Deployment of Noval Technologies for The Management of White Grubs in Lower Hills of Nw Himalyan Region

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Abstract
White grubs, a group of destructive insect pests of polyphagous nature, cause severe damage to crop plants in hill ecosystem. The grubs with subterranean habitat feed extensively on the roots and the adults defoliate the plants. A two pronged strategies involving an efficient, light weight, eco-friendly, low cost, light based insect trap for capturing the adults and a novel entomo-pathogen, Bacillus cereus strain WGPSB-2 for the management of grubs were developed. Large scale deployment of the above technologies were done on community basis in 5 locations including 4 villages and one experimental farm of Krishi Vigyan Kendra, Uttarkashi district of Uttarakhand. Three years experiments revealed drastic reduction in beetle population to the tune of 75.8% in low, altitude villages. A significant reduction of the grub population was recorded from 74.11% to 85.17% in three years across the different villages. As a result of reduction in grub population, per cent increase in yield of different crops was recorded from 39.0% to 59.2% in different villages and experimental farm of low hills. The technology is thus, capable of managing white grubs at different altitudes of hills in general and North Western Himalayas in particular.

Keywords
White grub; Bacillus cereus; Entomopathogen; Light trap; Uttarakhand hills; White grubs

Background
Scrub beetles (Coleoperta: Scarabaeids) commonly called as white grub are one of the major limiting factor in agricultural crop production (Sharma,2002). Among the different agro-ecological regions of India, the North Western (NW) Himalayan region comprising of the states of Uttarakhand (UK), Himachal Pradesh (HP) and Jammu-Kashmir (J&K) has been identified as a hot spot for white grub diversity. The damage caused by the grubs under rainfed condition, which account for about 80% of cultivated land in Uttarakhand and HP and 59% in J&K, may vary on an average from 10%~30% but some times complete crop failure is also observed. In NW Himalayas, cereals, millets, pulses, oilseeds and vegetables are cultivated in 1.32 million hectare area with an estimated production of 3.44 million tonnes under rainfed condition during kharif season. The damage caused by the white grubs under such situation at the rate 10% amounts to a loss of 0.34 million tonnes, which consequently causes an estimated economic loss of Rs 1.8 billion annually (Sushil et al., 2008).

Due to intensive cultivation and destruction of forests, white grubs have attained the status of pest of national importance during the last three decades. The grubs, feed on the roots of many agricultural crops, weed hosts, forest trees, ornamental and horticultural crops where as the adults feed on foliages, flower, pollen and fruits of the crops. There is a complex of white grub species prevalent in the agricultural areas of NW Himalaya. Existence of as many as 78 species belonging to sub families Rutelinae, Melolonthinae, Dynastinae, Cetoniinae, Aphodiinae, Euchirinae and Scarabaeinae has been documented from the Uttarakhand alone (Sushil et al., 2008). In Uttarakhand, Anomala dimidiata, Holotrichia longipennis and H. seticollis have been reported as the dominant white grub species (Garg, 1992; Sushil et al., 2007) because of varied altitude, steepness of slops, direction of mountains differences in microclimate were observed; Hence some of the areas of the region become hot spot for the pest.

To combet the problem farmers, extension workers and researchers of the region have been relying mainly on the pesticides, which did not provide sustainable management of the pest. More over use of chemicals pesticides is likely to be abandoned in view of the fact that the Uttarakhand government is pressing to hard for organic farming so the Vivekanand
Paratiya Krishi Anusandhan Sansthan, Almora have developed ecofriendly management tools against white grub. This technology comprising of two components viz., an insect trap for controlling the adults i.e. VL Kurmula Trap-1, which have low cost, light weight, user friendly and socio-economic viable. These installed at strategic location for the mass trapping of the beetles. Which is most appropriate mechanical practice for the management of adult stage of the scarabaeids and a bio-agent, comprising of the talc based formulation of the bacterium, *Bacillus cereus* strain WGPSB-2, considered as an alternative strategy for the management of the pest at the grub stage.

Hence, demonstrate the both component of the technologies in four villages and one experimental farm of lower hills of Uttarakhand to evaluate their effectiveness.

1 Results and Discussions

1.1 Management of beetle stage

In low hills of Uttarkashi district 47 traps (VL Kurmula Trap-1) were installed in four villages and one experimental farm. These traps installed in last week of may to first week of June, 2006 on strategic locations because after this monsoon has come and then beetles emergence start. This emergence are continue upto September month. The result showed that beetles trapped in 1st year (Year 2006) were maximum on experimental farm (0.28 lakh), Galari village (0.26 lakh), Mahargaon village (0.25 lakh) and followed by Tuliyara village (0.24 lakh) and Barethi village (0.22 lakh). The total beetles trapped in lower hills were 1.25 lakh in year 2006. Which showed the reduction in grub population in (damaging stage) were approximately 18.75 lakh. The 2nd year (Year 2007) maximum trapped beetles were 0.15 lakh in village Mahargaon and Barethivillage and followed by Tuliyara, Galari village and experimental farm i.e. 0.14 lakh. The total beetles trapped 2nd year were 0.72 lakh mean approximately 10.80 lakh grub population reduced. The 3rd year (Year 2008) maximum beetles trapped from experimental farm (0.10 lakh) and followed by Barethi village (0.70 lakh), village Mahargaon (0.06 lakh), Tuliyara (0.4 lakh) and Galari (0.4 lakh). The total beetles trapped in year 2008 were 0.31 lakh means grub population reduced approximately upto 4.65 lakh. Reduction in beetles population to the tune of 42.12 and 75.79 per cent was recorded during 2007 and 2008 respectively over the beetle catches of 2006 (Table 1). The peak period of beetle emergence was July in Uttarakhand hills. Three year study revealed that 36 species of white grub beetles were recorded in low hills, in which *Anomala dimidiata*, *A. rugosa*, *A. tristis*, *Holotrichia longipennis*, *H. seticollis* and *Xylotrupes gideon* were dominant. A complex of white grub species has been recorded in Uttarakhand hills, where some of the species cause extensive damage to crop plants (Sushil et al., 2008). The present investigation for the management of white grubs targets two vulnerable stages of the pest viz., adult and grub stages. The two pronged strategy resulted in a significant reduction in the white grub population as evidenced by about 80% reduction in beetle

| Adopted villages | Number of light traps installed | Beetles trapped (in lakhs) | Beetle reduction over 2006 (%) |
|------------------|---------------------------------|---------------------------|-------------------------------|
|                  | 2006  | 2007  | 2008   | 2007 | 2008 |
| Mohargaon       | 12    | 0.25  | 0.15   | 0.064 |        |
| Barethi         | 10    | 0.22  | 0.15   | 0.069 |        |
| Tuliyara        | 10    | 0.24  | 0.14   | 0.039 |        |
| Gailari         | 9     | 0.26  | 0.14   | 0.038 |        |
| Chinyalisaur    | 6     | 0.28  | 0.14   | 0.095 |        |
| Total           | 47    |        |        | 42.12 (Mean) | 75.79 (Mean) |
population within 2 to 3 years evidenced by about 80% reduction in beetle population within 2 to 3 years on entire village basis. Light based insect traps have been reported to be effective tool for mass trapping of the scarab beetles by other researchers too (Carne et al., 1956; Kato et al., 2000). Light based insect traps, unlike pheromone traps, are known to attract insects of both sexes of the scarabaeid (Harai et al., 2000) and this is in conformity of the findings of the present study, wherein both the sexes of more than 50 species of scarabaeids have been recorded through the light traps. The trap is specific to the scarabaeids and was found to trap negligible number of beneficial insects.

1.2 Management of grub stage
Reduction of grub population over the years was recorded in four adopted villages and one experimental farm through pit sampling. Among the adopted villages of low hills, population of white grubs recorded in the all the location Table 2~Table 6 and Table 7. Crop wise pit sampling data revealed a substantial reduction of white grub population over the years. The grub population was very high in June 2006, which went up to 2.6 grubs/ 30 cm² in tomato, 2.3 in potato and 1.6 in French bean. However, due to the continuous mass trapping of beetles and application of the bio-agent, *B. cereus* strain WGPSB–2 through FYM, a remarkable reduction in the grub population to a tune of 0.6 grubs/30 cm² in Aug 2007 and 0.4 grubs/30 cm² in Aug 2008 were recorded in tomato fields. By the end of the cropping season in 2008, the grub population was reduced to 0.2 and 0.4/30 cm² in potato and French bean fields, respectively. The mean per cent reduction in the grub population was 75.4% by the end of second year and it reduced further up to 83. 6% by the end of the third year. Similar trend was recorded in the other adopted villages of low hills. Crop wise pit sampling from the WGPSB–2 applied field, data showed that consistence decrease in the population of the grubs in the all the adopted villages. However in starting of the experiment, population was almost some or marginally high in non-adopted village. Based on periodic pit sampling, the overall reduction of grub population ranged from 70.5 to 84.3% in low hills of Uttarakhand state with a significant increase in crop yield.

The early stage grubs are known to feed on soil organic matter and hence it is the most suitable stage to control them through soil inhabiting entomopathogens. Therefore, microbial control was considered as viable and sustainable strategy for its management. The soil environment, rich in entomopathogens (Hochberg, 1989). In the present investigation, we isolated, characterized and evaluated the potential of bacterial pathogens as biological control agents against white grubs of north western Himalayan hill region. *Bacillus cereus* strain WGPSB–2 was found to cause about 90% mortality in predominant species of white grubs of the region. Thus considering the potential of the bio-agent, *B. cereus* strain WGPSB–2, protocol for mass production and talc based formulation was developed and found effective (Sushil et al., 2008).

This is in conformity with the earlier report by Sezen et al (2005) in which the insecticidal effect of a *B. cereus* isolate on larvae of the scarab, *Amphimallon solstitiale* was found to an extent of 90% mortality. In addition, several strains of *B. cereus* have also been isolated from various insects (Lipa and Wiland, 1972; Sezen and Demirbag, 1999).

1.3 Yield enhancement
Mean yield of different crops was recorded in all the villages and per cent increase in yield of the adopted villages was calculated and compared with the non-adopted villages of different altitudes. Data presented in the Table 8, reveal the per cent increase in yield of different crops in the adopted villages over non-adopted villages. The mean per cent increase in yield in adopted villages were 51.7 in tomato, 46.4 in potato, 39.0 in chilli and 59.2 in French bean was recorded during the three years of experimentation over non adopted village.

Approximately 495 hectare area was covered across the Uttarakhand hills benefiting 125 farm families of lower hills of Uttarkashi district during the course of experimentation. The present investigation on white grub management through combination of light mediated insect trap and bacterial formulation has led to the development of eco-friendly, cost effective and sustainable technology. Adoption of this approach is expected to help in the management of white grubs in other areas too.
Table 8  Per cent increase in yield of different crops in the adopted villages over non adopted villages

| Crop* | Mean Yield (q/ha) | Mean percent increase in yield |
|-------|-------------------|--------------------------------|
|       | 2006-2007 A B C | 2007-2008 A B C | 2008-2009 A B C |                   |
| Tomato | 171.0 105.0 62.8 | 170.6 104.0 64.0 | 237.6 185.5 28.4 | 51.7               |
| Potato | 213.6 150.0 42.4 | 215.8 145.0 48.8 | 211.8 143.0 48.1 | 46.4               |
| Chilli | 48.7 36.0 35.2   | 51.7 35.0 47.7   | 58.8 40.0 46.9   | 39.0               |
| French bean | 88.1 50.0 76.2 | 89.2 50.0 78.4 | 86.2 80.0 23.1 | 59.2               |

Note: A: Adopted village; B: Non adopted village; C: Increase (%); Varieties: Tomato: Manisha/ Himsona; Potato: Kufri jyoti; Chilli: Pant chilli; French bean: Contender/Arka komal

2 Materials and methods
The demonstration of newly developed technologies were conducted in villages and one experimental farm of lower hills (Below 1 000 amsl) of Uttarkashi district of Uttarakhand. The villages were selected based on random sampling of white grub occurrence. Only those villages were selected in which 10 grubs per square meter at 10 location were recorded.

2.1 Installation of insect traps
Considering the topography and aspect of the mountain, the newly developed light trap, VL-kurmulaTrap were installed at strategic locations of the adopted villages. Normally, one trap was installed in 1~2 ha area for mass trapping of the beetles. Total 47 light traps installed in four villages and one experimental farm of lower hills of Uttarkashi district (Table 9).

2.2 Application of bio-agent
Talc-based formulation of B. cereus strain WGPSB–2 with a spore load of 1×10^10/g was prepared as per the method of Sushil et al (2008). and the same was applied in all the compost pits made in the adopted villages and subsequently in the fields in order to get desired level of disease occurrence and mortality in the grub population. The talc based formulation was applied in the compost pits at the rate of 1 kg/tonne basis, a month before application in the field. It is noteworthy, that B. cereus strain WGPSB–2 has strong ability to colonize on different compost substrates Sushil et al (2008). In the worst affected fields a dose of 10 kg/ha talc based formulation of the bio-pesticide was applied directly.

2.3 Data recording and statistical analysis
Recording of the beetles trapped in the VL-kurmulaTrap–1 was done regularly from June to October during 2006 to 2008 in all the adopted villages. The number of beetles trapped and per cent reduction during the study period of three years has been calculated. Samplings were done every month for recording the grub occurrence under field condition. Pits of 30 cm² were dug with a depth of 20 cm at 20 random locations for assessment of the white grub population in the village for one crop. A similar method was adopted for different crops grown in the adopted villages. Data obtained was subjected to standard deviations and mean was calculated for comparison. Mean yield of different crops grown in the village was recorded and per cent increase in yield was calculated in comparison of the non-adopted villages for consecutive three years.

Table 9  List of villages adopted for testing and demonstration of white grub management technologies in low hills (<1000 m amsl)

| Sl. No. | Village       | Altitude (m amsl) | Block      | District    |
|---------|---------------|-------------------|------------|-------------|
| 1       | Mahargaon     | 900               | Chinyalisaur | Uttarkashi  |
| 2       | Barethi       | 855               | Chinyalisaur | Uttarkashi  |
| 3       | Tuliyara      | 850               | Chinyalisaur | Uttarkashi  |
| 4       | Galari        | 850               | Chinyalisaur | Uttarkashi  |
| 5       | K.V.K. Farm, Chinyalisaur | 855 | Chinyalisaur | Uttarkashi  |
Authors contributions
Dr. Deepak Rai have conducted designed plan of work and write the manuscript; Dr. S.N.Sushil and Dr. J. Stanley have analysis of data; RamKewal and J.P.Gupta have conducted the experiment; Dr. Veenika Singh have checked the manuscript critically responsibility for appropriate portions of the content.

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References
Bhatt J.C., and Sushil S.N., 2004, A compendium on diseases, insects and weeds of maize and wheat crops in Indian Himalayas, Vivekanand Parvatiya Krishi Anusandhan Sansthan (Indian Council of Agricultural Research), Almora, pp.118
Bourner T.C., Glare T.R., and Jackson T.A., 1996, Towards green pastures pathogens and pasture pests, New Zealand Journal of Ecology, 20:101–107
Carne P.B. and Chinnick L.J., 1956, The pruinose scarab (Sericesthis pruinose Dalman) and its control in turf, Australian Journal of Agricultural Research, 8: 604-616, http://dx.doi.org/10.1071/R9570604
Garg D.K., 1992, Insect Pests of Agricultural Crops in UP Hills and their Management, Vivekanand Parvatiya Krishi Anusandhan Sansthan (Indian Council of Agricultural Research), Almora, 25p
Harai A.R., Ben-Yakir D., and Rosen D., 2000, Male pioneering as a mating strategy: the case of the beetle Maladera matrida. Ecological Entomology, 25: 387–394, http://dx.doi.org/10.1046/j.1365-2311.2000.00278.x
Hochberg M.E., 1989, The potential role of pathogens in biological control, Nature, 337: 262-265, http://dx.doi.org/10.1038/337262a0
Hosking G.P., 1979, Trap comparison in the capture of flying coleopteran, Applied Entomology and Zoology, 34: 85–89
Kato M., Itioka T., Sakai S., Momose K., Yamane S., Hamid A.A., and Inoue T., 2000, Various population fluctuation patterns of light attracted beetles in a tropical lowland dipterocarp forest in Sarawak, Population Ecology, 42: 97–104, http://dx.doi.org/10.1007/s10440050014
Klein M.G., 1992, Use of Bacillus popilliae in scarab control, In use of pathogens in scarab pest management (eds Jackson T.A. and Glare T.R) Andover, UK: Intercept, pp.179–189
Lips J.J., and Wiland., 1972, Bacteria isolated from cutworms and their infectivity to Agrotis spp. (Lepidoptera, Noctuidae), Acta Microbiologica Polonica, 4: 127–140
Selvakumar G., Mohan M., Sushil S.N., Kundu S., Bhatt J.C., and Gupta H.S., 2007, Characterization and phylogenetic analysis of an entomopathogenic Bacillus cereus strain WGPSB-2 (MTCC 7182) isolated from white grub Anomala dimidiata (Coleoptera: Scarabaeidae), Biocontrol Science and Technology, 17: 525–534, http://dx.doi.org/10.1080/09583150701311663
Sezen K., Demir I., Kati H., and Demirbag Z., 2005, Investigations on bacteria as a potential biological control agent of summer chafer, Amphimallon solstitialis L. (Coleoptera: Scarabaeidae). Journal of Microbiology, 43: 463–468
Sezen K., and Demirbag Z., 1999, Isolation and insecticidal activity of some bacteria from the hazelnut beetle (Balanius nucum L.), Applied Entomology and Zoology, 34: 85–89
Sharma G., 2002, Indian phytophagous Scarabs and their management: Present status and future strategy. Jodhpur, India: Agrobios, pp.216
Stahly D.P., and Klein M.G., 1992, Problems with in vitro production of spores of Bacillus popilliae for use in biological control of the Japanese beetle, Journal of invertebrate Pathology, 60: 283-291, http://dx.doi.org/10.1016/0022-2011(92)90010-2
Sushil S.N., Mohan M., Bhatt J.C., and Gupta H.S., 2007, Management of white grubs in Uttarakhand hills, In National conference on Recent Trends in Rice Pest Management, CRRI, Cuttak, pp.40
Sushil S.N., Mohan M., Selvakumar G., Bhatt J.C., and Gupta H.S., 2008, Isolation and toxicity evaluation of bacterial entomopathogens against phytophagous white grubs (Coleoptera: Scarabaeidae) in Indian Himalayan hills, International Journal of Pest Management, 54: 301–307, http://dx.doi.org/10.1080/09670870802182724
Sushil S.N., Mohan M., Selvakumar G., Bhatt J.C. and Gupta H.S., 2008, White Grubs of Uttarakhand Hills and their Eco-Friendly Management, Technical bulletin no. 28, Vivekanand Parvatiya Krishi Anusandhan Sansthan (Indian Council of Agricultural Research), Almora, pp.49
Suzuki N., Hori T., Tachibana M., and Asano S., 1994, Bacillus thuringiensis strain buibui for control of cupreous chafer, Anomala cuprea (Coleoptera: Scarabaeidae), in turfgrass and sweet potato, Biological control, 4: 361–365, http://dx.doi.org/10.1006/bcon.1994.1045
Vyas R.V., Yadav D.N. and Patel R.J., 1991, Studies on mass production of Bacillus popilliae var. holotrichiae, a promising pathogen of white grub in Gujarat, Gujarat Agricultural University Research Journal, 17: 30-37
Table 2 Per cent reduction of grub population in different crops of the adopted village, Barethi (855 m amsl) in low hills

| Crop       | 2006       | 2007       | 2008       | A  |
|------------|------------|------------|------------|---|
|            | June      | July       | Aug        | Sep | Oct | June      | July       | Aug        | Sep | Oct | June      | July       | Aug        | Sep | Oct | 2006 | 2007 | 2008 |
| Tomato     | 2.0±0.7   | 1.6±0.8   | 1.6±0.4   | -   | -   | 1.0±0.8 | 1.1±0.8   | 0.6±0.7   | -   | -   | 0.8±0.8   | 0.6±0.7   | 0.5±0.5   | -   | -   | 20.0 | 70.0 | 75.0 |
| (1-3)*     | (1-2)     | (0-4)      | (1-2)      | -   | -   | (1-2)    | (1-2)      | (0-1)      | -   | -   | (0-2)      | (0-2)      | (0-2)      | -   | -   |      |      |      |
| Potato     | -         | -         | 1.2±0.6   | 1.0±0.1 | -   | -   | 0.4±0.5 | 0.4±0.5   | -   | -   | 0.4±0.5   | 0.4±0.5   | 0.3±0.4   | 0.3±0.4 | 0.3±0.4 | 37.5 | 66.7 | 75.0 |
| Chilli     | 1.2±0.3   | 1.2±0.3   | -         | -   | -   | 0.6±0.5 | 0.4±0.5 | -         | -   | -   | 0.4±0.5   | 0.3±0.4   | -         | -   | -   | 0.00 | 66.7 | 75.0 |
| (0-2)      | (0-2)      | -         | (0-2)      | -   | -   | (0-1)    | (0-1)      | -         | -   | -   | (0-1)      | (0-1)      | -         | -   | -   |      |      |      |
| French     | 1.4±0.5   | 0.0±0.1   | -         | -   | -   | 0.7±0.8 | 0.3±0.5 | -         | -   | -   | 0.5±0.5   | 0.4±0.5   | -         | -   | -   | 29.0 | 78.6 | 71.4 |
| bean       | (0-3)      | (0-2)      | -         | -   | -   | (1-2)    | (0-1)      | -         | -   | -   | (0-1)      | (0-1)      | -         | -   | -   |      |      |      |

Mean per cent reduction in grub population: 21.6 70.5 74.1

Note: A: Per cent Reduction in grub population over June, 2006

Table 3 Per cent reduction of grub population in different crops of the adopted village, Tuliyara (850 m amsl) in low hills

| Crop       | 2006       | 2007       | 2008       | A  |
|------------|------------|------------|------------|---|
|            | June      | July       | Aug        | Sep | Oct | June      | July       | Aug        | Sep | Oct | June      | July       | Aug        | Sep | Oct | 2006 | 2007 | 2008 |
| Tomato     | 2.4±0.3   | 1.8±0.8   | 1.0±0.7   | -   | -   | 1.2±0.9 | 0.8±4.2   | 0.4±0.5   | -   | -   | 0.7±0.5   | 0.6±0.8   | 0.4±0.5   | -   | -   | 58.3 | 83.3 | 79.2 |
| (1-4)      | (1-2)     | (0-2)      | (1-2)      | -   | -   | (1-2)    | (0-1)      | (0-1)      | -   | -   | (0-1)      | (0-2)      | (0-1)      | -   | -   |      |      |      |
| Potato     | -         | -         | 0.6±0.6   | 0.6±0.4 | -   | -   | 0.5±0.5 | 0.4±0.5   | -   | -   | 0.5±0.5   | 0.8±0.8   | 0.6±0.8   | 0.5±0.5 | 0.2±0.5 | 66.7 | 77.8 | 77.8 |
| Chilli     | 1.8±0.8   | 0.8±4.4   | -         | -   | -   | 0.5±0.4 | 0.5±0.5 | -         | -   | -   | 0.5±0.7   | 0.4±0.5   | -         | -   | -   | 55.6 | 72.2 | 77.8 |
| (1-2)      | (1-2)     | (0-1)      | (1-2)      | -   | -   | (0-1)    | (0-1)      | -         | -   | -   | (0-1)      | (0-1)      | -         | -   | -   |      |      |      |
| French     | 1.8±4.4   | 1.0±0.5   | -         | -   | -   | 1.1±0.9 | 0.6±0.5 | -         | -   | -   | 0.3±0.48  | 0.3±0.48  | -         | -   | -   | 44.4 | 66.7 | 83.3 |
| bean       | (1-2)      | (0-2)      | -         | -   | -   | (1-2)    | (0-1)      | -         | -   | -   | (0-1)      | (0-1)      | -         | -   | -   |      |      |      |

Mean per cent reduction in grub population: 21.6 70.5 74.1

Note: A: Per cent Reduction in grub population over June, 2006; * Figures in parentheses are range
Table 4  Per cent reduction of grub population in different crops of the adopted village, Mahargaon (900 m amsl) in low hills

| Crop         | Mean number of grubs/square feet (30 cm²) ± standard deviation | A         | 2006       | 2007       | 2008       | 2006       | 2007       | 2008       | 2006       | 2007       | 2008       |
|--------------|----------------------------------------------------------------|-----------|------------|------------|------------|------------|------------|------------|------------|------------|------------|
|              | Mean number of grubs/square feet (30 cm²) ± standard deviation | A         | 2006       | 2007       | 2008       | 2006       | 2007       | 2008       | 2006       | 2007       | 2008       |
| Tomato       | 2.6±0.7 (0-5) 2.4±0.3 (0-5) 2.0±0.4 (0-5) 0.8±0.8 (1-2) 0.6±0.8 (1-2) 0.6±0.5 (0-1) 0.7±0.5 (2-2) 0.6±0.8 (2-2) 0.4±0.5 (0-1) | 31.6      | 23.0       | 76.9       | 84.6       |
| Potato       | - - - 1.2±0.6 (0-3) 0.8±0.1 (0-2) - - - 1.1±0.9 (1-2) 0.3±0.5 (0-1) - 0.8±0.8 (0-2) 0.6±0.8 (0-1) 0.5±0.5 (0-1) 0.2±0.5 (0-1) | 33.0      | 37.5       | 62.5       | 87.5       |
| French bean  | 1.6±0.1 (0-2) 1.0±0.5 (0-1) - - - 1.1±0.9 (1-2) 0.6±0.5 (0-1) - - - 0.8±0.8 (0-2) 0.2±0.8 (0-1) - - - 0.2±0.5 (0-1) 0.3±0.5 (0-1) 0.2±0.4 (0-1) 0.2±0.4 (0-1) | 37.5      | 20.0       | 70.0       | 80.0       |
| Mean per cent reduction in grub population | | 31.6 | 23.0 | 76.9 | 84.6 |

Note: A: Per cent Reduction in grub population over June, 2006

Table 5  Per cent reduction of grub population in different crops of the adopted village, Galari (850 m amsl) in low hills

| Crop         | Mean number of grubs/square feet (30 cm²) ± standard deviation | A         | 2006       | 2007       | 2008       | 2006       | 2007       | 2008       | 2006       | 2007       | 2008       |
|--------------|----------------------------------------------------------------|-----------|------------|------------|------------|------------|------------|------------|------------|------------|------------|
| Tomato       | 1.6±1.4 (0-3) 1.2±0.1 (0-3) 1.0±2.2 (0-2) 0.5±0.5 (0-1) 0.8±0.8 (1-2) 0.5±0.5 (0-1) - - - 0.6±0.7 (0-1) 0.6±0.5 (0-1) 0.4±0.5 (0-1) | 37.5      | 37.5       | 68.7       | 75.0       |
| Potato       | - - - 1.0±0.1 (1-2) 0.8±0.1 (0-2) - - - 0.6±0.7 (0-1) 0.3±0.5 (0-1) - 0.4±0.5 (0-1) 0.3±0.5 (0-1) 0.2±0.4 (0-1) 0.2±0.4 (0-1) | 20.0      | 20.0       | 70.0       | 80.0       |
| Chilli       | 1.6±5 (0-1) 1.4±0.5 (0-2) - - - 0.4±0.5 (0-1) 0.3±0.5 (0-1) - - - 0.4±0.5 (0-1) 0.2±0.4 (0-1) - - - - | 12.5      | 12.5       | 81.3       | 87.5       |
| French bean  | 1.4±0.5 (0-2) 1.0±0.7 (0-2) - - - 1.0±0.8 (0-2) 0.5±0.5 (0-1) - - - 0.6±0.5 (0-1) 0.6±0.5 (0-1) - - - - | 28.6      | 28.6       | 64.3       | 57.1       |
| Mean per cent reduction in grub population | | 24.8 | 24.8 | 71.1 | 74.9 |

Note: Per cent Reduction in grub population over June, 2006
### Table 6 Per cent reduction of grub population in different crops of the adopted village, KVK, Farm (855 m amsl) in low hills

| Crop          | 2006       |       |       |       | 2007       |       |       |       | 2008       |       |       |       |       |       |       |       |       |
|---------------|------------|-------|-------|-------|------------|-------|-------|-------|------------|-------|-------|-------|-------|-------|-------|-------|-------|
|               | March      | April | May   | June  |            | July  | August| Sep   | Oct        | June  | July  | August| Sep   | Oct   |       |       |       |       |
| Tomato        | 2.6±0.9    | 0.5±0.5| 0.6±0.8| 0.3±0.5| 0.5±0.5    | 0.3±0.5| 0.4±0.5| -     | 46.2       | 88.5  | 84.6  | 30.0  | 84.3  | 85.2  |       |       |       |       |
|               | 2.0±0.4    | (0-2)  | (1-2) |       |            | 1.4±0.5| (0-2) |       | 28.6       | 78.6  |       | 14.3  |       |       |       |       |       |       |
| Potato        | -          | -     | 1.4±0.5| 1.0±0.8| -          | -     | -     | 0.3±0.5| 0.5±0.5    | -     | -     | -     | 3.5±1.3| 3.1±1.3|       |       |       |       |
| French bean   | 1.4±0.5    |       | 0.5±0.5| 0.2±0.4| 0.3±0.5    | 0.2±0.4| 0.3±0.5| -     | -          | -     | -     | -     | 4.0±1.1| 3.9±1.1| 3.5±1.3| 3.1±1.3|       |       |
|               | 1.2±0.4    | (0-2)  | (1-2) |       |            |       |       | 0.3±0.5| -          | -     | -     | -     |       |       |       |       |       |       |
| Mean per cent reduction in grub population | 30.0 | 84.3 | 85.2 | | | | | | | | | | | | | | |