Farmers' empowerment on potato disease management through participatory research in Nepal

Buddhi P. Sharma, Prakash Bhattarai, Ram C. Adhikari and Bhim B. Khatri

Nepal Agricultural Research Council
National Potato Research Programme
Corresponding address: bpsharma.adhi@ymail.com

Abstract

Participatory research on management of potato diseases particularly on late blight (*Phytophthora infestans*), wart (*Synchytrium endobioticum)* and black scurf *(Rhizoctonia solani)* were conducted in Nepal at different agro climatic conditions during 2003-2008. Potato clones CIP-384321.15, CIP-391058.35, CIP-392657.8 and LBr-40, PR-15860.8, PR-85861.12 and PR-15861.16 were found resistant to late blight under natural epiphytotic conditions of Chitwan (260 masl). Among the selected late blight resistant clones PR-85861.12 was most preferred by the farmers for its yield and tuber skin colour. Potato clones CIP-394005.115, CIP-393674.72B and some NPRP crosses, PR-15861.6, PR-25861.10, PR-25861.14, PR-35861.13, PR-35861.12 were found resistant to wart under naturally wart infested soil conditions at Nigale (2450 masl). Despite of having wart resistant character, farmers were reluctant to adopt these clones because of lower tuber yield than the existing cultivar 'Rosita'. Different management options were tested against black scurf disease, among them seed tuber treatment with 2% boric acid was found to be economical with highest disease control (41.7%) followed by seed and soil treatment with antagonist *Trichoderma harzianum* (30%). These options were accepted by the participating farmers of Bardiya (350 masl). Participatory research have enhanced the technology adoption process with respect to late blight and wart resistant clone selection and adoption of best black scurf management option as per their socio-economic conditions.

Keywords: black scurf, boric acid, late blight, participatory, *trichoderma*, wart.

Introduction

Late blight (*Phytophthora infestans* Mont de Bary), Bacterial wilt (*Ralstonia solanacearum*), Wart (*Sinchytrium endobioticum* (Schilb) Perc), Black scurf (*Rhizoctonia solani*) are the economically important potato diseases causing substantial yield losses in Nepal. Due to the individual disease yield loss ranges 15-40% depending on potato varieties grown and the conduciveness of weather prevailing at a particular location (NPRP 2005).

In high hills above 2000 masl late blight disease occur every year with the significant yield losses whereas, in the palin disease epidemic usually occurs after 2-3 years. The monitory loss estimated at the National level reaches beyond 72.5 million USD based on only 15% loss of production of 2008. Potato growers of Kathmandu valley itself spray fungicides from 11 to 15 times, which leads to increase cost of production (Sharma et al., 2007). The disease can be controlled considerably using resistant varieties, cultural practices and fungicides. The level of late blight resistances in presently available potato varieties is only intermediate and access of resistant varieties to the farmers is often limited and fungicides are too costly for resource poor farmers of Nepal.

Wart is second most serious disease of potato particularly in the cooler region (>2000 masl) of the country. The most favorable conditions for its development are warm temperatures (but not over 20°C) with enough humidity. Winter sporangia can remain viable for more than 40 years (Stuart et al., 2008). This disease is of quarantine significance due to the production of persistent resting spores and lack of effective chemical control measures (Putnam and Sindermann,1994; Hehl et al., 1998). Use of resistant varieties is only the most practical way of managing this disease. However, disease could be managed to some extent by soil treatment with fungicides and long crop rotation. In high hills long crop rotation is not accepted by the farmers because other crop's productivity is very low that can not cope with food deficit in the hills. Previously recommended all potato varieties are resistant to wart but farmers from wart infected areas are reluctant to accept these management options. Existing potato cultivar 'Rosita' is highly susceptible to wart and because of its severity productivity is decreasing (NPRP, 2007). Therefore there is high demand of high yielding, red skinned and resistant to late blight and wart disease.

In mid western region of Nepal espacially plain area , yield losses due to black scurf disease has been estimated ranging 5-60 percent depending on the prevailing weather during the crop period and crop rotation followed (Sharma and Khatri. 2004). Some recommendations have been made for disease control through seed tuber treatment with Sodium hypo-chloride (NaOCl). The seed treatment with mixture of Acetic acid 1% + Zinc sulphate 0.05 % solution for 15 min dip gave 100% kill of sclerotia (Dutta and Gupta 1982; NPRP, 1994). Seed tuber treatment with 3% boric acid solution dip for 30 minutes prior to planting to control black scurf disease of potato has been recommended (NPRP, 1994). Black scurf could be controlled by adopting appropriate crop husbandry i.e. planting vigorous sprouted seed, avoiding deep planting and avoid planting into cold and wet soil (Hawthorne,1997).

Farmers are eager to learn new options and seek solutions to their problems, but in many cases they lack know-how or access to them. Over the last 35 years, and particularly since the early 1990s, interest in participatory crop research and improvement has grown in recognition of its potential contribution to marginal areas with low agricultural potential (Hellin et al., 2006). There is a need to identify varieties and technologies that are suited to a multitude of environments and farmer preferences.

The participatory process involves narrowing the gap between research organizations and farmers' realities by ensuring direct farmer involvement at different stages of the research process. Taking these points in view, participatory research was performed on three major potato diseases i.e late blight, wart and black scurf, at their respective climate and socio economic conditions.

Materials and methods

Participatory experiments were conducted in three major potato growing locations representing high hills, inner terai and mid western terai of the country as per potato disease problems faced by the farmers.

For potato clone selection against late blight, **f**ifty seven potato clones received from the International Potato Center (CIP) and other sources were screened against late blight disease under farmers field at Sharadanagar, Chitwan (270 masl) inner terai during 2007/08. Ten tubers of each potato clones were planted in augmented design (Scott and Milliken, 1993) with a spacing of 25 x 60 cm in 2.5 m long rows under natural epiphytotic conditions. Tubers apparently healthy and in the same physiological conditions were planted in the fields during 3rd week of November to align with local cropping systems. Kufri Sinduri was used as late blight susceptible check variety, which was planted after each 9 rows of test clones and in the border around the trial to increase pathogens inoculums pressure. Prior to planting, fertilizer 150:100:60 kg N, P_2O_5, K_2O/ha respectively, along with 10 t/ha farm yard manure were applied as a basal dose. Cultural operations and irrigation was applied as per participating farmers' decision. Fungicides were not applied against late blight throughout the crop period. Experiment was conducted under natural late blight infected conditions.

Disease severity was scored on 1-9 CIP rating scale (Henfling, 1987). Where 1 indicates no disease infection and 9 indicates 100% foliage damaged by the disease. Disease was scored three times at 60, 70 and 80 days after planting (DAP). The disease score of 70 DAP was used for comparing the disease reaction of the potato clones. Test clones were categorized into five groups based on 1-9 disease rating scale as follows.

Range of score	Reaction category
<=1	HR (Highly resistant)
>1 to <=2	R (Resistant)
>2 to <=4	MR (Moderately resistant)
>4 to <=6	S (Susceptible)
>6 to <=9	HS (Highly susceptible)

Farmers in association with researchers scored the disease first at 60 Days after planting (DAP) then farmers themselves scored disease on succeeding observations.

For potato clone selection against wart, experiment was conducted on highly wart-infested soil, identified during the previous crop harvesting time. Forty five clones were tested and compared with wart susceptible check variety 'Rosita'. Sources of test genotypes were International Potato Center (CIP) and National Potato Research Programme (NPRP). Experiment was planted at the farmer's field at Nigale Sindhupalchok during first fortnight of February 2008.

Susceptible check variety was planted after each 9 test entries and was made its borderline. Experiment was in rod-row augmented design (Scott and Milliken.1993; Burgueno Ferreira et al., 2005) susceptible check was repeated 5 to 6 times depending on the number of test clones. Plot size was with row length of 2.5m long and 0.6 m width and planted in a spacing of 25cm X 60cm. Field was prepared as furrow and ridges with a spacing of 60cm. Compost @ 10 t/ha and fertilizer @ 150:100:60 Kg N, P_2O_5 and K_2O/ha were applied as basal. Intercultural operations were followed as per the farmers' practice. Fungicides were not applied throughout the crop period. Wart incidence was recorded at the time of harvesting based on the number of infected symptomatic tubers and apparently healthy tubers produced per 1.5 m^2 plots.

For Black scurf management at Bardiya, a heavily infested farmers field with *Rhizoctonia solani* was selected prior to experimentation at Mainapokhar, Bardiya. Treatments were fixed on consultation with participant farmers. Experiment was laid out in randomized complete block design (RCBD) with seven treatments and three replications. Black scurf infected seed tubers of variety 'Cardinal' were used in this experiment. Experiment was planted on second week of November in all the experimental years (2003-2005). Plot size maintained was 2.4m x 3.0m. Sprouted seed tubers were planted in 25 cm x 60 cm spacing at a normal depth. Recommended manures and fertilizers were applied@ 10 t/ha and 150:100:60 kg N, P_2O_5 and K_2O Kg/ha respectively were applied. Nitrogen was applied as three split doses. Half amount of Nitrogen, was applied at planting as basal and remaining half was applied during two intercultural operations as split doses. As per the treatments, soil was sterilized with Formaldehyde 1.0 % ai concentration through commercial Formalin 39%. *Trichoderma harzianum* in the form of NIPROT (Manufactured by Bio-Control Research Laboratories, Bangalore, India) was applied as seed and soil treatment and drenching after the emergence. As per manufacture's instructions *Trichoderma* was multiplied in well-decomposed FYM @ 10 g NIPROT/Kg FYM. Commercial brand of *Trichoderma* 'NIPROT' was well mixed in FYM and kept for 10 days under polyethylene cover to maintain the conducive temperature. Seed tubers were treated with boric acid of two concentrations (2% and 3%) prior to panting.

Crop was harvested at 105 days after planting and total yield per plot was recorded at harvest. Finally, disease severity was recorded on percentage comparing the corresponding pictorial severity scale developed and severity index was computed as reported by Tanil et al. 1982.

Results and discussion

Potato clone selection against late blight

Out of fifty seven potato clones screened under participatory late blight disease screening trial at Sharadanagar Chitwan, clones LBr-40 and CIP 384321.15 were found highly resistant and CIP clones 391058.35, 391617.54, 392270.32, 392271.58, 392657.8, 392661.18, 393280.57, 393280.64, 393385.39, 396233.38, 800982 were moderately resistant and rest of the clones showed susceptible to highly susceptible reaction (Table). Observation on late blight disease severity showed that environment of experimental site was found to be the most conducive for late blight development.

Highest tuber yield (33.30 t/ha) was obtained from the clones LBr-40 followed by 391616.54 (32.0 t/ha), 392657.8 (25.23 t/ha) and 391058.35 (24.60 t/ha) along with resistant reaction to the disease (Table1).

NPRP crossed potato clones PR 15861.8 and PR 15861.16 were found highly resistant with the considerable tuber yield 19.67 t/ha and 13.47 t/ha respectively. Eight clones showed resistant reaction to late blight with the significantly higher tuber yield ranging 16.33 to 26.6 t/ha. Participating farmers highly preferred PR 85861.12 because of its highest yield (26.6 t/ha) and tuber skin colour with moderate level of resistance against blight. Obtained yields were almost 3 to 4 times higher than susceptible check cultivars Cardinal and Desiree (Table 2). Participating farmers had expressed their satisfaction by getting late blight resistant potato clones with the desirable tuber yield without spraying any fungicides. Farmers have decided to multiply resistant clones and popularize them further in the community.

Table 1. Performance of potato clones showing moderately to highly resistant reaction to late blight under Chitwan valley conditions in 2007/08

Potato clones	LB score (1-9 scale)	Over all reaction to LB	Tuber yield (t/ha)
CIP 384321.15	1	HR	16.19
CIP 391058.35	2	R	24.60
CIP 391616.54	2	R	32.00
CIP 392270.32	2	R	23.70
CIP 392271.58	3	MR	19.05
CIP 392637.10	2	R	24.00
CIP 392657.8	2	R	25.23
CIP 393280.57	2	R	21.48
CIP 393385.39	4	MR	23.68
CIP 396010.42	3	MR	18.00
CIP 800982	2	R	12.50
LBr-40	1	HR	33.30
CIP 392227.15	4	MR	15.56
Kufri Sindhuri (Check)	9	HS	6.40
Total no. of test clones = 57			

LB score 1 = no disease; 2 = < 5%; 3 = 5 to <15%; 4 =15 to <35%; 5 =35 to <65%;
6 = 65to<85%; 7 =85 to <95%; 8 = 95 to <100 % and 9 = 100% damage
Reaction: HR (<=1); R (>1 to <=2); MR (>2 to <=4); S (>4 to <=6); HS (>6 to <=9)

Table 2. Farmers' participatory selection of National Programme bred potato clones at Sharadanagar in 2007

Clones	LB score	Reaction	tuber yield t/ha	Tuber colour
PR 15860.8	2	R	19.67	W
PR 15861.35	3	MR	20.33	W
PR 35861.24	3	MR	16.33	R
PR 225861.7	3	MR	19.53	W
PR 85861.9	7	HS	4.67	W
PR 85861.12	3	MR	26.60	R
PR 255861.2	3	MR	22.47	W
PR 255861.1	3	MR	20.47	W
PR 85861.8	3	MR	22.33	R
PR 15861.16	2	R	13.47	R
PR 85861.11	3	MR	22.33	W
PR 15861.1	9	HS	3.33	W
Resistant check (LBr-44)	1	HR	19.87	W
Susceptible check (Desiree)	9	HS	6.67	R
Susceptible check (Cardinal)	9	HS	7.33	R
Susceptible check (K. Sindhuri)	9	HS	8.20	R

LB score 1= no disease; 2= < 5%; 3= 5 to <15%; 4=15 to <35%; 5=35 to <65%;
6= 65to<75%; 7=75 to 85; 8=85 to <95%; and 9= 100% damage
Reaction: HR (<=1); R (>1 to <=2); MR (>2 to <=4); S (>4 to <=6); HS (>6 to <=9); Tuber colour R= Red; W=White

Potato clone selection against wart

Out of 45, sixteen potato clones namely CIP-378711.7, CIP-383178.22, CIP-384329.21, CIP-392228.66, CIP-392243.17, CIP-392243.52, CIP-392661.18, CIP-394005.115, CIP-93574.72B, CIP-394038.105, CIP-390682.7, CIP-392270.32, Panauti, Kufri Giriraj, CIP-388764.26, CIP-392206.35 were found resistant to wart under field natural infested conditions (Table 3). It was observed that, potato clones showing susceptibility to wart produced comparatively better tuber yield than the wart resistant clones. The reason could be that new exotic clones were not suitable for that climatic condition.

Widely adopted cultivar 'Rosita' produced highest tuber yield along with wart-infected tubers (23.4/ha) followed by LBr-40 (20.7t/ha) and 384321.15 (16.7t/ha), but found to be susceptible to wart. Warty tubers reduce the market price. Since, wart incidence was recorded to 64% in Rosita. Farmers will have to face extensive economic losses in the future. LBr-40 and CIP-384321.15, wart susceptible clones showed better performance in Chitwan and farmers had preferred for their high yield and late blight resistance. There was no wart disease problem in warm climate below 1000 masl.

NPRP crosses PR 15861.6, PR 25861.10, PR 85861.14 PR 35861.13 and PR 35861.12 showed resistant to wart under field conditions (Figure 1). In addition to previously released potato varieties three new potato genotypes PR 25861.10 and PR 85861.14 were found to be resistant to wart with considerable tuber yield ranging 15 to 21 t/ha. Participating farmers were positive to those clones and selected for further evaluation. Other resistant clones, produced very low tuber yields, were not acceptable to the farmers.

Table 3. Performance of potato clones against wart at Nigale during 2007/08

Acc no.	Infected tubers (No.)	Healthy tubers (No.)	Wart incidence %	Tuber yield (Kg/1.5 m^2)	Tuber yield (t/ha)
378711.7	0	50	0.0	1.2	8.0
383178.22	0	38	0.0	1.0	6.7
384321.15	6	73	7.6	2.5	16.7
384329.21	0	22	0.0	0.6	4.0
392228.66	0	54	0.0	0.7	4.7
392243.17	0	10	0.0	0.4	2.7
392243.52	0	36	0.0	1.5	10.0
392657.8	2	11	15.4	1.85	12.3
392661.18	0	51	0.0	1.9	12.7
393077.54	5	39	11.4	2.5	16.7
393385.39	11	55	16.7	2.1	14.0
394005.115	0	44	0.0	1.7	11.3
393574.72 B	0	45	0.0	1.9	12.7
LBr-40	4	35	10.3	3.1	20.7
394038.105	0	33	0.0	2.2	14.7
396082.7	0	43	0.0	0.83	5.5
392270.32	0	37	0.0	0.85	5.7
Panauti	0	22	0.0	2.05	13.7
BSUPO-3	33	38	46.5	2.19	14.6
K. Giriraj	0	25	0.0	0.66	4.4
388764.26	0	41	0.0	1.60	10.7
392206.35	0	67	0.0	1.90	12.7
Rosita (Ch)	**48**	**26**	**64.9**	**3.51**	23.4

Total test entries 45

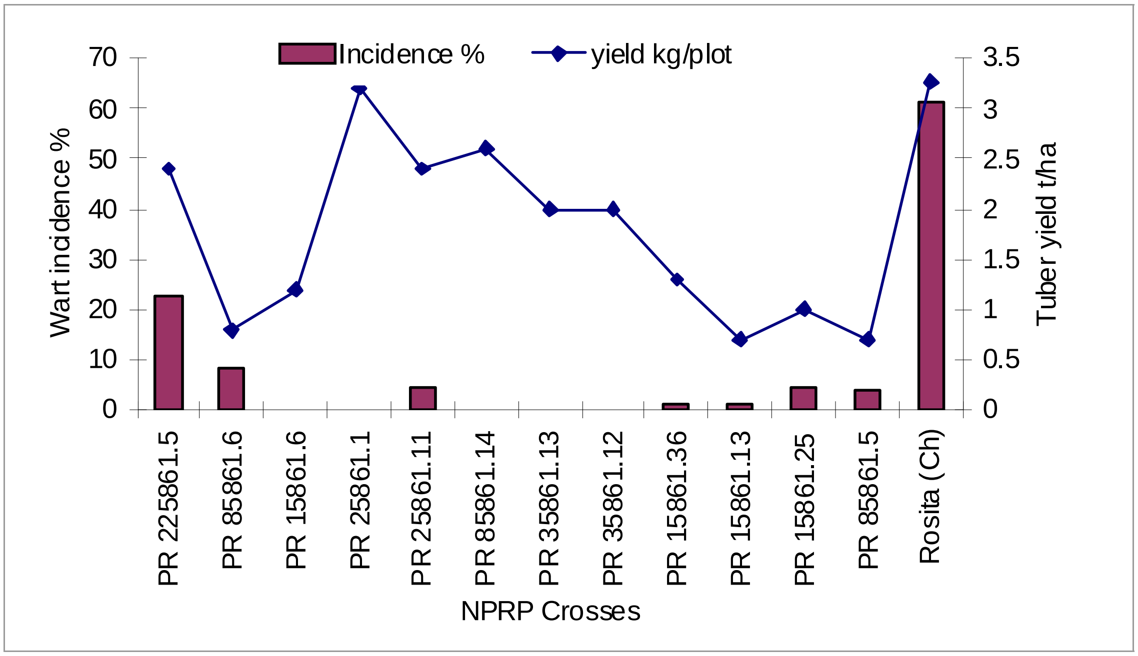

Figure 1. Performance of NPRP crosses against wart disease at Nigale in 2007/08

Black scurf management

There were significant differences in the disease index observed due to the treatments. The plots having healthy seed (pre basic seed) planted in sterilized plots showed minimum disease index by 6.8 % followed by 3% boric acid treated seed planted in sterilized plots (10.8%) and in seed and soil treated with *T. harzianum* (17.1%). Seed treatment with Thiophanate methyl was not found effective in controlling the black scurf disease under farmers field conditions (Table 4).

Treatments were assessed for impact on black scurf disease control based on the severity disease index. On an average disease control was achieved up to 70.9 % where disease free tubers planted in sterilized soil. Efficacy of *T. harzianum* showed effective control with 30.0% over the three crop seasons. Soil sterilization with Formaldehyde 1% had a role of controlling 14.8%. Role of infected seed tubers on developing disease severity was found higher than the *Rhizoctonia* infested soil.

There was no significant differences between treatments of 3% boric acid treated seed and of boric acid 2% concentration in the first two consecutive experimental years, whereas in the third year disease index was found significantly low in Boric acid 3% treated plots (Table 4). Despite of low mean disease index of three years due to seed treatment of boric acid 3% planted in sterilized soil (11.1%) farmers choose seed treatment with boric acid 2% planted in infected soil simply because of low cost on seed treatment and no need of formaldehyde application for soil sterilization.

Over all results of three years showed that planting healthy seed in sterilized soil was the best option for black scurf management. Farmers were found hesitatating for using chemicals like formaldehyde for soil sterilization, which increases the cost of production. Evaluating the pros and cons of all treatments farmers preferred seed treatment with boric acid 2 percent. Application of antagonistic fungus (*T. harzianum*) to tuber treatment, soil treatment and drenching was found comparable with infected seeds planted in sterilized soil with formaldehyde (Table 4). In 2001 Tsror *et al* had also reported the efficacy of *T. harzianum* on pathogenic *Rhizoctonia* in reducing the incidence of black scurf on daughter tubers using naturally infested soil and contaminated seed tubers. Martin and Robert (2005), also have reported similar results on the efficacy of *T. harzianum* against *R. solani*.

Table 4. Black scurf disease index on potato tuber at harvest under field conditions during 2003/04 to 2005/06

Treatments	Disease Index				MDC* %
	03/04	04/05	05/06	Mean	
T1:Seed and Soil treatment with *T. harzianum*	17.7	18.7	16.1	17.5	30.0
T2:Boric acid (3 %) treated seed in sterilized soil	13.4	9.5	10.5	11.1	55.4
T3:Boric acid treated (2%) seed in infected soil	18.3	13.6	11.8	14.6	41.7
T4:Infected seed in sterilized soil	22.6	20.2	21	21.3	14.8
T5:Treated seed with ROKO fungicide in infected soil	25.4	26	16.8	22.7	9.1
T6:Healthy seed in sterilized soil	9.6	4.8	7.6	7.3	70.9
T7:Infected seed in infected soil (Farmer's practice)	27	29.3	18.7	25.0	0.0
F Test	**	**	*		
CV (%)	13.4	22.2	10.4		
LSD(0.05)	4.6	2.4	2.05		

* Mean disease control of three years

Tuber yield from the plot of pre basic seed planted in sterilized plot was highest (29.73 t/ha) followed by seed treatment with boric acid 3% planted in sterilized plot (27.7 t/ha) and *T. harzianum* applied plot (24.88 t/ha). This yield was comparable with the yield of boric acid 2% treated plot (26.04 t/ha). Among the results of three years, yield differences between the two treatments boric acid 2% and 3% in the last two experimental years were found at par. Significantly higher tuber yield was harvested *T. harzianum* treated plot (25.12 t/ha) as compared to farmers practice (Table 5). Results indicate that biological control through *T. harzianum* would be one of the new options for long-term black scurf management under mid western terai conditions of Nepal. When population of *T.harzianum* gets well established in the soil, disease could be controlled significantly in the succeeding years.

Table 5. Effects of different treatments and farmers acceptance score on potato tuber yield (t/ha) under field conditions

Treatments	Tuber yield (t/ha)				FAS (1-5)*
	03/04	04/05	05/06	Mean	
T1:Seed and Soil treatment with *T. harzianum*	27.41	25.12	22.11	24.88	2
T2:Boric acid (3 %) treated seed in sterilized soil	30.32	28.76	24.00	27.70	4
T3:Boric acid treated (2%) seed in infected soil	27.08	27.66	23.38	26.04	1
T4:Infected seed in sterilized soil	23.80	26.50	22.08	24.13	5
T5:Treated seed with ROKO fungicide in infected soil	24.81	22.89	21.71	23.14	5
T6:Healthy seed in sterilized soil	32.87	30.50	25.81	29.73	3
T7:Infected seed in infected soil (Farmer's practice)	23.61	22.49	21.39	22.50	
F Test	**	**	*		
CV (%)	4.54	4.47	7.15		
LSD(0.05)	1.58	2.7	2.89		

* Farmers acceptance score 1= highly accepted; 5 = poorly accepted

The tuber yield of three years was found in decreasing trend. The reason behind it could be the experiment conducted on highly fertile soil and better irrigation in the first year. On second and third year experimental plot was changed as per the farmers' crop rotation scheme. In addition, there was no rainfall during the crop period of third year.

Conclusion and recommendations

The participants did not accept sterilization of soil with Formalin in a large potato growing area. All the treatments connected with soil sterilization were rejected even yield was significantly higher (Table 5). Seed treatment with 2% boric acid planted in unsterilized soil was comparable with boric acid 3% along with soil sterilization. Therefore farmers selected lower dose of boric acid. As the impact of the experiment experiment potato seed producers of Mainapokhar, Bardiya followed seed treatment with Boric acid 2% and a total of 100 kg Boric acid was utilized for this purpose. Similarly, Application of *T. harzianum* produced the significantly higher yield than the check plot. These two treatments were considered as most effective and easy to use under farmers' conditions. Researchers, working with farmers, realized that participatory potato clone selection serves as best statistical tools for significant validation of the result.

References

Burgueno Ferreira, J.A.; Martinez Garza, A.; Crossa, J.M. and Lagunas, A. 2005. Experimental designs with repeated controls. Agrociencia (Montecillo) 39 (6). 679-691

Dutta, B.L. and Gupta, S.C. 1982. Efficacy of treatment of tubers in the control of potato black scurf. Potato in developing Countries. Proceedings of International seminar, 20-30Nov1978. pp 333-338.

Hehl, R.; Faurie, E.; Hesselbach, J.; Salamini, F.; Whitham, S.; Baker, B. and Gebhardt, C. 1998. TMV resistance gene N homologues are linked to *Synchytrium endobioticum* resistance in potato. Theoretical and Applied Genetics.1998 (3/4). 379-386

Hellin, J.; Bellon, M. and Badstue, L. 2006. Bridging the gaps between researchers' and farmers' realities. LEISA Magazine Vol. 22(3) pp 21-28.

Martin, T.B. and Robert, P.L. 2005. Efficacy of several potential bio-control organisms against Rhizoctonia solani on potato. Crop Protection, Volume 21, Issue 11, Pp 939-950.

Norton, G.A. and Mumford, J.D. 1993. Decision analysis techniques. *In* Decision tools for pest management. CAB International, UK.pp43-68.

NPRP. 1994. The effects of different chemicals for the control of black scurf (*Rhizoctonia solani*) disease of potato. Potato Research Programme, Annual report 2050/51(1993/94). pp.36-37.

NPRP. 2005. Annual Report. 2004/05 (2061/62). National Potato Research Programme, Nepal Agricultural Research Council, Khumaltar, Nepal.

NPRP. 2007. Annual Report. 2006/07 (2063/64). National Potato Research Programme, Nepal Agricultural Research Council, Khumaltar, Nepal.

Putnam, M.L. and Sindermann, A. B.1994. Eradication of potato wart disease from Maryland. American Potato Journal. 1994. 71 (11). 743-747.

Scott, R. A. and Milliken, G. A. 1993. A SAS program for analyzing augmented randomized complete-block designs. Crop Science. 1993. 33 (4). 865-867

Sharma, B.P. and Khatri, H.B. 2004. Participatory IDM Research on Potato late blight through Farmers Field School. Advances of Horticultural research in Nepal. *In* proceedings of the Fourth National Workshop on Horticulture.2-4 march, 2004. pp 205-210

Sharma, B.P.; Rambahadur, K.C.; Dhital, S. P.; Haribahaduir, K.C. and Chand, G.B. 2007. Farmers' Empowerment and adoption of Potato Disease Management Technologies through Farmers' Field School and Participatory Research. Proceedings of the 8th National Outreach Research Workshop 19-20 June. pp 220-229.

Stuart,W.; Platt, H.W. and Cattlin., N. 2008. In Diseases, Pests and Disorders of Potatoes: A Colour Handbook. Manson Publishing Ltd. pp64-65.

Tanil, A. J.; Akai and Aota, T. 1982. Chemical control of several diseases transmitted through seed tubers. Potato in Developing Countries. In proceedings of International Seminar. 20- 30 Nov 1978. pp. 271-278.

Tspor, L.; Barak, R. and Synch, B. 2001. Biological control of black scurf on potato under organic management. Crop Protection. Volume 20, Issue 2, pp.145-150.