

## **CROP PROTECTION PROGRAMME**

Promotion and impact assessment of tomato leaf curl virus disease resistant tomatoes: phase III of sustainable management and molecular characterisation of *Bemisia tabaci* and tomato leaf curl virus (ToLCV) on tomato in India

**R No 8247 (ZA 0546)**

## **FINAL TECHNICAL REPORT**

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## Executive Summary

The whitefly, *Bemisia tabaci* (Gennadius), and tomato leaf curl virus disease (ToLCVD) currently cause huge economic losses in most tropical and sub-tropical regions of the world. In response to the demand for a solution to this “burning problem” in India, previous phases of this project developed three open-pollinated (OP = true breeding) ToLCVD-resistant tomato varieties, as well as alternative management practices to the intensive use of pesticides. These new technologies and practices were designed to enable tomatoes to be grown with greatly reduced input costs and without the use of insecticides and, therefore, they directly benefit the poorest farmers, consumers and the environment.

The wider aims of this phase were to begin to create a significant developmental impact, firstly by obtaining official authorization to release the three ToLCVD-resistant tomato varieties and, subsequently, to promote and disseminate them alongside the alternative pest and disease management practices. These activities involved developing links with other stakeholders in the public and private sectors, as well as NGOs, who provided efficient uptake pathways.

In the early stages of this phase, the three ToLCVD-resistant tomato varieties, named *Vybhav*, *Nandi* and *Sankranthi*, were released successfully and were notified in the Gazette of India for use throughout India. As part of this process, the National Bureau of Plant Genetic Resources, New Delhi, conserved the varieties’ seed.

Demonstration field days were held at the University of Agricultural Sciences and successful negotiations took place with commercial vegetable seed producers. This resulted in ten of them taking up the rights, on a non-exclusive basis, to multiply and distribute the varieties and/or use them as parental material to develop ToLCVD-resistant hybrids. The latter process is still underway and several of the seed companies have provided the project with information, which shows that they are close to developing ToLCVD-resistant hybrid tomatoes.

Through cooperation with the commercial seed companies, data on the performance of the tomato varieties in different Indian States have been obtained, and samples collected of the different tomato leaf curl virus species and *B. tabaci* populations present in those locations. The molecular and biological data obtained were published in scientific journals and presented at an international conference. The project’s results, lessons learnt and ideas for ‘the way forward’ were used to prepare a policy briefing paper. They were also been promoted through the release of radio and TV programmes and by building a project web site.

Information has been collected and compiled for worldwide seed distribution through AVRDC. Impact assessment data were also collected with regard to the economic, social, health and environmental benefits to Indian farmers who are growing the project’s varieties. The data showed that these farmers could obtain up to 10 times the profits achieved by growing an existing ToLCVD-susceptible OP variety and that they used the extra income for improved nutrition, children’s education and health.

In order to ensure the sustainability of the project’s impact, a ‘revolving fund’ is in the process of being set up by the National Seed Project of the University of Agricultural Sciences, where receipts from seed sales through various outlets are used to produce replacement seed that, in turn, will be sold.

## Background

After China, India is the world's second largest vegetable producer with 5.5 million ha of land under vegetable crops and an annual production of 74 million tonnes. At present, vegetable production in India is limited by losses caused by insect pests and diseases to the extent that the per capita consumption of vegetables is only 25 - 33% of the daily minimum requirement.

Over the previous two decades, whiteflies have been gaining worldwide prominence as important crop pests, causing direct and indirect losses through phloem feeding, the excretion of honeydew and the transmission of viruses. In 1987-88 in India, the estimated yield loss due to whitefly-transmitted viruses was 1.2 million tons, representing an annual loss of approximately US\$53 million. Since then, and with the arrival of the B biotype of *B. tabaci*, the magnitude of this already serious problem has increased.

As part of a response to the problem in tomatoes, the UASB screened 1306 *Lycopersicon* genotypes for resistance to ToLCV, with the long term objective of introducing ToLCV-resistance genes into edible tomatoes through conventional plant breeding techniques (Muniyappa et al., 1994). The UASB was keen to collaborate with integrated pest management (IPM) researchers in areas outside its current field of expertise and therefore the initial phase of the project assessed a range of measures with the potential to address these problems.

At approximately the same time, the task force that initiated the Inter Centres Initiative on Whiteflies identified evidence for a global demand for research in this area. More specifically, in Asia, the Asian Vegetable Research and Development Centre (AVRDC) included under *Project 1, Solanaceous Vegetables*, the priority activity: *Integrated technologies to control tomato geminiviruses*. AVRDC, therefore, were able to provide the project with tomato germplasm, which could be screened to identify the best sources of resistance to ToLCVD in South India.

In the first phase of the project, the socio-economic survey showed a clear demand from all types of tomato farmers for ToLCVD-resistant varieties (Nagaraju et al., 2002) and, in the second phase, it was decided to focus efforts on meeting this demand.

In the second phase of the project, the farmer-participatory trial results on ToLCVD resistant varieties TLB111, TLB 130 and TLB 182 were presented at the Joint Meeting of the Zonal Research Extension Advisory Council (ZREAC) and Zonal Research Extension Formulation Committee (ZREFC) for the different zones in Karnataka State, where technical Officers from the State Departments of Agriculture, Horticulture and farmers representatives were present. During annual Krishi melas (demonstration farmer field days) the varieties were also exhibited and feedback obtained from farmers. Each year about 4,000 farmers were able to see the varieties and provide feedback. Throughout this participatory process, all of the above stakeholders provided encouragement and continued to express a clear demand for the project's outputs.

In June 2001, at the end of the second phase, a workshop was held at the UASB, which was attended by approximately 500 participants who included tomato farmers, extension workers, private-seed company representatives and both government and university research scientists. There was a discussion about how to maximise the impact of the ToLCVD-resistant lines, which by this stage had stopped segregating and had effectively become true breeding varieties. It was concluded that their chances of being widely adopted and generating impact would be improved if the private sector became involved. This would either occur through their production, distribution and sale, or through the development of tomato hybrids in which the ToLCV resistance had been incorporated. It was felt that the latter route could be handled by the private sector on its own, but that there was scope by the public sector to promote the varieties in their own right to the poorest farmers. These

farmers usually grow open-pollinated tomato varieties and could produce their own seed from the project's varieties. In the past, the varieties available to them have had no ToLCV-resistance and therefore tomato production involved particularly high financial risks in the ToLCV-epidemic season, often resulting in complete crop failure and loss of capital invested in the crop.

Justification for a third phase of the project, which is the subject of this report, was based on the following advantages evident in the newly developed ToLCVD-resistant tomato varieties.

- Greater than 100% increase in yields compared to susceptible varieties and on-farm trial benefit to cost ratios as great as 6.6 to 1.
- A 50-75% reduction in insecticide use applied for control of whiteflies and geminiviruses.
- Increased tomato production during ToLCVD-epidemic periods, leading to reduced seasonality of tomato supply and lower prices for consumers.
- Lower production costs and higher productivity leading to higher farmer income and of other stakeholders involved in the supply chain.
- Reduced risk of crop loss from ToLCVD that may encourage more poor farmers to grow tomatoes.
- Improved understanding of disease epidemiology, which has already led to the design of rational and environmentally friendly management techniques.
- Increased understanding and improved awareness of whiteflies and ToLCV amongst stakeholders and the general public.
- Facilitation of ToLCV-resistant hybrid development by the private sector.

The outputs of this project were considered to have the potential to reach millions of the poorest tomato farmers in India and have an enormous impact. An important activity proposed for the third phase, therefore, was to begin to collect impact assessment data and also on the worldwide distribution of the project's varieties.

### **Project Purpose**

Promotion of pro-poor strategies to reduce the impact of key pests, improve yield and quality of crops, and reduce pesticide hazards in peri-urban systems.

Improved methods for the management of insect pests of fruit and vegetables, particularly whitefly and spider mites, developed and promoted

### **Research Activities**

1. *Facilitation of the final approval and release of the ToLCV-resistant tomato varieties TLB 111, TLB 130 and TLB 182 by attending the meeting of the Varietal Release Committee. A demonstration field day will be held at the UASB to which Heads of relevant Institutes, private seed company and NGO representatives will be invited. The UASB Technology Transfer Committee and project staff will carry out negotiations for non-exclusive licences with interested parties.*

These activities were carried out as planned (see Outputs below).

2. *Selected seed companies and/or NGOs to carry out their own trials in different areas of India. These trials will be monitored by project staff to (a) collect molecular diagnostic data to confirm any potential ToLCV infection or presence of the B biotype of B. tabaci. Fifteen to twenty samples per location of tomatoes showing ToLCVD symptoms will be collected and tested by PCR for the presence of ToLCVs. Samples will be taken independently, i.e. from different plants and from different*

areas within each location, by a randomised selection process. *B. tabaci* biotype identification will be carried out by RAPD-PCR on five individuals per site. For those sites where populations have unusual RAPD patterns, CO1 sequences will also be obtained; (b) provide plant protection advice and best cultivation practices depending on the results of part a (years 1-2) (UASB, NRI).

These activities were carried out as planned (see Outputs below).

3. At least three populations of *B. tabaci* associated with ToLCV epidemics will be characterised by RAPD-PCR and CO1 gene sequences as described by Maruthi et al. (2001). The *B. tabaci* populations on brinjal are normally relatively high, but appear to be separate from those associated with ToLCV-host plants. At least two 'brinjal' *B. tabaci* colonies will also be established and characterised molecularly. Reciprocal crossing experiments according to the methodology described in Maruthi et al. (2001, 2002) will be carried out to determine whether or not the 'brinjal' and the 'ToLCV-epidemic' populations interbreed (years 1-3) (UASB, NRI). At least one peer-reviewed scientific paper will be written from research carried out in this and previous phases and the results will be presented at an international conference (years 1-3). Dr Muniyappa will visit NRI in the second and final year to assist in writing up the project's data into a publication on ToLCV and *B. tabaci* that will be placed on the CPP web-site (years 2 & 3) (UASB, NRI).

These activities were carried out as planned apart from the web publication, which became something more ambitious. After a review of the information generated by the project, it was decided to apply for an add-on to build a project web site. This was approved and the web site has been built (see Outputs below).

4. (a) Impact assessment data will be collected on the scale of the distribution of the ToLCV-resistant varieties. The Karnataka State Seed Agency, the AVRDC and the UASB will collect and supply data on the numbers of requests, the amount of seed supplied and to whom. The UASB will also keep records of the numbers of private seed companies and NGOs that take out non-exclusive rights to market the varieties. A standardised data collection sheet will be provided to these agencies. (b) In collaboration with the seed companies, the intended distribution areas will be identified and a base-line data survey will be carried out prior to any seeds being distributed. General demographic and geographic information will also be collected about the areas, e.g. weather, soil types, economic status, in case these affect the statistical outcomes. An initial stratification of possible locations will be carried out and a stratified sampling scheme devised. Data will also be collected on the factors that influence household livelihoods that can realistically be attributable to the uptake of these varieties. At this stage, measures will also be developed for assessing the performance of the distribution agencies as leading indicators of the likely impact of the project. (year 2). (c) The quantity of seed distributed and sold in the different tomato production areas of India will be obtained. Dependent on the seed distribution data, visits will be carried out to selected locations where farmers have been growing the tomato varieties for at least one ToLCV-epidemic season to collect short-term impact assessment data on the economic, health, social and environmental benefits of growing them (years 3) (NRI, UASB). As the project ends in March 2005, the full impact of the varieties may not have had sufficient time to be generated and so this impact assessment will probably be an underestimate of the longer-term impact.

These activities were carried out as planned (see Outputs below).

5. *A policy briefing paper on the impact of ToLCV and the B biotype will be prepared, which will collate the views of farmers, scientists, NGOs and private business representatives. Further press articles will be prepared for the media to increase awareness of the project's outputs (year 3) (UASB, NRI).*

This activity was carried out as planned (see Output below).

#### **Additional outputs: (Add-on) Setting up of a project web site**

As mentioned above, an add-on was agreed to build a project web site. The agreed activities were:

- *Data collection to be set up electronically*
- *Outlining of the first draft of the web site*
- *Presentation of the draft to stakeholders*
- *Feedback of the stakeholders*
- *Completion of the web site*
- *Electronic set up*
- *Launching of the web at the end of April 2004*

The project has developed a web site to provide a mechanism to disseminate electronically, the results, achievements, lessons learnt from the project. The website has not yet been handed over to the UASB, due mainly to this activity becoming more ambitious over time and the large quantity of material that has been generated and compiled. Some outstanding alterations and text for the section on Impact Monitoring will be added before the end of March. The web site will then be handed over to the UASB and will be maintained within the UASB's web site under 'Breakthrough Research'. The project's web site can currently be viewed at: <http://www.mensacomp.com//tomato/>

#### **(Add-on) Impact generation & promotion activities for the UAS National Seed Project, GKVK, and Extension Education Unit, Nagenahalli**

As the project progressed, it became clear that the OP-growing farmers are unwilling to pay the high price of hybrid seeds and other associated production costs (particularly plant protection). It was necessary, therefore, for the University's National Seed Project (NSP) and Directorate of Extension to promote the project's OP tomatoes by putting into place a sustainable system involving a revolving fund. The USAB proposed to produce sufficient seeds to be able to market and sell the tomato varieties in seed packets before the beginning of the summer of Feb. 2005 to April 2005, when the ToLCVD problem would be severe. The seed packets would have information on germination requirements, genetic purity and would highlight the varieties' resistance to tomato leaf curl virus disease. With the receipts obtained from selling the seed, the University would set up a revolving fund, which it will use to produce more seed for subsequent sales. The specific activities were:

- *ToLCV-resistant tomato seed production by contract farmers through the NSP.*
- *Seed packets produced for three genotypes, Nandi, Sankranthi and Vybhav.*
- *Training programmes & field days for tomato farmers. Emphasis will be placed on the reduced costs of production, which lowers the farmers' risk. Also, the message will be transmitted to the farmers that these varieties can be grown without spraying insecticides to control ToLCV.*
- *Promotion of the project's varieties will be organised through exhibition materials, radio and TV coverage prior to the summer season of 2005.*

These activities were carried out as planned (see Outputs below).

## References:

- Maruthi MN, Colvin J, Seal S (2001) Mating compatibility, life-history traits and RAPD-PCR variation in *Bemisia tabaci* associated with the cassava mosaic disease pandemic in East Africa. *Entomologia Experimentalis et Applicata* **99**, 13-23.
- Maruthi MN, Colvin J, Seal S, Gibson G, Cooper J (2002) Co-adaptation between cassava mosaic geminiviruses and their local vector populations. *Virus Research* **86**, 71-85.
- Muniyappa, V., Padmaja, A.S., Venkatesh, H.M., Sharma, A., Chandrashekar, S., Kulkarni, R.S., Hanson, P.M., Chen, J.T., Green, S.K., Colvin, J. (2002) Tomato leaf curl virus resistant tomato lines TLB111, TLB130, and TLB182. *HortScience*, **37**, 603-606.

## Outputs

1. *Official release of ToLCV-resistant tomato varieties and non-exclusive agreements with NGOs and/or private seed companies to multiply and distribute, and/or market at least one variety.*

After the State Seed sub-committee meeting, held on 03/12/02, the UASB Director of Research sent a letter to Dr Muniyappa asking him to send seed samples of the three varieties to the National Bureau of Plant Genetic Resources (NBPGR). Dr Muniyappa then submitted the seed samples of the three varieties, *Sankranthi* (TLB-111), *Nandi* (TLB-130) and *Vybhav* (TLB-182) to the NBPGR. Subsequently, the Head, Germplasm Conservation Division (NBPGR) informed the UASB that the genetic material had been conserved in the National Genebank at NBPGR, New Delhi. *Sankranthi*, *Nandi* and *Vybhav* have been assigned, respectively, the following National Identity Numbers, IC 296388, 296389, 296390 (Annex 1).

A meeting of the Central sub-committee on Crop Standards, Notification and release of Varieties for Horticultural Crops took place where the submission of the three varieties was considered. At this meeting, the three varieties were amongst the few approved for Notification. Following consultation with the Central Seed Committee, official notification took place by the variety names being published in The Gazette of India on May 31, 2004. This means that these are notified agricultural varieties for use in the whole of India (Annex 2).

*Demonstration field day will be held at the UASB to which Heads of relevant Institutes, private seed company and NGO representatives will be invited.*

The success of the project's tomato varieties had already received wide publicity in the Indian press and articles about them appeared in the Economic Times, Prajavani and the Deccan Herald. This generated widespread interest and, as a result, the importance of these breakthrough varieties, which reduce the costs of cultivation and are pesticide free, was raised in a parliamentary question.

In addition, more than 10 private seed companies expressed an interest in obtaining non-exclusive licensing agreements to use the varieties. On 21<sup>st</sup> June 2002, therefore, a demonstration field day and meeting was held with interested seed company representatives at the UASB, Hebbal Campus. After this, negotiations with commercial seed companies by UASB Technology Transfer Committee for non-exclusive licences were carried out and the 10 companies listed in Table 1 purchased breeder seed from the UASB. In addition, seed was supplied to two NGOs who were interested in the varieties: One in Hyderabad called the Centre for World Solidarity and one called Gram Vikas Samstha – Andhra Pradesh Farmer Managed Ground Water

Systems Project, Madanapalli, who have distributed seeds to their farmers to try out this season. In addition, AVRDC has responded to Indian and international requests for seed of these varieties (Tables 2 & 3).

2. Data on the performance of at least one of the TLB varieties in different locations within India, with respect to the ToLCV strains and *B. tabaci* biotypes present in those locations.

The varieties were grown in several new states, including northern India (Himachal Pradesh) and Nagpur (central India). Eight of the companies returned information on crop performance and most stated that the tomatoes did not show any ToLCVD symptoms. The highest incidence was seen in Haryana, where it reached 5.5% (Table 4).

Samples of ToLCV-infected tomato plants, weeds and *B. tabaci* populations were collected and analysed molecularly (Chowda Reddy *et al.*, 2005 Annex 3) The non-indigenous B biotype of *Bemisia tabaci* was identified in three regions (Kolar and Nagamangala in Karnataka and from several locations in Gujarat State), which supports previous predictions that its distribution within India would expand (Chowda Reddy, 2004).

Project staff provided information on best cultivation practices and prepared a single sheet pamphlet, written in the local language of Karnataka. This described the resistant tomato varieties' characteristics, their high yield potential, low production costs and the significant advantage that they can be grown without insecticides, which are normally sprayed intensively on susceptible tomato varieties to protect them against *B. tabaci* and ToLCVD (Annex 4).

3. Molecular and biological data on the *B. tabaci* biotypes associated with ToLCVD epidemics.

Analysis of the Coat Protein DNA sequence data for the viruses found in leaf curl symptomatic plants showed that there were five different ToLCV groups in India. ToLCVs were detected in alternative hosts including chilli, cowpea, okra and tobacco, as well as the weeds *Croton* sp., *Parthenium* sp. and *Malvastrum* sp. *Papaya leaf curl virus* and *Pepper leaf curl Bangladesh virus* were also detected in tomato for the first time. At least two completely new ToLCV species were identified. These data appear in Chowda Reddy (2004) and Chowda Reddy *et al.* (2005) (Annex 3 and listed below).

Colonies of three *B. tabaci* populations from eggplant, collected from Rannibenur, Coimbatore and Belgaum, and a population from *E. geniculata*, collected from Bangalore, were established in the NRI insectary. The CO1 gene sequences of the Rannibenur, Coimbatore and Bangalore populations were obtained and they fitted into the previously identified population clusters. The reciprocal crosses were carried out and the data were published in Maruthi *et al.* (2004) (Annex 5) and in Rekha A.R. Swamy (2004a) (Annex 6). Some of these data were also presented at the 2nd European Whitefly Symposium (see below) and there are sufficient whitefly data remaining to write an additional paper.

4. Impact assessment and benefit:cost data available for at least one TLB variety.

A survey form was prepared and approved by the NRI statistician (Annex 7). Regions were identified in Karnataka and Andhra Pradesh where open pollinated (OP) tomato varieties are widely grown. More than 90 farmers were then visited and socio-economic data collected from them. As an additional activity, a small group of 20 farmers were given the ToLCV-resistant tomato seed. These were monitored



closely and compared with another group of farmers in the same area who are growing the traditional ToLCV-susceptible varieties. A comparison of the benefit:cost obtained from the two farmer categories showed that those growing the project's tomatoes made up to 10 times more profit than those growing ToLCV-susceptible OPs (Tables 5 – 7).

The data from the survey carried out in the first year have been analysed and written up into a report called, "Socio-economic baseline survey of farmers growing open-pollinated and hybrid tomatoes in Karnataka" (Annex 8). Additional survey data were also collected from farmers in Kaggere and Chittur districts. Sufficient data are now available for a journal publication and this has been proposed as one of the activities for the nine month extension period.

Links were also maintained with the private seed companies that purchased the project's ToLCV-resistant lines, in order to collect impact data. Companies such as Namdhari, Cee Kay and Ankur Seeds have been very co-operative and responded positively to our impact assessment questionnaire. They are making rapid progress towards producing ToLCV-resistant hybrid varieties that have our lines as one of the parents.

Even though most of these farmers have only been growing the project's varieties for a single season, their improved income is already clearly apparent. In group four, all the farmers confirmed that the project's varieties are good yielders and ToLCVD resistant. Farmers obtained good price by selling these varieties in the local market equal to that of farmers' other varieties. In this group, three farmers are growing the resistant varieties for the second time. This is because they are convinced by the yield in spite of not having used staking in the crop. Out of the three varieties, their most preferred was Vybhav.

In the baseline-survey data, farmers said that any increased income would be spent on improved education for their children, improved nutrition and medical welfare. The project's varieties, therefore, contribute directly to the improved livelihoods of these farmers and in the longer term will potentially generate a greater impact. Recording this will justify to DFID that the research funds have been used wisely and productively and have improved the livelihoods of the poorest farmers.

5. A policy briefing paper on the impact of ToLCVD, *B. tabaci* and, in particular, the B biotype and release of further press articles in the media.

A policy briefing paper called, "Countering the whitefly and plant-virus disease threat to sustainable livelihoods in India", has been written and produced as a leaflet (Annex 9A & B), which will be handed out to the appropriate participants at the project workshop, which is to be held during the extension period.

Press articles, radio and TV programmes have been released on the project's outputs (see below).

#### **Additional outputs: (Add-on) Setting up of a project web site**

As part of the impact generation process, the project has developed a web site to provide a mechanism to disseminate electronically, the results, achievements, lessons learnt from the project over the previous nine years. The website has not yet been handed over to the UASB, due mainly to this activity becoming more ambitious over time. Some outstanding alterations and text for the section on Impact Monitoring will be added before the end of March. The web site will then be handed over to the UASB and will be maintained within the UASB's web site under 'Breakthrough Research'. The project's web site can be viewed at: <http://www.mensacomp.com//tomato/>

#### **(Add-on) Impact generation & promotion activities for the UAS National Seed Project, GKVK, and Extension Education Unit, Nagenahalli**

By September 2004, it had become clear that the private sector, which is focussing on breeding ToLCV-resistant hybrids, would create enormous impact amongst 'better-off' tomato growers. The poorest growers, however, risked missing out on getting access to the project's OP varieties, because of a lack of effort at promoting them by the private sector. In order to address this potential problem, a 'revolving fund' has been set up by the National Seed Project.

Fifty thousand seed packets (Annex 10) have been produced for the sale of the ToLCV-resistant tomato varieties. Technical information such as crop name, variety, lot number, date of test, date of validity, quantity, purity (min.), other crop seeds (max), weed seeds (max), germination (min), moisture (max.) etc were printed on the packets. Five and ten gram seeds were packed separately for each variety. In view of the demand for growing these resistant tomato varieties in kitchen gardens one-gram seed packets were also prepared.

In order to reduce grower input costs, the cost of seed sold by the UASB outlets was reduced from Rs. 20 /g to Rs.13.50/ g for Vybhav and from Rs. 15/ g to Rs 8.50/ g for both Sankranthi and Nandi.

In order to try to obtain feedback on the ToLCVD resistant varieties without having to visit farmers' at their farms, survey letters were sent to those who had purchased seed from the National Seed Project (NSP), the Agricultural Technology Information Center (ATIC) and different UAS campus Krishi Melas. They were asked to give their opinion about the performance of variety, incidence of tomato leaf curl virus and yield potential compared to other open pollinated varieties. Unfortunately, only two farmers responded to the letter, although both were completely satisfied with variety performance, resistance to ToLCVD and yield. Of these two farmers, one requested the purchase of an additional 120 g of Vybhav seed.

The UASB conducted two field days with training programmes at Mandya (Kannahatti village on 22/12/04) and Nagamangala (Kachanahalli and Sahana nursery of Bellur Cross on 10/1/05) taluks.

All India radio was contacted and TV coverage has already taken place filmed at KVK, Gulbarga (Dharwad Agricultural University), 13<sup>th</sup> Feb 2005. An additional full TV programme has been prepared and will be put out on air shortly.

Wren Media also conducted interviews with project staff (October 2004, track 5) and produces a programme called, "Sustainable solution to tomato virus".

A brief description of the ToLCV resistant varieties *Vybhav*, *Nandi* and *Sankranthi* and information regarding the package of practices, season of growth, yield potential and availability of seeds was published in the well known Agricultural monthly magazine called as *Halli Kara* during the month of December 2004.

Due to these promotional efforts, total quantities of seed sold so far are **5.95** kg and demand is increasing. There is especially strong demand for Vybhav and sales occur through the Agricultural Technology Information Centre (ATIC), the (NSP), the Dept. of Plant Pathology, UASB, and are beginning to take place through Krishi Vignana Kendras (KVKs) (Table 8).

**Publications:** \*Not reported previously in this phase.

#### **Journal papers**

Chowda Reddy, R.V., Colvin, J., Muniyappa, V. and Seal, S.E. (2005) Diversity and distribution of begomoviruses infecting tomato in India. *Archives of Virology*, in press. DOI 10.1007/s00705-004-0486-5.

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- Chowda Reddy, R.V., Muniyappa, V., Colvin, J. and Seal, S.E. (2005) A new begomovirus isolated from *Gossypium barbadense* in Southern India. *Plant Disease*, in press.

#### Abstracts

- Colvin, J., Chowda Reddy, R.V., Rekha, A.R., Muniyappa, V., Seal, S.E., Maruthi, M.N. (2004) Ecological and reproductive isolation amongst African and Asian *Bemisia tabaci* populations. p. 12. In: *Proceedings of the 2<sup>nd</sup> European Whitefly Symposium*. 5 – 9 October. 2004. [abstract] English (A).
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- Rangaswamy, K.T., Raghavendra, N., Shankarappa, K.S., Govindappa, M.R., Aswatha Narayana, D.S. and Prameela, H.A. (2004) Analysis of indigenous and B biotype *Bemisia tabaci* whitefly for esterase profiles and activity. Abst. In National symposium on Molecular Diagnostics for the management of Viral Diseases, held at IARI, New Delhi, 14-16th October. p-78. [abstract] English (A).
- Shankarappa, K.S., Manjunatha Reddy T.B., Raghavendra, N., Rangaswamy, K.T. and Prameela, H.A. 2004. Biotype determination of Karnataka populations of *Bemisia tabaci* whiteflies. Abst. In: Symposium on Biology, Biotechnology, Epidemiology and Management of Plant Diseases, held at Gulbarga 9th – 10th December, p-40. [abstract] English (A).
- Shankarappa, K.S., Rangaswamy, K.T., Raghavendra, N., Govindappa, M.R., Girisha Reddy, M.C., Manjunath, B. and Prameela, H.A. (2004) RAPD analysis of *Bemisia tabaci* whitefly populations of southern Karnataka. Abst. In: National symposium on Molecular Diagnostics for the Management of Viral Diseases, held at IARI, New Delhi, 14-16th October. p-85. [abstract] English (A).

#### MSc and PhD Theses

- CHOWDA REDDY, R.V. (2004) Molecular characterisation of tomato leaf curls viruses and their vector, *Bemisia tabaci*. PhD Thesis, Natural Resources Institute, University of Greenwich. 269 pp. (F).
- REKHA A. R. SWAMY (2004a) Evidence of cryptic sibling species amongst the *Bemisia tabaci* populations of the Indian sub-continent and diversity of associated begomoviruses. MSc Thesis. Natural Resources Institute, University of Greenwich. 125 pp. (F).
- REKHA A. R. SWAMY (2004b) Molecular characterization of pumpkin yellow vein mosaic virus and *Bemisia tabaci* on vegetables and weeds. PhD thesis. University of Agricultural Sciences, Bangalore. 157 pp (F).

#### Internal Reports:

1. Quarterly reports submitted to NR International each quarter
2. Annual reports submitted to NR International at the end of each financial year
3. Field visit reports
4. Varietal approval and notification meeting reports.

- State Seed Sub-committee (03/12/02).
- Minutes of the 9<sup>th</sup> meeting of the Central Seed Committee on Crop Standards, Notification and Release of Varieties for Horticultural Crops. 27/12/02, Coimbatore.

#### **Other Dissemination of Results:**

##### **Extension information**

Tomato leaf curl virus resistant varieties and their cultivation practices. Factsheet. Kannada. 1p. University of Agricultural Sciences, Bangalore, India. (Factsheet).

\*Dharwad Agricultural University have included photographs and descriptions of our ToLCV-resistant varieties in their book on Package of Practices for Horticultural Crops, pp. 172-173.

##### **Radio, TV programmes & newspaper articles**

All India Radio has been contacted and TV coverage has already taken place filmed at KVK, Gulbarga (Dharwad Agricultural University), 13<sup>th</sup> Feb 2005. An additional full TV programme has been prepared and will be put out on air shortly. Due to these promotional efforts, demand for seeds is increasing.

\*Wren Media also conducted interviews with project staff (October 2004, track 5) and produced a programme called, "Sustainable solution to tomato virus".

Deccan Herald (8<sup>th</sup> November 2003). The success of the ToLCV-resistant tomato genotypes was recognised at the valedictory function of the Krishi Mela-2003. Agricultural monthly magazine called as *Halli Kara* (December 2004). Description of the ToLCVD-resistant varieties and pest management practices.

##### **Varietal Notification for use throughout India**

The Gazette of India. The notified tomato variety seeds of *Sankranthi*, *Nandi* and *Vybhav* can be sold for the purposes of agriculture. 31<sup>st</sup> May 2004.

#### **Contribution of Outputs to developmental impact**

Include how the outputs will contribute towards DFID's developmental goals. The identified promotion pathways to target institutions and beneficiaries. What follow up action/research is necessary to promote the findings of the work to achieve their development benefit? This should include a list of publications, plans for further dissemination, as appropriate. For projects aimed at developing a device, material or process specify:

All of the outputs were achieved and in several cases exceeded. The only activity remaining to be completed is the updating and handing over to the UASB of the project web site. The outputs have contributed to the project goal by developing, promoting and disseminating ToLCV-resistant tomato varieties and pest management recommendations that, if followed, produce higher tomato yields and reduce insecticide use. They also provide the poorest farmers with up to 10 times the profit, which is spent on improved diet, children's education and health. The project has, therefore, begun to generate significant impact and, at the same time, has improved our understanding of the factors driving whitefly transmitted plant-virus disease epidemics in India.

The project is also at a stage where we are able to produce a significant number of additional peer-reviewed scientific publications. Interest generated in the scientific and donor communities by research publications of this type should stimulate further research in this area, which will ultimately benefit the growers.

- a. What further market studies need to be done?

In the future and in order to assess the impact of the project, impact data needs to be collected from private seed companies on the distribution and sales of the ToLCV-

resistant hybrids that they are currently developing. In order to assess the longer term developmental impact of the project, the farmers identified in this phase who are using the ToLCV-resistant OP varieties could be re-assessed two to three years after the end of the this phase in order to collect additional information on how the project's technologies had improved their livelihoods.

b. How the outputs will be made available to intended users?

The project will benefit the poorest tomato growers directly by providing technology to manage their most important biological constraint. Seed will be available to farmers through the outlets described above and the system will be sustainable, because of the mechanism of a 'revolving' fund. We are also proposing an additional nine month phase to this project in order to ensure that the maximum impact is generated from the project's outputs. After this, we have applied for further funding for promotion and dissemination activities through the Inter Centres Tropical Whitefly Initiative (Phase III).

The other ways the outputs will be available to the intended users are through the:

- UASB extension services.
- The media.
- Private seed companies such as Mahyco, Nagarjuna Group, Sungrow, Leadbetter.
- The AVRDC South Asian Vegetable Research Network and the CGIAR Tropical Whitefly IPM Project, and the AVRDC website for distribution of the technologies and information to other researchers worldwide.
- NGOs, who are involved in livelihood systems.

c. What further stages will be needed to develop, test and establish manufacture of a product?

Sixty percent of the area under tomato production in India involves OP varieties and so, in order to maximise impact, it is desirable that one or more commercial seed company becomes involved in the multiplication, distribution and marketing of the project's tomatoes. Many small private seed companies market inbred lines and we will try to interest one based in either Orissa or West Bengal during the nine month extension period.

d. How and by whom, will the further stages be carried out and paid for?

Further funding is necessary because the project has been so successful in identifying several potentially extremely useful IPM measures and technologies that have the potential to impact greatly on the *B. tabaci*/ToLCV problem in India. The two proposal mentioned above have been approved for funding, which will ensure that the outputs of this project have clear uptake pathways over the next three years. The private seed companies and the NGOs that we work with will make a contribution in kind.

### **Biometricians Signature**

*The projects named biometrician must sign off the Final Technical Report before it is submitted to CPP. This can either be done by the projects named biometrician signing in the space provided below, or by a letter or email from the named biometrician accompanying the Final Technical Report submitted to CPP. (Please*

*note that NR International reserves the right to retain the final quarter's payment pending NR International's receipt and approval of the Final Technical Report, duly signed by the project's biometrician)*

I confirm that the biometric issues have been adequately addressed in the Final Technical Report:

Signature:

Name (typed):

Position:

Date:

Table 1. Seed companies that purchased the ToLCV resistant varieties

Sl. No	Name & Address	Varieties (Qty in gms)			Date	Amount (Rs)
		Sank-ranathi	Nandi	Vybhav		
1	Unicorn Seeds Ltd., 1-7-139/3,Sarogini Devi Road, Hyderebad-500003	2	2	2	03.03.03	17000.00
2	Zuari Seeds Ltd., 805,13 <sup>th</sup> A cross,80 feet Road, Yelahanka New Town, Bangalore-560064	--	2	2	10.03.03	12000.00
3	Namadhari Seeds Pvt Ltd., Uragahalli P.O. Bidadi-562109	2	2	2	12.03.03	17000.00
4	Cee Kay Seeds &Seedlings 12 K.M., Opp.Jakkur Aerodrome, Jakkur Post, Bangalore-560064	--	--	2	13.03.03	7000.00
5	ECL Agrotech Ltd. N0.101, Varsha Apt. 220/24,Sir C.V.Raman Road,RMV Extension,Bangalore-80	2	--	2	17.03.03	12000.00
6	Century Seeds Pvt Ltd. BA-22-24,Phase II Industrial Area Mangolpuri Delhi-110034	2	2	2	21.03.03	17000.00
7	Ankur Seeds Pvt Ltd. 27,New Cotton Mkt Layout Opposite Bus Station Nagapur-440018	2	2	--	22.04.03	10000.00
8	Nath Seeds Ltd. Nath House, Nath Road, P.B.No.318, Itkheda Aurangabad-431005	2	2	2	30.05.03	17000.00
9	Ashoka Farm Aids No.11,2 <sup>nd</sup> Main,2 <sup>nd</sup> Block Goraguntepalya, Yashavanthapur,Bangalore- 25	2	2	2	27.11.03	17000.00
10	Pradham Biotech Pvt. Ltd. No. 207, Orange Block, Myhome rainbow complex, Tolichowki Road, Hyderbad- 500 008	10	10	-	24-01-05	300-00
Total qty		14	14	16		126300.00

\*Cost : Sankranthi- Rs.5000/ 2 g, Nandi- Rs. 5000/ 2g, Vybhav- Rs.7000/ 2g.

Table 2. Distribution of ToLCV resistant varieties by AVRDC.

Name & Address	Varieties (Qty in gms)		
	Sankranthi TLB 111	Nandi TLB 130	Vybhav TLB 182
Prof. Zhihao XU Institute of Vegetable Zhejiang Academy of Agricultural Sciences 198 Shiqiao Road, Hangzhou, 310021 Zhejiang Province P.R. of China Email: zhxu2003@sohu.com			
Farmer Seed & Agricultural Co. Ltd. P.O. Box 45, Siu Swei 504 Tiawan	100 seeds	100 seeds	100 seeds
S. Gorin GREEN Co. Ltd 81/10 BHO VAN HUE Street Dist. PHU NHUAN, Ward 9 HO CHI MINH CITY VIETNAM Email1: <a href="mailto:GreenCo@green-seeds.com">GreenCo@green-seeds.com</a> Email1: <a href="mailto:GreenCo@tropical-seeds.com">GreenCo@tropical-seeds.com</a>	1 gm	1 gm	1 gm
E.T. Metwally Horticulture Department Faculty of Agriculture Kafr El-Sheikh 33516 EGYPT			
Anthony Tse Clover Seed Co. Little Hong Kong Village Lots 91-104	1 gm	1 gm	1 gm
Yurie Shintaku 2-10-2, Shimizu, Suginami – ku Tokyo, 167-0033 JAPAN	100 seeds	100 seeds	100 seeds



Table 3. Distribution through AVRDC of ToLCV resistant varieties in India.

Name & Address	Varieties (Qty in gms)		
	Sankranthi TLB 111	Nandi TLB 130	Vybhav TLB 182
RASI Seeds Ltd. 273, Karajanagar Road Attur, Salem district Tamil Nadu 636102 INDIA	100 seeds	100 seeds	100 seeds
Vishal Seeds Ltd 8-2-108/3, Hastinapuram North Nagarjuna Sagar Road Vanasthali Puram Hyderabad, AP-500070	100 seeds	100 seeds	100 seeds
Southern petrochemical Industries Corporation Seed conditioning Unit & Breeding Research Centre Kelamangalam Road, Cattle Farm Post Hosur-635110 Tamil Nadu INDIA	1 g	1 g	1 g
Zuari Seds Limited 805,13 <sup>th</sup> A Main, 80 feet Road Yelahanka New Town Bangalore 560064 INDIA	100 seeds	100 seeds	100 seeds

Table 4. Summary of the performance of ToLCV resistant tomato varieties at R & D farms of different seed companies

Sl. No.	Name of the Company and place of grown	Sankranthi			Nandi		Vybhav		Opinion/ Utilisation of Project's tomato varieties
		Season	Fruit yield/ ha (ton)	ToLCV disease incidence (%)	Fruit yield/ ha (ton)	ToLCV disease incidence (%)	Fruit yield/ ha (ton)	ToLCV disease incidence (%)	
1	Namadhari Seeds, Pvt., Ltd, Bidadi, Bangalore rural Dist	Aug 2003	55	0	55	0	60	0	Good yielder, very good resistant to ToLCV, used in breeding programme.
2	<i>Century Seeds Pvt Ltd,</i> Research Farm, Haryana	March 2004	40	5.5	40	4.5	65	2.5	Good tolerance to ToLCV and good yielding potentiality. In future resistant source and other fruit quality will be used in breeding programme
3	<i>Nath Bio Genes (India Ltd) Pvt, Ltd,</i> Aurangabad	Nov 2003	38.03	3.7	19.58	1.9	27.88	0	Good tolerance to ToLCV. ToLCV tolerance source will be used in breeding programme
4	<i>Ashoka Farm Aids, Magadi Road. Bangalore,</i>	June 2004	50	0	55	0	60	0	Good yielder and further use in breeding programme
5	<i>Ankur Seeds Pvt Ltd,</i> Hingana, Dist-Nagpur	August 2003	50	0	50	0	65	0	Good resistant to ToLCV, foliage was excellent and resistant source will be used in breeding programme.

Table 4 continued

6	ECL Agrotech Ltd, Nelamangala Bangalore Rural Dist	April 2003	56	0	Not purchased	62	0	Fruits of Sankranthi are acceptable as variety where as Vybhav may not be accepted as variety and both will be used in breeding programme	
7	Zuari seeds Ltd Doddaballapur Bangalore rural Dist	April 2003	Not purchased		50	Moderate tolerant to ToLCV	65	Tolerant/ resistant to ToLCV	Acceptable fruit quality, used for local market, cab be distributed to farmers and also used in breeding programme
8	Cee Kay Seeds and seedlings, Kanakapur Bangalore rural	April 2003	Not purchased		Not Purchased		88	0	Vigorous, Good tolerance to ToLCV, good firmness, very good bearing even under high temperature further will be used in breeding programme
9	Uni corn Seeds Pvt Ltd, Hyderbad	April 2003	Results awaiting		Results awaiting		Results awaiting		-
10	Pradham Biotech Pvt Ltd, Hyderbad	Jan 2005	Results awaiting		Results awaiting		Results awaiting		

Table 5. Profits gained by farmers of Mysore and Mandya District who grew the ToLCV-resistant variety Nandi and other OPs

Farmers Name and Place of Grown	Tomato var. Grown	Yield obtained (kg/ Acre)		Cost of Cultivation per acre		Total Income obtained		Net profit	
		Nandi	PKM-1	Nandi	PKM-1	Nandi	PKM-1	Nandi	PKM-1
Singappa, Naganahalli	Nandi PKM-1	9300	1750	10180	7690	23000	9625	12820	1935
Jagadeesh Gowda, Naganahalli	Nandi PKM-1	6000	1675	8010	5425	11910	6650	3900	1225
Mani, Manikyapura,	Nandi PKM-1	9800	1700	10850	6625	19600	7700	8750	1075
Mahadev, Kalstavadi	Nandi PKM-1	7500	2050	11125	6200	19000	7175	7875	975
Puttathayamma, Halebudhanur	Nandi Ruchi	10553	2120	13855	8560	21105	7330	7250	-1230
Somashekar, Halebudnur	Nandi Ruchi	14000	2250	11860	7465	21600	7875	9740	410
Siddegowda, Kudlukuppe	Nandi PKM-1	9000	2150	10485	6225	18000	7525	7515	1300
Lokesh, Kudlukuppe	Nandi PKM-1	7405	2250	9650	7500	18810	7875	9160	375
Thyagaraju, Kaggere	Nandi PKM-1	8000	2300	10880	7545	17600	8050	6720	505
Average		9062	2027	10766	7026	18958	7756	8192	730

Rs 1.5-2.75 / Kg of Nandi and Rs 3.5-5.5/ kg of PKM-1 variety

Table 6. Profits gained by farmers of Kaggere, Mysore District, who grew the ToLCV-resistant variety Nandi and other OPs

Farmers Name and Place of Grown	Tomato var. Grown	Yield obtained (kg/ Acre)		Cost of Cultivation per acre		Total Income obtained		Net profit	
		Nandi	PKM-1	Nandi	PKM-1	Nandi	PKM-1	Nandi	PKM-1
Thyagaraju, K.T. S/o K.B.Thammaiah	Nandi PKM-1	9200	2500	10820	5300	23000	8750	12180	3450
K.P.Suresh s/o Puttegowda	Nandi PKM-1	9700	2250	9900	7145	24250	7875	14350	730
D. Raju s/o Devegowda	Nandi PKM-1	8500	1250	11370	4800	21250	4375	9880	-425
Kumar s/o Marigowda	Nandi Ruchi	6800	2650	10890	8505	17000	9275	6110	770
G. Puttaswamy s/o Gundappa	Nandi Ruchi	8500	2280	12600	7065	21250	7980	8650	915
K.B.Prakash s/o Basevegowda	Nandi PKM-1	9600	2240	12650	6410	24000	7840	11350	1430
K.R.Nagaraju S/o Ramegowda	Nandi PKM-1	10200	2350	12500	8233	25500	8225	13000	2
Kantharaju S/o Nagendrappa	Nandi PKM-1	7500	2470	13250	8010	18750	8645	5500	635
Ramakrishne Gowda	Nandi PKM-1	8700	2500	13100	7028	21750	8750	8650	1722
Average		8744	2276	11897	6944	21861	7968	9963	1025

Rs 2.5 / Kg of Nandi and Rs 3.5/ kg of PKM-1 variety

Table 7 Profits gained by farmers of Chittor District, who grew the ToLCV-resistant varieties Sankranthi and Nandi

Farmers Name and Place of Grown	Tomato var. Grown	Yield obtained (kg/ Acre)		Cost of Cultivation per acre		Total Income obtained		Net profit	
		Sankranthi/ Nandi	PKM-1/ NP-5005	Sankranthi/ Nandi	PKM-1/ NP-5005	Sankranthi / Nandi	PKM-1/ NP-5005	Sankranthi /Nandi	PKM-1/ NP-5005
Ramamohan, Cheegalabailu	Nandi NP-5005	6000	4500	14650	15170	24000	22500	9350	7330
G. Kannaiah, Cheegalabailu	Nandi PKM-1	7200	3500	13450	13120	18000	16500	4550	3380
Ramakrishna, Cheegalabailu	Sankranthi Swathi	4590	4000	18492	16470	36720	20000	18228	3530
Chandrashekar, Barlapalli	Sankranthi NP-5005	10500	3000	20800	15290	84000	24000	63200	3610
Ravishankar, Angallu	Sankranthi NP-5005	9500	5000	15720	13570	47500	25000	14280	11430
Ramappa, Kantivarapalli	Nandi NP-5005	9000	4750	18230	18115	54000	33250	35770	15135
Bayya Reddy, Nayanabavi	Nandi NP-5005	8500	6750	21820	22100	42500	40500	20680	18400
Reddy Shekar, Chowdepalli	Sankranthi PKM-1	10000	4000	20235	16290	60000	20000	39765	3710
Kuppaswamy, Malleri	Sankranthi PKM-1	6500	2500	12980	10130	32500	12500	19520	2370
Average		7976	4222	17375	15583	44357	23805	25038	8047

Rs.1.50-6.0 / kg of ToLCV resistant varieties (Sankranthi & Nandi), Rs. 5.0-8.0/ kg of Check varieties

Table 8. Summary of the quantities of seed sold through the UASB outlets.

<b>Different places</b>	<b>Quantity (gm)</b>		
	<b>Sankranthi</b>	<b>Nandi</b>	<b>Vybhav</b>
<b>Agricultural Technology Information Center (ATIC), Hebbal, Bangalore</b>	<b>100</b>	<b>60</b>	<b>-</b>
<b>National Seed Project (NSP), GKVK</b>	<b>238</b>	<b>260</b>	<b>1272</b>
<b>Dept. of Plant Pathology UAS, Bangalore</b>	<b>780</b>	<b>2095</b>	<b>392</b>
<b>Krishi Vignana Kendra, Kandili, Hassan (District)</b>	<b>250</b>	<b>250</b>	<b>250</b>
<b>Total quantity</b>	<b>1368</b>	<b>2665</b>	<b>1914</b>