994) and the special attachment to traditional rice farming system in Bhutan (Thinlay, 1997). Therefore, the ensuing discussions on rice blast management strategies have special reference to traditional subsistence farming systems of Bhutan.

Climatic factors

The effect of environmental conditions on infection and development of rice blast described elsewhere implies that the blast epidemic is triggered by favorable climate. Many workers (Hashioka, 1965; Ono, 1965; Ou, 1965, 1985; Teng, 1994; Luo *et al.*, 1998) indicate that the relation of temperature to the growth of blast fungus is solely conditioned by the prevalence of blast in the temperate regions. Air and dew temperature significantly affects blast infection processes including infection, latency, lesion growth and sporulation. The optimum and minimum temperature for sporulation of fungus range from 15-37°C and 10-15°C, respectively, but the conidia are most pathogenic at 28°C for many strains of fungus. Humidity ranging from 93-96 percent is required for host infection by the blast fungus.

Since, meteorological factors are most important elements in the epidemiology of rice blast (Singh, 1990), effective and efficient control of disease will have to depend on the ability to anticipate outbreak that requires sound knowledge on the predisposing factors (Ono, 1965; Ou, 1985; Luo *et al.*, 1998). Therefore, both the extension agents and farmers must frequently monitor the fields and be vigilant of any sign of disease, especially during the most susceptible growth stages of the crop: seedbed, tillering and heading (Bastiaans *et al.*, 1994). Ou (1985) claims that the prevalence of blast in the temperate regions is conditioned solely by temperature to the growth of the blast fungus. In the sub-temperate regions, it is controlled by temperature and by the relation of the age of the plant to resistance; and in the subtropical and tropical regions, prevalence is governed mostly by factors relating to the resistance of the host.

In context of the disease management in the study area, very low literacy rate of the rural communities (11 percent) and complex nature of rice blast, impel research and extension to play a key role in tracking early warning from prevailing weather conditions and monitoring of farmers' fields during the susceptible growth stages of crop. Thinlay *et al.* (2000) account the 1995 blast epidemic in Bhutan, to unusual weather conditions that were favorable for disease development coupled with ubiquitous presence of pathogen. The research and extension should be able to alert farmers, promote cooperation amongst the stakeholders and inculcate farmers the benefit of immediate response, mobilization of resources and manpower in the events of such outbreak. From this point of view, meteorological facilities and human resource development to deal with disease forecasting and sound knowledge on management strategies are indispensable for all the stakeholders. More specifically, extension agents of the rice growing areas must be the focus, as they do not seem to have enough knowledge and confidence to warrant effective identification of disease symptoms and control (personal observation). Therefore, as

Byerlee (1998) states, "the information intensive technology requires considerable improvements in the quality of extension service", and such can be accomplished by training extension agents and farmers in the basics of agro-meteorological relationships and pest management disciplines (Strand, 2000).

8.1.2 Chemical management

Chemical management of blast control is dominated by spraying of fungicides (56.2 percent) mostly after the infection and only 19 percent of the respondents treated seed, representing the diverse and uncoordinated plant protection management system in the area. The subsistence farming systems and the complex nature of disease are impediment to pursue and convince farmers to take up coordinated precautionary measures. Where socio-economics and technical hitches persist, chemical control is unlikely to succeed in the study area as in the developed and some developing countries (Froyd and Froeliger, 1994; Shahjahan, 1994).

Successful and extensive use of fungicide for control of rice blast is closely associated with Japan, where seed treatment (seed disinfection) before sowing and spraying or dusting of fungicides on the standing rice crop even in the absence or less severe disease incidence is socio-economically and technically feasible (Okamoto, 1965; Ou, 1985; Froyd and Froeliger, 1994). Ou (1985) accounts the success of chemical management in Japan to a number of factors such as very high supporting price for rice by the government;, extensive disease forecasting and agricultural extension services; well-developed industry capable of producing cheap chemicals; well organized communities that facilitate the use of air craft over large area even though the individual land holdings are small. The short-stature rice cultivars also enable the use of simple equipment to apply chemical.

Nonetheless, rice blast occurs so suddenly that a rapid response is critical, if prevention is to be successful (Shen and Lin, 1994). A mechanism to deal with such an eventual calamity first calls for creating deep understanding of the nature and threat the disease poses to the farmers and establish coordination for cooperative action amongst the stakeholders. Byerlee (1998) states that crop management practices especially for pest and water management cannot be implemented effectively without community collaboration.

8.1.3 Cultural practices

Manipulation of potential cropping practices, which are known to influence blast epidemic must take precedence over other factors that are beyond the farmers' control. Since, farmers cannot manipulate nature (Kumar and Jha, 2000), they need to incorporate other management strategies that are under their control. Some of these factors that farmers can wield, include a mixture of management toolkits propounded by Teng (1994): knowledge tools (systems analysis and problem definition techniques, diagnostic aids, surveillance and early warning systems, cultural knowledge, environmental risk rules and integrated control guidelines); physical tools (resistant variety, biological control agents, chemical application, fertilizer application, Silicon amendments, mechanical control methods, tools to modify the rice ecosystem); communication tools (field days, demonstrations, group discussions, radio/TV, management information systems); and policy tools (pesticide subsidies, plant quarantine laws, varietal deployment acts, campaigns, and seed health laws).

Teng (1994) suggests that the knowledge of blast pathosystem, in context of the whole rice environment, should precede design of any management strategy, so that the extension agents and farmers have a clear definition of the problem that the blast poses. When the knowledge tools are fully understood by the farmers, then the long held tradition or some specific practices known to influence blast could be changed or adjusted based on the rational understanding of prevailing situation.

Planting date

None of the farmers growing local varieties have changed the traditional planting date and only 5.8 percent adjusted their planting date for improved blast resistant varieties. The choice of planting date by farmer is influenced by past experience, group traditions, superstitions, astrology, etc., (Thurston, 1994), however, Strand (2000) states that manipulation of planting date is of prime importance in pest management tactic to render crop less vulnerable to the pest. Therefore, wherever possible sustained intervention from the extension is required to convince farmers to manipulate their planting date as demanded by the particular biophysical aspects of the area or region in relation to disease management.

Notwithstanding the social obligations, superstitions and traditions, Kozaka (1965) has cited many works on the advantages of early transplanting by stating that the low air temperature at tillering, when the rice plants are most susceptible to leaf blast, as well as the high temperature at heading stage, when it is critical for neck rot infection, are avoided. However, there are some contradictions with regard to planting time. Many earlier workers (Kozaka, 1965; Ou, 1985; Thurston, 1994) believe that early planting in Japan usually have less disease. However, Shen and Lin (1994) found out that early season rice and single-season rice varieties in China were vulnerable to blast, since a large part of the crop's growth occurred during the rainy season, which was characterized by long spells of fog and less sunlight. Therefore, further research on the planting date in relation to crop growth stages, in the context of warm temperate region of the study area would help determine appropriate time of planting, so that critical and susceptible stages of blast development and infection are avoided.

Water management

Water management in temperate region, *vis-à-vis* irrigation water, is the need to raise temperature of the cool mountain water entering the field at the irrigation source, since higher temperature suppresses blast development (Thinlay, 1998). The temperature of irrigation water at 20°C or below usually increases blast incidence, but also relates to the length of time that plants, usually as seedlings, are subjected to the cold water (Kozaka, 1965; Ou, 1985). Maintaining proper floodwater level, throughout the growing season suppresses blast infection possibly because of fewer hours of dew occurrence that do not provide enough free moisture for spore penetration (Lee, 1994; Thurston, 1994).

None of the farmers followed the recommended practice of withholding water at the source before entering the paddy fields and only 2.9 percent of the sample farmers maintained paddy fields under floodwater conditions. The first option of allocating one or more terraces to collect water may not be the feasible option for subsistence farmers and the second option would implicate that the irrigation systems be extensively developed so that farmers have access to constant water supply.

Fertilizer management

The total amount of nutrients applied by farmers was calculated based on the Integrated Plant Nutrient Systems (IPNS) Manual (DRDS, 2001d). The use of inorganic nitrogenous fertilizer in the study area for both the local and improved variety was 7.4 and 11.6 kilogram per acre, which was much lower than the general recommended rate of 20 and 32 kilogram per acre N, respectively. When the nitrogen supplied by FYM (20 kg basket FYM contains 0.16 kg N) was incorporated, then the total quantity applied by the sample farmers, amounted to 23.3 and 26.2 kilogram per acre for local and improved varieties, respectively.

The average amount of nitrogen supplied to local variety (23.3 kg/acre) was higher than the recommended quantity (20 kg/acre) that might have predisposed the crop to blast. However, N supplied by FYM is based on guestimation, since exact rates and nutrient contents of FYM in Bhutan are not known (Department of Research and Development Services, 2001d). Therefore, the influence of nitrogenous fertilizers and manures on blast incidence cannot be interpreted with full confidence as the widely accepted empirical evidence reported by many workers (Kozaka, 1965; Ou, 1965, 1985;

Datnoff, 1994; Lee, 1994; Teng, 1994), which state that excessive application of nitrogenous fertilizers predispose plants to blast.

Another line of thoughts report that the time and method of fertilizer application affect blast incidence. Application of nitrogen at the late crop development compared with early and equal-split applications suppress the leaf blast (Ou, 1985; Kurschner *et al.*, 1992; Datnoff, 1994), but it is not recommended to apply nitrogenous fertilizers too late or at a low temperature during the early crop growth stages (Ou, 1985).

Though, farmers need to be cautioned of the excessive use of synthetic fertilizers and FYM in the local blast susceptible varieties, the nutrient requirement of the improved variety is still below the general recommended rate. Therefore, researchers, extensionists and farmers need to collaborate in monitoring crop growth stage; observe the impact of the method of nitrogen fertilizer application, nitrogen status and pest pressure to precisely identify their relationships, so that a responsive and field-specific management approach is developed for integrated nutrient, insect and disease management (Cassman and Doberman, 2001).

Straw and stubble management

Despite the fact that straw and stubble management is part of the recommended blast management strategy, hardly anyone followed it (2.9 percent). Straw forms one of the major components of cattle feed and any management strategies that impede from their traditional use are unlikely to succeed.

Farmers' indigenous knowledge of using FYM in the paddy fields conforms to the scientific knowledge. Straw and stubble may not act as a primary source of inoculum in the areas, where there is an extreme climatic condition such as snow and frost during the winter season (Asuyama, 1965; Kozaka, 1965; Ou, 1985). Blast pathogen, though cannot overwinter in straw in cold conditions, survives in warm areas and dry weather conditions, a premonition for the extension agents and farmers of other rice-growing regions of the country. Kozaka (1965) no longer emphasize on removal of affected plant materials because of the difficulty of completely eliminating the inoculum from the field, but advises farmers to avoid placing affected straw piles near paddy fields at the time of seeding and also to avoid placing the affected plants into paddy fields, except for use as compost. The effect of compost or farmyard manure as the source of inoculum is ruled out because it is unlikely that the spores remain viable after passing through the ruminant digestive system (Reed, 1994). Instead many workers acknowledge that the silica released from the compost/FYM contribute to the formation of silicated epidermal layers that act to prevent physical penetration and more significantly lower nitrogen absorption (Kozaka, 1965; Ou, 1985; Datnoff *et al.*, 1991, 1997; Thurston, 1994). However, Ou (1985) warns that once the pathogen has penetrated, the silicated epidermal layer produced during the penetration does not inhibit further mycelial growth. This is an implication that prevention of blast pathogen should be carried out prior to the curative measures.

8.1.4 Varietal resistance

Of all the management options, farmers have widely adopted blast resistant varieties (87.3 percent), but the most worrisome trend is the adoption of one type of variety over large area, especially in Thimphu district because the use of resistant variety in pure strands sometimes results in new virulent races of pathogen (Mundt, 1994, 2001; Koizumi, 2001). Naito (1994) also warns of the cultivars with a true resistance gene developing virulent races, when they are extensively planted in the area. Since, the un-relented effort of research in collaboration with the extension after 1995 epidemic to introduce new blast resistant varieties in farmers' fields, through on farm trials and promotional programs, serious threat from epidemic has been reduced from the adoption of these varieties, however, Thinlay (1998) reports that the infection by neck and node blast on Chumroo, the most popular and widely grown resistant variety in the study area, may be the evidence of the resistance breaking down. Moreover, the farmers of Paro, who had been growing improved varieties much earlier than their counterparts in

Thimphu, reported of having observed rice blast symptoms on improved varieties. It may also be the further evidence to all the stakeholders of slow breakdown of resistance that needs close attention and investigation. If the trend of monoculture continues, then it may explode to significant economic loss in the presence of favourable conditions.

Winterer *et al.* (1994) report that introducing genetic diversity by mixing or alternating varieties of rice slows the evolution of pathogen. They believe that the most effective strategies are sequential rotation of resistance alleles, using multiline varieties and the creation of spatial mosaic of rice (in which, each local rice field follows a complex rotation that is out of phase with neighbouring fields). Varietal diversification as one of the options of blast management to extend longevity of host-plant resistance (Mundt, 1994, 2001), gives a glimmer of hope to the low input subsistence farming system of the area, because research and extension do not have resources and capability to develop hi-tech multilines varieties. Moreover, cultivar mixtures do not require additional breeding of agronomic uniformity (Mundt, 1994); the research and extension in Bhutan can exploit this concept as farmers are growing more than one variety in their fields. Significant contribution of genetic diversity to protection from disease in natural ecosystems and in traditional agriculture is attributed to: (i) an increased distance between plants of the same genotype, which dilutes inoculum of compatible pathogen races; (ii) interactions between pathogen races, such as induced resistance and competition; and (iii) a barrier effect of resistant plants in blocking spore dispersal among compatible hosts.

Youyong *et al.* (2001) reports that panicle blast severity on the susceptible glutinous varieties was 94-99 percent less severe, when the varieties were grown in mixtures than monocultures. So, exploiting the varietal diversity seems to be the viable strategy that the vulnerable warm temperate region of Bhutan could focus on. However, the implementation consideration of growing in mixtures is that the varieties grown must be compatible especially in height, duration, and quality (Mundt, 1994, 2001); nonetheless these varietal characteristics may not undermine their adoption, since most of the operations in Bhutan are done manually. Conversely, there is no room for complacency as Ezuka (1979) reports the striking evidence of resistance break-down of a variety found in a field adjoining one with the domestic susceptible variety that was more severely damaged than the domestic susceptible variety. If such were the case, then the devastation from another epidemic would be phenomenal in both the districts.

In addition to the foregoing facts, Ezuka (1979) states that resistance of a variety is not sufficient enough to control disease as farmers use nitrogenous fertilizers more intensively on improved resistant varieties to realize increased yield. Drawing on the conclusions from earlier workers, the contemporary workers on rice blast advocate the use of integrated crop management (Ou, 1985; Kim, 1994; Mundt, 1994; Shahjahan, 1994; Teng, 1994; Du *et al*., 2001).

8.1.5 Extension approaches

Extension in the district plays a major role in the flow of information and the source of knowledge about agricultural production system in rural areas. Though, their impact cannot be quantified in this study, the main source of information for blast management strategies have come from the extension (96.8 percent) compared to other sources. The mode of information flow from the extension was predominated by extension agents' individual visit to farmers' home or fields and farmers' training; an indication of the most commonly used methods in the districts. The other source of information was largely determined by the communal integrity (neighbours), the level of participation in on-farm trials, field days and the severity of the problems, whereby other institutions such as the Plant Protection and Research Centres were called upon for assistance and joint action. For instance, the contribution of the National Plant Protection Centre has been the direct involvement in inspection and diagnosis of disease on intimation from the district or farmers. On-farm trials and field days are likely to be focussed on selected group of farmers unless the government, project or local institution allocate sufficient budget to meet the expenses for wider coverage.

Farmers' preferences of extension methods seem to be those approaches they were familiar with, such as farmers' training and individual farmer visit that created awareness of the disease with a score of 6.6 and 6, respectively, but do not provide a foolproof evidence that these methods are effective means of communication.

Training usually covers wide range of topics that are often theory-oriented, which may be difficult for those farmers who are illiterate to fully understand the management strategies in relation to complex epidemiology of the disease. On the other hand, individual farmer visit has created dependence on extension agents for monitoring and reporting of the condition of their crops and in the process farmers do not understand the nature of problems that prevail in their fields. Consequently, without deeper understanding of the cause and effect, it may be difficult to convince and pursue farmers to opt for management strategies. Kilpatrick (2000) also draws the evidence from many workers that education and training is one of the several factors, which influence farmers in altering values and attitudes towards new practices as the result of interaction between the participants and with the trainers, and enhance farmers' ability and willingness to change those components that require adaptation to change.

The indication of impact from participatory research and extension approach such as on-farm trial in the study site is very encouraging, as majority of the farmers seem to prefer it. This kind of extension approach gives farmers, first hand empirical experience and knowledge of the technology through direct observation of its impacts in the form of desirable agronomic traits (taste, colour, threshability, plant height, etc.), increased yield, suppression or control of pests. Besides on-farm trials, if field days are synchronized with certain critical crop growth stages, the theoretical knowledge and visual observations are likely to motivate farmers to adopt those technologies that conform to their needs and situation, i.e., a situation where individual learning to collaborative learning and theory dominated learning to praxis-oriented learning is facilitated (Wals, 2000). Experience has also shown that successful innovations are developed, when the actors themselves experimented, evaluated and determined the practices most appropriate for themselves (Deutsche Gesellschaft für Technische Zusammenarbeit, 1997).

From the extension agents' standpoint, while farmers' training (7.3 score) and individual farmer visit (6.5 score) dominated their preferences, low scores for on-farm trials (3) and field days (3.3) indicate that their involvement and decision on these activities is not much, possibly because of the joint activity, whereby researcher plays the major role, besides extension agents' technical incompetence, lack of inputs, financial constraints and bureaucratic procedures. Therefore, updating extension agents' knowledge and enhancing their technical skills in participatory extension methods are imperative to bring about desirable changes as the development programs and activities are being decentralized at the block level in the 9th Five Year Plan (2002-2007).

8.1.6 Technological attributes to adoption of rice blast management technologies

The various components of the technology that constitute the management package of blast control were extended to farmers from the extension standpoint that imparting knowledge to farmers, most commonly through individual farmer visit and training would lead to adoption of these management strategies. However, the field survey found out that farmers would be willing to spray chemicals, if the disease incidence is confirmed on their crops, but would not take the risk of investing on unforeseen events. The emergency blanket chemical spray campaign of 1995 has also created some misconception on the credibility of chemicals in controlling the blast. Byerlee (1998) also asserts the importance of gaining credibility for the recommendation among farmers because the poor quality of recommendations issued in the past will undermine credibility and will require the sustained quality overtime to renew farmers' confidence in research recommendations in the future.

In real situation, farmers have adopted those technologies, which were simple and affordable. The other attribute of technology that induces adoption is effectiveness of the technology in addressing farmers' perceived needs coupled with the efficient and sustainable use of resources at their disposal (Boyd *et al.*, 1999). This is demonstrated by the fact that resistant variety received the highest mean value (3.9 out of 4) and very high index of acceptability (68.4) among the other options. Though, the importance of straw and stubble management was stressed, hardly anyone accepted it (index of acceptability at 1.3) because it directly came into conflict with its traditional use as the feed for cattle that ultimately return to their fields as farmyard manure.

With regard to the resistant varieties, Kumar and Jha (2000) cite many studies on unavailability of modern varieties and associated technologies as the major constraints to the adoption or slow adoption of such innovations and also emphasise that the adoption of improved varieties is proportional to the availability of complementary inputs. Even for the farmers to adopt water management to contain rice blast, the precondition of adoption of such management is the availability of water. Therefore, in future the Ministry of Agriculture should ensure the availability of new improved varieties at affordable price and improve the irrigation system.

Technologies that are knowledge-intensive such as improved varietal selection, improved timing and applications of fertilizers; integrated pest management and improved water management have drawn limited interest from farmers (Pingali, 1998). Perhaps any future work in technology development should entail farmers' participation at all levels, from problem identification to the implementation of technologies to bridge the gap between farmers' technical knowledge and scientific know-how of these technologies.

Pingali (1998) has also drawn up the positive relationship between the real agricultural wages and the adoption of labour-saving mechanical and chemical technologies as the result of labour scarcity. Though, the present study cannot explicitly explain the adoption of labour-saving mechanical and chemical technologies, the adoption of herbicide applications by almost all the respondents (89.2 percent) implicitly indicates that farmers adopt those technologies that directly address their constraints.

The difference in average wetland land holding of farmers growing local varieties (1 acre) and resistant varieties (1.3 acres), which was significant at 5 percent, confirms to the positive relationship between size of land holding and adoption of improved technologies given by Lee and Stewart (1993), Sarap and Vashist (1994), and Robinson and Napier (2002). It was more pronounced, in the case of adoption of one of the management technologies on local varieties, as the difference of size of wetland between the adopters (1.1 acres) and non-adopters (0.7 acre) was highly significant.

8.1.7 Benefits of adopting the blast management technologies

Vulnerability of the temperate region to pests and diseases, especially that of rice blast is well documented and widely researched, yet scientists and rice farmers are consistently threatened by its looming onslaught. Many workers cited elsewhere argue that growing improved varieties resistant to blast is the most economical option of blast disease management and at the same time elicit many dire consequences as the result of resistance break-down within few years after its release in many rice growing countries. Against this backdrop, many believe that integrated crop management is possibly the best option of disease management (Datnoff, 1994; Kim, 1994; Shahjahan, 1994; Teng, 1994; Kogan, 1998; Cook, 2000; Jahn *et al.*, 2001), but it is knowledge-intensive, besides entailing many other enabling conditions such as substantial improvement in collection and dissemination of information on rice, its production factors and technologies, well-established markets, good research and extension that are often beyond the reach and capability of poor resource farmers (Morse and Buhler, 1997; Tran, 2001). Such may be the underpinning factors that led to poor adoption of blast management technologies in the study area and, thus, justifies the use of resistant varieties, regardless of many limitations.

Therefore, in the absence of enabling factors and biophysical constraints, adoption of resistant varieties provides the best possible options of blast management to safeguard from its onslaught. Moreover, even in the low input production systems of the area, improved blast resistant varieties have fared better than the local varieties in terms of yield. The average yield difference of 19.5 percent per acre was highly significant. The gross margin of resistant variety (Ngultrum 17,659.4 or US$ 375.5 per acre) was higher than the local variety (Ngultrum 11,307.4 or US$ 240.6 per acre) with the difference of 36 percent per acre at 1 percent. The returns to materials cost of resistant variety (4.1) and local variety (3) and the returns to labor cost of the former (2.7) and the later (2.1) were highly significant, indicative of the higher returns from resistant varieties.

The benefits of using one of the recommended blast management technologies on local varieties are exhibited by the highly significant yield difference of 10.4 percent between the adopters and non-adopters of technology. However, there was no significant difference in the total variable cost incurred between the adopters and non-adopters of blast management technologies. This is because in some management strategies, farmers used family labor before or after the normal working hours (water management) or required only a part of family labor in the slack season (straw and stubble management). On the other hand, less expenditure was incurred on chemical fertilizer from its reduced quantity and also the low cost of chemical fungicide did not make the significant cost difference between the adopters and non-adopters of technologies on local varieties. Thus, it can be concluded that the adopters have better benefits and higher gross margin (Ngultrum 12,201.5 or US$ 259.6 per acre) than the non-adopters (Ngultrum 9,346.1 or US$ 198.9 per acre). In addition to the above gains, the average cost of producing a kilogram of rice is cheaper by Nglutrum 1.5 (US$ 0.03) for adopters (Nu.12.9 or US$ 0.3 per kg) than the non-adopters (Nu.14.4 or US$ 0.31 per kg).

8.2 Summary

Rice is the most preferred and indispensable staple food for the Bhutanese. Rice contributes about 42 percent of the total cereal production in the country. Unlike the other agro ecological zones, vulnerability of the temperate region to rice blast is higher. The unprecedented rice blast epidemic, caused by *Pyricularia oryzae* Cavara (Telemorph

Magnaporthe grisea) in 1995 was a bitter experience and a premonition to the rice farmers and the Ministry of Agriculture that the disease can create havoc as the consequence of management practices in the presence of favorable conditions. Since then, the Research and Extension have been playing a vital role in developing and disseminating technological packages to counteract such threats. Subsequently, many control measures were advocated for the rice farmers.

The survey found out that 54 percent of the sample households cultivated both blast resistant and local varieties, 34 percent grew only blast resistant and the rest cultivated only local varieties (13 percent). The result shows that growing of resistant variety dominated over other strategies such as chemical spray, seed treatment, water, and straw and stubble management; strongly indicating farmers' inclination to adopt those technologies, which display physical effectiveness and do not impinge on their resources and traditional use. These technologies were extended through variety of extension methods, of which, farmers mostly preferred farmers' training and individual farmer visits. Extension agents were found to be instrumental and the major source of knowledge and information for the rural farming communities.

After affordability of adopting the technology, effectiveness of the technology in addressing farmers' perceived needs coupled with the efficient and sustainable use of resources at their disposal was the key aspect favouring adoption. In order to facilitate adoption of technologies, complementary or associated components or services should be made available to the farmers to induce adoption. However, knowledge intensive or complex nature of technologies such as seed treatment and chemical spray, have drawn limited interest from farmers.

The positive relationship between labour shortage and the adoption of labour-saving technologies as the result of labour scarcity is implicitly implied by the adoption of herbicide. Though the present study cannot explicitly explain the adoption of labour-saving mechanical and chemical technologies, the adoption of herbicide applications by almost all the respondents illuminate that farmers adopt those technologies that directly alleviate their constraints.

The study reveals the significant positive relationship between the farm size and the adoption of technology. The adoption of resistant varieties has provided the best possible options of blast management to safeguard from its onslaught. Moreover, even in the low input production system of the area, blast resistant varieties have fared better than the local varieties in terms of yield and gross margin. Similarly, even the adoption of one of the blast management technologies on local variety has proved beneficial and profitable in terms of yield and gross margin.

8.3 Recommendations

The ensuing recommendations are drawn from the foregoing discussions that are targeted to all the relevant stakeholders, i.e., individual farmers; extensionists; researchers; input suppliers; local, district and central administrators and policy makers.

1. In the wake of fast growing body of knowledge and technologies in the field of renewable natural resources, the success has to come from the capacity to translate new knowledge into practical innovations by taking the advantage of existing central, regional, district and local institutions to develop and strengthen human resources. Possibly, farmers' field school and on-farm trials are best suited for knowledge-intensive crop management strategies because illiterate farmers need to be convinced of the underlying theoretical principles by empirical evidence and learn by doing.

2. Although, the present extension methods cannot be critically commented for its effectiveness and efficiency, it would be desirable to involve every farming member of the household in extension activity. Unlike, the normal training module, whereby only one member of the family represents the household in the training course, it would be better to extend such training to all the members of the households for wider coverage. It would also be convenient for the farmers and, thus, more effective to conduct such

training in the field or village itself; and more importantly to synchronize the topic and content that has relevance at that particular point of time.

3. The characteristics of technology have largely determined its adoption. The more complex and abstract the technology is, lower the adoption rate. If the adoption of technology is to succeed, then it should be affordable and display visual impact or evidence, or otherwise the farmers need to be made aware and convinced through intensive training, demonstrations, field days or facilitate group discussions with those farmers, who are credible and well-versed with the knowledge of such technologies.

4. The very high rate of adoption of herbicide (Butachlor 5G) is possibly the best example that directly addresses the farmers' problem. Any future technology development should solve farmers' burgeoning problems. However, while developing technology or any other technologies *per se*, first, the task performed by male or female has to be identified so that appropriate technology is developed for the ultimate user. For instance, women normally do weeding in Bhutan and if the rotary weeder is to be introduced as the labor saving device, then it should be women user friendly.

5. Since, the horizontal expansion of wetland cultivation is precluded by the mountain landscape and environment, besides the rapid expansion of towns, engulfing the most productive agricultural land, food self-sufficiency even at the farm household level is at stake and so one can only hope for increasing the productivity per unit area. Notwithstanding, the man-made and natural constraints imposed on the farmers, the use of chemical inputs (synthetic fertilizers and pesticides) in the subsistence paddy production system of Bhutan, by any standard, is low and there is still a room to achieve the attainable yield of about 2 ton/acre, through increased use of chemical fertilizers on improved varieties. Therefore, enabling the spread of productivity-enhancing technologies should take the center stage to enhance productivity from the limited area of arable land.

6. Farmers growing local varieties need to be motivated to treat seeds with fungicides and make aware of the prompt action and full cooperation required in the events of disease outbreak. This calls for strengthening the local institution such as the Block Development Committee to mobilize both human and material resources in any eventualities.

7. The present cropping practice is dangerously poised towards triggering blast epidemic, if favorable environment for the disease sets in. Even the resistant varieties have been in the field for few years and it is a matter of time for breaking their resistance and become virulent in the favorable conditions. Since, breeding resistant variety and ultimately reaching farmers' fields take some years, research and extension should have strategic and coping plans and programs in pipeline.

8. With the current trend of technology adoption, introducing varietal mixtures in the farmers' field could possibly help reduce blast pressure, where farmers are growing either local, improved or both the varieties. Hence, a twin pillar strategy of varietal improvement and selection coupled with improved production technologies addressing the farmers' constraints matched by suitable infrastructures, services and policy initiatives are decisive in bringing about changes.

9. The possibility of introducing silicon fertilizer to reduce blast severity should be explored and further study on the nitrogen content in the farmyard manure is recommended to arrive at the economic and optimum amount of nitrogen required by the crop, since excessive nitrogen is believed to predispose the crop to rice blast.

10. Development of decision tools for insect and disease management at the local level through historical and seasonal profiles, expert systems, etc., would help improve farmers' knowledge, attitudes and practices. Since, the concept of focus village program is in place, incorporating this method may complement to developing close interactions among the farmers and extensionists.

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