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Australian Centre for International Agricultural Research

Final report

project

Heat stress alleviation in summer vegetables: enhancing the use of genetic diversity in central Punjab Pakistan

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Contents

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Executive summary

The Pakistani province of Punjab has predominantly a semi-arid climate where average temperatures rise above 40^{o}C during the summer. Vegetable production can be severely limited by periods of very high temperature. Although high temperature stress is less common in Australia, this is projected to change as climate becomes more variable (CSIRO Report, 2006). This project addresses the significant need for high temperature tolerant tomato and okra cultivars for both Pakistani and Australian production conditions.

The intensity and duration of heat stress in Pakistan is much greater than experienced in the countries where most of Pakistan's vegetable seeds are produced. However, surprisingly little research has focussed on the limitations of high-temperature stress on tomato and okra production in Pakistan. ACIAR commissioned the current project to introduce more heat tolerant tomato and okra materials in Pakistan.

Diverse germplasm of tomato (330 lines) and okra (193 lines) was collected from various local and international sources and evaluated for heat tolerance in controlled and field conditions in Pakistan and Australia. A range of heat tolerant materials were identified and characterized and molecular markers linked to this response were subsequently identified to assist future cultivar development.

These heat tolerant materials were then multiplied and shared with partners including The Directorate of Vegetable Research Institute in Faisalabad, The National Agricultural Research Centre in Islamabad and IHS at University of Agriculture, Faisalabad, Pakistan. The best new tomato materials with tolerance to heat stress were also made available to the Australian project partner, Abundant Produce, for use in Australia.

Pakistani farmers were trained in cultivation strategies specifically designed for vegetable production under high temperatures. Sixteen farmer training workshops were organized in various districts of Punjab and more than 1,050 male and female farmers participated in these events. In addition, 35 local extension workers were trained in these production techniques at IATI Sargodha, Pakistan.

This research also provided a strong basis for post-graduate development in both countries. Eight postgraduate students (two PhD and six Masters) at The University of Agriculture, Faisalabad and three PhD students at The University of Sydney completed their thesis research within the scope of the project.

Information generated by the project has been widely disseminated. Details on vegetable production under high temperatures were delivered in technical brochures. Four booklets on various aspects of vegetables production in Punjab were published in the Urdu language. Three research papers have so far been presented/published in conferences/scientific journals and more are in the pipeline. An international seminar on vegetable production and a workshop on vegetable seed production was organised at The University of Agriculture Faisalabad, Pakistan. A website was developed to reach out to the wider audience (www.aslpveg.pk).

The sustainability of this work depends on the establishment and maintenance of a viable seed production system locally in Pakistan. The heat tolerant materials identified by this research are the catalyst for the initiation of such an industry locally. Commercial hybrid seed production is already underway at the VRI, Faisalabad and this initiative provides a basis for a viable local vegetable seed industry.

Background

Vegetables are widely grown in Pakistan however the production per unit area is fairly low due to various biotic and abiotic stress conditions. Most vegetables prefer relatively mild temperatures, thus productivity is low in the hot and humid lowlands of Southeast Asia (Ali, 2000).

Pakistan experiences four distinct seasons. The central Punjab, the target area of this project, has a semi-arid climate with hot summer having average temperatures above 40^{o}C and maximum temperature reaching 45^{o}C or more (May-July), (*FAO Report, 1998; HKO Report, 2012)*. Punjab and Sindh province experience the hot summer in Pakistan and similar weather extremes are also frequent in the crop production areas of Australia (BOM Report, 2012).

High temperature events in Australia are less common compared to Pakistan, however increased weather extremes are likely due to climate change (CSIRO Report, 2006). High temperature, even for short duration, inhibits photosynthesis, respiration rate, and interrupts plant water status due to high rate of leaf transpiration. It may cause abortion of buds, flowers and young fruits. Successful pollination, fruit quality, and seed viability are affected by excessive temperature (Abdul-Baki, 1991; Abdelmageed and Gruda, 2009). There is a need to introduce better adapted germplasm to high temperature conditions in Pakistan and Australia.

Disease and insect pressure, under low management regime, although affect vegetable production considerably but in summer the damage due to heat far exceeds that due to other factors. Due to limited resources the farmers can't manage a sufficient degree of control over heat stress and genetic intervention was considered a viable option under Pakistani conditions.

With increase in population the farm size has reduced and more than 90% of farmers cultivate less than five hectares of land in Punjab. The staple food crops are usually inadequate and there is an increasing trend to adopt high value crops like vegetables to meet daily family needs (AVRDC, 2006). The health benefits of vegetables as part of the daily diet also demand a bigger supply in the markets.

Two popular summer vegetables, tomato and okra were selected to enhance genetic diversity in central Punjab, Pakistan. These vegetables are suitable to grow in small land holdings under relatively low/moderate management and promise reasonably good market returns. They are planted at the start of the summer season when they produce proficiently, production is markedly reduced in the peak summer and the second crop again produces well when the summer peak is over.

The heat stress, both in terms of intensity and duration, is much greater in Pakistan compared to other countries where modern varieties of vegetables are bred. Unfortunately very limited research work has been conducted on screening, evaluation and mitigation of heat stress effects on vegetable crops in Pakistan. This project was the first comprehensive effort to initiate research work in this regard.

Objectives

The project aimed at offering the better adapted and genetically diverse germplasm while elucidating the genetic and physiological basis of improved adaptation under heat stress in Pakistan and Australia. The aims of this work were accomplished by achieving the following objectives:

- Screening and evaluation of indigenous and exotic germplasm of tomato and okra to heat stress under controlled and field conditions.
- Explaining the existing genetic diversity in the germplasm using molecular markers and elucidating the physiological basis of adaptation.
- Characterization of the selected germplasm for commercial traits and evaluation for its industrial use.
- Sharing the heat tolerant elite germplasm with stake holders and the partners.
- Training staff and students from Pakistan in heat stress breeding, agronomy, and seed production in summer vegetables.
- Training farmers to enhance capacity to grow vegetables more successfully.

Methodology

Key steps in the methodology:

Diverse tomato and okra germplasm comprising of 330 tomato and 193 okra genotypes was collected from AVRDC, UC Davis, USDA, VRI, Faisalabad Pakistan, and PBI The University of Sydney. Initially identical sets of the germplasm were requested for both the countries but due to different quarantine regulations in Pakistan and Australia the entries reaching onshore were considerably different in the two countries (see Appendix 1 & 2).

As tomato and okra are predominantly grown under field conditions in Pakistan so the new germplasm was assessed under matching field conditions in Pakistan. The tunnel house vegetable production being popular in Australia the materials were assessed under tunnel house conditions at PBI.

The detailed methodology at two nodes of the project is given as under:

A) University of Agriculture Faisalabad (UAF)

To meet milestones within the stipulated timeframe and to run the project effectively research planning and execution was done after consultation with the Pakistani partners. Important points in the methodology at UAF were as under:

- The screening and characterization of the germplasm was done in two stages; stage1 screening using full set of germplasm under controlled conditions in 2013-14 followed by stage2 screening using selected (25%) materials under field conditions in 2014-15.
- For preliminary screening the plants were grown in growth room. Heat treatment was started four weeks after emergence. Plants were harvested 6 weeks after emergence to analyze the effects of heat stress; 40^{o}C (day) and 32^{o}C (night). The data were taken on shoot length, shoot fresh weight, number of leaves, chlorophyll content, transpiration rate, and leaf temperature.
- Out of the full set 62 lines of tomato and 29 of okra were shortlisted (see Appendix 3) to test in the second stage screening under field conditions.
- To maximize reliability of selection across the season the second stage screening was done in replicated trials in the field with two sowing dates.
- On the basis of stage2 screening a set of eight promising lines, each of tomato and okra, was selected. Two more lines (a standard cultivar and a sensitive line) each of tomato and okra were added to the set to make a final set of ten entries for multi-location testing.
- The fruit yield and quality of final set was assessed in multi-location trials in four districts of Punjab in 2015-16.
- At the end of the multi-location testing the final set of materials of tomato and okra was shared with VRI Faisalabad, gene bank at NARC Islamabad, and IHS at The University of Agriculture Faisalabad.
- Farmer training was an integral part of the project. Sixteen farmer trainings were organized in various districts of Punjab. More than 1050 male and female farmers

attended the trainings. Thirty five extension workers were also trained at IATI Sargodha, Pakistan.
- Eight postgraduate students (two PhD and six Masters) were supported at The University of Agriculture, Faisalabad to complete their thesis research within the scope of the project.

B) PBI, The University of Sydney

- The physiological and agronomic studies on heat stress tolerance were conducted under tunnel house conditions in summer 2014-15 at PBI Cobbitty. The ventilation in the tunnel house was adjusted to get the desired temperature range (>40^{o}C) during the day time. The germplasm was characterized on biomass, flower and fruit traits. Strong genetic variation was found among the materials. The materials were ranked as per their performance under tunnel house conditions (see Appendix 8).
- The genotyping of the materials was done by DArT technologies (Cruz et al. 2013). The phenotypic variability in the germplasm was supported by the genotypic data.
- Although the materials were tested and selected under different environments a degree of complementarity was quite noticeable between the data from the two countries.
- The promising tomato and okra materials were shared with Abundant Produce, an Australian enterprise.
- On the basis of the genome wide association studies (GWAS) genomic regions important in heat stress tolerance were identified for both tomatoes and okra.
- To evaluate and upgrade existing skills in plant breeding, agronomy and seed production seminars/workshops were conducted in Pakistan. The workshops were attended by both Australian and Pakistani partners.
- Three PhD students at The University of Sydney completed their thesis research within the scope of this project.

Partnerships

This work attracted public and private sector attention resulting in new partnerships in Pakistan and Australia. The following organisations worked together in this project:

- **Plant Breeding Institute (PBI), University of Sydney** - PBI has a long history of cultivar improvement in both cereal and horticultural crops. The institute has access to a wide range of skills from plant breeding, to agronomy, soil science and agricultural economics.
- **Institute of Horticultural Sciences, The University of Agriculture, Faisalabad, Pakistan** - The institute is currently providing post graduate training to more than a hundred students every year. With the help of this institute, the project organised trainings for scientists/researchers, students, farmers, and other stake holders in Pakistan.
- **Department of Agronomy, University of Agriculture Faisalabad, Pakistan** – The department has ongoing and successfully completed research projects on abiotic stress physiology. Many post-grad students, including Ph.Ds, have been trained in this department.
- **Abundant Produce** (formerly working under the name NuFlora) a private-public sector partnership in horticulture, NSW, Australia – Abundant Produce has strong linkages

with vegetable growers in NSW along with public sector alliance with The University of Sydney in the area of vegetable breeding and seed production.

- **NSW farmers association** – This is an ultimate user organisation of the new technologies. Working in partnership with this organisation provided useful feedback from the farming community which was vital to an effective strategy formulation in vegetable research.

Interaction with the farming community in Australia

PBI, The University of Sydney maintained a regular contact with the following farmer organizations/private businesses during the project:

- NSW farmers association
- Abundant Produce, local vegetable seed enterprise
- Local vegetable farmers around Cobbitty.

The NSW farmer association provided a letter of support endorsing the project activities. As a collaborator the association agreed to work closely and provide feedback on the matters of their interest. At a meeting with the NSW farmers representative on 3 March 2014 at PBI Cobbitty the NSW farmers association highlighted the Australian farmer needs from vegetable research. This interaction resulted in increased collaboration with Abundant Produce for the benefit of the Australian farmers. Communication and feedback continued to flow both through direct contact and through Abundant Produce. An Abundant Produce representative also travelled to Pakistan to advise local groups on the Australian business model. This Australian company has acquired the project characterized germplasm and information and it is being used to commercially develop more stress resistant germpaslm for Australia.

Achievements against activities and outputs/milestones

Objective 1: **To screen and evaluate the adaptation of locally available indigenous and exotic germplasm of tomato and okra to heat stress under controlled and field settings.**

No.	Activity	Outputs/ milestones	Completion date	Comments
1.1	-Sites identification - Purchase of equipment - Recruitment of staff -Growth room start working	All the components were completed as per schedule.	2013	All the components in Project activity 1.1 were achieved and reported.
1.2	Survey & collection of germplasm	Documentation/Transportation/storage of materials has been done.	2013	The milestones were met and reported.
1.3	Screening and evaluation	Identification of heat tolerant germplasm	2013-14	The milestones were met and reported.
1.4	Genotyping of the collected germplasm	Genotyping data available	2013-14	Genotyping for the tomatoes was completed as per schedule however for okra the genotyping work took longer than expected. Due to less effective DNA extraction and purification protocols for okra the genotyping work experienced delays until a workable protocol was defined.

PC = partner country, A = Australia

Objective 2: **To characterise the selected germplasm and to evaluate it for its profitable use in commercial farming.**

No.	Activity	Outputs/ milestones	Completion date	Comments
2.1	Genotyping of the germplasm	Diversity analysis done	2014	The analysis has been done as planned.
2.2	Germplasm characterisation both in lab and field. This will need data for at least two seasons	Germplasm characterisation has been completed	2014-15	The characterisation continued through 2014-15 and it has been completed both in the field conditions and under controlled environments.

2.3	Data analysis and report writing	Research papers submitted for publication	2015	Some research papers have already been submitted for publication and some more are expected to be submitted post 2016.

PC = partner country, A = Australia

Objective 3: To improve seed production and distribution of thermo tolerant germplasm to stake holders both in Pakistan and Australia.

No.	Activity	Outputs/ milestones	Due date of output/ milestone	Applications of outputs
3.1	Seed production training workshop at UAF	More than thirty people participated.	2015	Local and international speakers delivered their lectures on seed production.
3.2	Planting for seed multiplication	Delivery of stress tolerant genotypes.	2015	Completed as per schedule.
3.3	Harvesting grading & packing	Delivery of stress tolerant genotypes.	2015	Completed as per schedule.
3.4	Distribution to stake holders	Delivery of stress tolerant genotypes.	2015	Completed. The seed of elite materials was handed over to the stakeholders in Pakistan and Australia.

Key results and discussion

- The tomato and okra materials gave variable response against heat stress and allowed selection of the promising lines. Sixty two (62) tomato entries and twenty nine (29) okra entries were shortlisted for second stage screening in the field (see Appendix 3).
- The shortlisted materials were evaluated for physiological and agronomic response in the field in summer 2014-15 at UAF. Sixty two lines of tomatoes and twenty nine of okra were ranked according to their performance in the field (see Appendix 4).
- A set of ten genotypes was selected after the second cycle of screening (see Appendix 5) for multi-location trials in four districts of Punjab. Graphical representation of fruit yield and quality traits in multi-location trials is presented in Appendix 6 and 7 respectively. High yielding genotypes with better quality fruit were selected.
- The promising tomato and okra materials were shared with the gene banks, plant breeders, and other stake holders in Pakistan.
- Although the materials were tested and selected under different environments in both the countries yet the complementarity between the results was quite obvious in the data.
- The materials at PBI were tested for their adaptability under hydroponic tunnel house conditions using cocopeat bags. The genotypes were ranked according to their performance in the tunnel house (see Appendix 8).
- The association genetics analysis based on the markers showed strong associations between markers and the phenotypic data both in tomatoes and okra (see Appendix 9). The results will be published in scientific journals to scale out the project outcomes. A high number of markers was found influencing the traits in these materials. Validation of marker associations on other materials is to be conducted in the post-project research at PBI to verify the results.
- To evaluate and upgrade existing skills in plant breeding, agronomy and seed production seminars/workshops were conducted in Pakistan. The workshops were attended by both Australian and Pakistani partners.
- Sixteen farmer trainings were conducted on vegetable cultivation under stressful conditions in various districts of Punjab, Pakistan. More than one thousand farmers attended the training workshops. In addition, 35 extension workers were trained at IATI Sargodha, Pakistan (see Appendix 10).
- Eight postgraduate students (two PhD and six Masters) at the University of Agriculture, Faisalabad and three PhD students at the University of Sydney were supported with their thesis research within the scope of the this project (see Appendix 11).

Project Outcomes for Australian Farmers

- New germplasm representing extensive new genetic diversity was accessed from around the world.
- Promising accessions of tomato and okra and supporting data and information were shared with the vegetable industry in Australia.

- New sources of genes for heat stress tolerance identified. Although still putative (requiring confirmation through validation studies) these genes have been targeted by local breeders in Abundant Produce.
- Useful collaborations between Australian and Pakistani partners were developed and Abundant Produce continues to advise local Pakistani groups on the business model and opportunities for marketing. These opportunities may in future include avenues to market Australian hybrid cultivars/seed in Pakistan.
- Three Ph.D research projects on heat stress tolerance in tomatoes and okra were supported locally in Australia within the scope of the project.

Impacts

Scientific impacts – now and in 5 years

High temperature in summer affects crop growth to a large degree in Pakistan. The vegetable crops are badly affected by heat stress. The current project mainly focussed on scientific research in the area of heat stress tolerance in tomato and okra. The scientific impacts of this project are listed below:

- Identified tomato & okra germplasm with significantly better heat tolerance than currently available to farmers

Pakistan faces the hot summer every year. The summer vegetables are hard hit by the excessive heat. Farmers need suitable germplasm of tomato and okra that could resist heat stress and has good agronomy. This project has identified the materials that are heat tolerant and high yielding.

After fulfilling the seed registration pre-requisites the breeders may recommend these materials for cultivation at the farmer field or they may be used as a source of new heat tolerance genes that were not available in the country before. The new sources of heat tolerance may benefit the country for long time.

- The mechanisms of heat tolerance understood and screening methods to assist breeders developed

This research has helped understand the mechanism of heat tolerance in tomato and okra crops better than before. Various physiological mechanisms have been studied to distinguish heat tolerant materials. Some mechanisms proved more effective than others. The detailed screening methodology will be published in scientific journals for the benefit of the wider audience.

- The genetic control of heat tolerance explored and molecular markers linked to important traits discovered

The molecular markers associated with heat stress tolerance have been identified through genome wide association studies. The markers identified as important will be validated in other materials so to provide plant breeders with reliable method of identifying the heat tolerance genes to incorporate in the breeding materials. After validation these markers will help identify the heat tolerant materials, in Pakistan or elsewhere.

This project is the first of its kind in vegetable sector in Pakistan, and will help establish vegetable industry on scientific grounds.

Capacity impacts – now and in 5 years

Pakistan faces a severe shortage of trained manpower in the vegetable sector. Capacity building was an important component of this project. This project helped train farmers and

extension staff to build capacity in the vegetable farming particularly under heat stress conditions. The project organised training workshops in various districts of Punjab and at UAF. Research, extension, and teaching staff along with students and farmers were trained to upgrade skills in vegetable cultivation under heat stress conditions.

The vegetable seed available in Pakistan is produced overseas in the environments that generally do not match to the local climatic conditions. Availability of locally produced quality seed is an important area of farmer interest in Pakistan and this project helped build capacity in this area.

Training workshops, seminars, and publications (in local language) were produced to disseminate knowledge among the stake holders. In sixteen farmer training workshops more than one thousand farmers and extension staff were trained in various districts of the Punjab.

Eight post-grad students at The University of Agriculture Faisalabad and three Ph.D students at The University of Sydney conducted their research work within the scope of this project. Some students have already completed their thesis while others are supposed to complete by 2017-18. The student trainings will go a long way in providing leadership in the vegetable industry in Pakistan and Australia.

Community impacts – now and in 5 years

Pakistan is an agricultural country with more than seventy per cent of its population directly or indirectly involved in agriculture. Low productivity of horticultural crops is hindering improvement in the livelihood of the farming community. This project focussed on tomato and okra crops to increase farm productivity and income, and make more vegetables available in the country to improve dietary status of the public in the country. The impact of this project may go a long way for the welfare of the farming community and the general public in Pakistan and Australia. The significant community impacts are highlighted below:

- The heat tolerant germplasm identified in this project will help extend the crop season which gets compromised due to excessive heat. Longer crop season means higher yields, and longer availability of the fresh produce in the market. This will help reduce the vegetable import bill and lower cost to the consumer.

- The locally adapted germplasm is to be used by the local breeders to develop new crop cultivars. The breeding activity will help establish a local seed production industry thus creating extra employment opportunities, particularly for women. Trained women labor is already involved in local hybridization and seed production.

- Longer term impacts are to be realized after the closure of the project when new heat tolerant cultivars are available to the farmers. Farmers will have higher and more stable yield and therefore less production risk. The stabilization of family income will lead to better quality of life and better health and education opportunities for the children.

Economic impacts

Vegetables are considered high value crops in Pakistan however high management cost, non-availability of good quality seed, and abiotic stresses particularly the heat stress badly affect the overall vegetable production in the country.

Tomato and okra, two important summer vegetables, are grown at relatively bigger scale compared to some other vegetables. Tomato is grown on 123.56 thousand hectares producing 476.80 thousand tonnes of fruit whereas okra is grown on 15.18 thousand hectares producing 116.10 thousand tonnes (FAO 2009).

The production losses due to heat stress range from complete crop failure to a minimum of 30% loss. Mitigation of heat stress through the introduction of heat tolerant germplasm will make strong impact on vegetable farmers. With a modest increase of only 5% in production due to better adapted germplasm may increase annual market returns by Rs 58.75m for tomato and 27.5m for okra.

Pakistan spends heavy amounts on the seed import. In 2008-09 it spent Rs. 1072.01 million on vegetable seed import (http://sap.com.pk/nature-of-seed-tarde/). Production of domestic vegetable seeds will save the country substantially. In the longer term the project will help develop local vegetable cultivars and cut the vegetable import bills.

Social impacts

The current project aims to increase farm production through increased use of better adapted vegetable cultivars. Improvement in production at the farm level will increase farm income and raise the purchasing power of the cash deprived farming families.

With rising population, dwindling agricultural resources, and global warming Pakistan needs to improve food security in the country. This project will help ensure food security, improved equity and better livelihood to the farming community. Increased vegetable production will also help improve the social wellbeing of the farmer in the society.

Subsistence farming is a general practice in Pakistan and farmers generally lack capacity to buy foods from the markets. Availability of home grown vegetables will provide a cheaper alternative to the farmer to eat healthy and more balanced diet.

Environmental impacts

Vegetables are environment friendly crops and improving vegetable productivity will make a positive impact on the environment. The project is intended to improve production in summer vegetables thus making positive impact on the environment and reducing the heat intensity.

Improved awareness through farmer trainings, this project helped improve environment quality through reduced pollution in the atmosphere, and less chemical residues in the food system.

Communication and dissemination activities

The project has provided a platform to communicate effectively among Pakistani and Australian scientists. Communication among researchers in both the countries has been facilitated through visits, phone calls, emails, and other channels. These measures have been effective to maintain a robust contact.

The vegetable farmers, extension staff and researchers are the main stakeholders in this project. Farmers are mostly illiterate with having only limited access to media outlets. Verbal communication including face to face meeting is the effective way of communication. University of Agriculture Faisalabad has well developed network in farmer linkage and extension. The farmers regularly visit university facilities at farmer days and share their experiences with the experts. The current project has facilitated farmer meetings on and off the campus along with researcher meetings through seminars and meetings.

To inform stakeholders, the results are being reported in scientific journals, seminars, workshops, field days and the local media. A website was developed to help improve communication between the stakeholders (www.aslpveg.pk).

The extensive network of Agricultural Extension Department is very helpful in communication as it has extension staff available at the farm gate. The staff understand local problems and suggest suitable scientific solutions locally. The agricultural extension department is strongly linked to agricultural research organizations including University of Agriculture Faisalabad (UAF). The training workshops helped train extension staff and the farmers.

Predominantly the Pakistan is an agricultural country and Punjab represents more than 50% of the farming and research community in the country. A genetic solution to the effects of heat stress in vegetables in Punjab will impact ultimately the whole country.

Conclusions and recommendations

The project aimed at identifying the right tomato and okra germplasm for Pakistan and Australia. Along with germplasm identification the project also focussed on the development of genetic markers for heat stress tolerance in both the crops. The capacity building was yet another important feature of the project. The conclusions and recommendations based on this work are summarised below:

Conclusions

- Eight heat adapted lines each of tomato and okra were selected for breeding, hybrid seed development and commercialization in Punjab Pakistan. The seed was multiplied and shared with other interested groups including The Directorate of Vegetable Agricultural Research Institute in Faisalabad, The National Agricultural Research Centre in Islamabad, and IHS at University of Agriculture Faisalabad, Pakistan.

- Five heat adapted lines each of tomato and okra were identified under tunnel house conditions in Australia. The heat tolerant tomato materials were made available to the Australian company The Abundant Produce for use in Australia.

- Molecular markers associated with heat stress tolerance were identified for tomatoes and okra.

- Farmer and extension workers were trained in the training workshops. Sixteen training workshops were conducted and more than 1,050 male and female farmers participated in the trainings. In addition, 35 extension workers were trained at IATI Sargodha, Pakistan.

- Thesis research of eight students (two PhD and six Masters) at the University of Agriculture, Faisalabad and three PhD students at the University of Sydney was supported in this project. Student participation significantly augmented the project achievements.

- Information on vegetable production under high temperature conditions was delivered in technical brochures. Four booklets on various aspects of vegetables production in Punjab were published in Urdu language. Three research papers have so far been presented/published in conferences/scientific journals to scale out the project outcomes, and more are in the pipeline. An international seminar on vegetable production, and a workshop on vegetable seed production was organized at The University of Agriculture Faisalabad, Pakistan.

Recommendations

Following are the recommendations:

- That the fledgling hybrid seed industry initiated by this research be developed and expanded to include other vegetable crops in other regions of Pakistan.
- That the flow of promising genetic resources is encouraged across organizations, regions and countries.
- That the putative molecular makers linked to heat tolerance be confirmed in a wider range of materials before they are used intensively in cultivar development.
- That the relationships developed under HORT/2012/002 be maintained and expanded to include a wider range of Pakistani and Australian commercial partners.
- That private and public sector relationships explored under this project be expanded and further developed.
- That the extension workers trained in vegetable production under high temperature be supported locally to continue the legacy of this research.
- That training workshops specifically targeted to farmers are extended to other groups and regions.
- That the post-graduate students trained in high temperature vegetable breeding and production are nurtured locally to ensure their participation in local research and development.

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List of publications produced by the project

Publications

M Hameed, C Keitel, N Ahmed, T Mahmood, R Trethowan 2015 Screening tomatoes for heat stress tolerance under controlled conditions. Poster presented at Agriculture and Climate Change Conference, 15-17 Feb 2015, Amsterdam, Netherlands.

S Hayamanesh, C Keitel, N Ahmed, T Mahmood, R Trethowan 2015 Heat tolerance in diverse okra (Abelmoschus esculentus L. Moench) germplasm. Poster presented at Research Symposium Faculty of Agriculture and Environment, The University of Sydney. Tuesday 14 July, 2015.

MR Shaheen, CM Ayyub, M Amjad and EA Waraich 2015 Morpho-Physiological Evaluation of Tomato Genotypes under High Temperature Stress Condition. Journal of the Science of Food and Agriculture. (*Published online*) DOI: 10.1002/jsfa.7388

M Safdar, N Ahmad, T Mahmood, R Trethowan 2016 Genetic basis of morphological and biochemical variation under heat stress in okra. Poster presented at Research Symposium, Faculty of Agriculture and Environment, The University of Sydney on 12 July 2016.

Publications in process

S No.	Title	Status
1	Morphological, physiological and biochemical characterization of tomato genotypes under high temperature	In process
2	Effect of salicylic acid on physiological attributes and chlorophyll contents of heat tolerant and heat sensitive tomato genotypes under high temperature regime	
3	Effect of salicylic acid on physiological, biochemical and yield attributes of heat tolerant and heat sensitive tomato cultivars under agro-climatic conditions of Faisalabad	
4	Characterization of okra genotypes on the basis of Morphological, physiological and biochemical attributes under high temperature regime	
5	Enhancement of heat tolerance in Okra by exogenous application of proline	
6	Screening of diverse tomato germplasm agaist Fusarium wilt (*Fusarium solani)* under greenhouse conditions	
7	Phenotypic diversity and association analysis for heat stress tolerance in cultivated tomato and related species	

Appendixes

Appendix 1: List of tomato entries received at UAF and PBI

S No.	Prev List ID	Accession ID	Acc No. / Temp No	Genus	Species	Origin	Designation	Source	Entry rcvd at
1	1	VI005503	L00090	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
2	2	VI005504	L00091	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
3	3	VI005595	L00184	TM:SOLANUM	LYCOPERSICUM	Sri Lanka		AVRDC	UAF/PBI
4	4	VI005670	L00263	TM:SOLANUM	LYCOPERSICUM	Australia		AVRDC	UAF/PBI
5	5	VI005672	L00265	TM:SOLANUM	LYCOPERSICUM	Australia		AVRDC	UAF/PBI
6	6	VI005673	L00266	TM:SOLANUM	LYCOPERSICUM	Australia		AVRDC	UAF/PBI
7	7	VI005856	L00451	TM:SOLANUM	LYCOPERSICUM	Australia		AVRDC	UAF/PBI
8	8	VI005894	L00489	TM:SOLANUM	LYCOPERSICUM	Sri Lanka		AVRDC	UAF/PBI
9	9	VI005896	L00491	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
10	10	VI005897	L00492	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
11	21	VI005999	L00594	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
12	22	VI006000	L00595	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
13	23	VI006006	L00601	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
14	24	VI006007	L00602	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
15	25	VI006008	L00603	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
16	26	VI006009	L00604	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
17	27	VI006467	L01062	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
18	28	VI006468	L01063	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
19	29	VI006475	L01070	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
20	30	VI006476	L01071	TM:SOLANUM	LYCOPERSICUM	Pakistan		AVRDC	UAF/PBI
21	31	VI006477	L01072	TM:SOLANUM	LYCOPERSICUM	Pakistan		AVRDC	UAF/PBI
22	32	VI006578	L01173	TM:SOLANUM	LYCOPERSICUM	Australia		AVRDC	UAF/PBI
23	33	VI006603	L01198	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
24	34	VI006604	L01199	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
25	35	VI006605	L01200	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
26	36	VI006606	L01201	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
27	37	VI006607	L01202	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
28	38	VI006608	L01203	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
29	39	VI006610	L01205	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
30	40	VI006611	L01206	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
31	41	VI006612	L01207	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
32	42	VI006613	L01208	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
33	43	VI006614	L01209	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
34	44	VI006617	L01212	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
35	45	VI006618	L01213	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
36	46	VI006619	L01214	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
37	47	VI006621	L01216	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
38	48	VI006622	L01217	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI

39	49	VI006628	L01223	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
40	50	VI006629	L01224	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
41	51	VI006630	L01225	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
42	52	VI006695	L01290	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
43	53	VI006706	L01301	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
44	54	VI006748	L01344	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
45	55	VI006749	L01345	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
46	56	VI006750	L01346	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
47	57	VI006754	L01350	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
48	58	VI006777	L01373	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
49	59	VI006778	L01374	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
50	60	VI006779	L01375	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
51	81	VI007532	L02131	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
52	82	VI007533	L02132	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
53	83	VI007534	L02133	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
54	84	VI007535	L02134	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
55	85	VI007536	L02135	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
56	86	VI007537	L02136	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
57	87	VI007538	L02137	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
58	88	VI008101	L02701	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
59	89	VI008108	L02708	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
60	90	VI008132	L02732	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF/PBI
61	198	CLN-2366 A		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
62	199	LA-2662		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
63	200	LA-3120		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
64	201	Early Annie		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
65	202	Sasha Altai		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
66	203	KHT-15		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
67	204	Subarctic-A		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
68	205	Way Ahead		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
69	206	Jagour		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
70	207	Iles Yellow Latvian		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
71	208	Zarnitza		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
72	209	Pakit		TM:SOLANUM	LYCOPERSICUM	Pakistan		VRI, FSD Pakistan	UAF/PBI
73	210	UC-134		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
74	211	Bradley		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
75	212	Subarctic		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
76	213	Long Keeper		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
77	214	Parter Improved		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
78	215	Roma		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
79	216	Chaus		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI

80	217	Legend		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
81	218	Alaskan Fancy		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
82	219	Raad Red		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
83	220	Early Wonder		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
84	221	Polar Beauty		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
85	222	Zhezha		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
86	223	Campbells' 1327		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
87	224	Bonita		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
88	225	Rio Grande		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
89	226	New Yorker		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
90	227	Beefsteak		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
91	228	Leeper		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
92	229	LA-2010		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
93	230	Grushovka		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
94	231	Nepoli		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
95	232	Dona		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
96	233	Prescott		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
97	234	TAI-1042		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
98	235	Bush Beefsteak		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
99	236	Cold Set		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
100	237	Naqeeb		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
101	238	Kaldera		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
102	239	Manitoba		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
103	240	Caro Rich Tomato		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
104	241	Forme De Coeur		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
105	242	NTH-671		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
106	243	Spekled Siberian		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
107	244	Northern Delight		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
108	245	Anahu		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
109	246	Taxi		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF/PBI
110	247	Nagina		TM:SOLANUM	LYCOPERSICUM	Pakistan		VRI, FSD Pakistan	UAF/PBI
111	254	LA0373		SOLANUM	LYCOPERSICUM			UC Davis	PBI
112	255	LA0716		SOLANUM	LYCOPERSICUM			UC Davis	PBI
113	256	LA1930		SOLANUM	LYCOPERSICUM			UC Davis	PBI
114	257	LA2375		SOLANUM	LYCOPERSICUM			UC Davis	PBI
115	258	LA2661		SOLANUM	LYCOPERSICUM			UC Davis	PBI
116	259	LA3320		SOLANUM	LYCOPERSICUM			UC Davis	PBI
117	260	LA3344		SOLANUM	LYCOPERSICUM			UC Davis	PBI
118	261	LA3345		SOLANUM	LYCOPERSICUM			UC Davis	PBI

119	262	LA3847		SOLANUM	LYCOPERSICUM			UC Davis	PBI
120	263	LA3866		SOLANUM	LYCOPERSICUM			UC Davis	PBI
121	264	LA3867		SOLANUM	LYCOPERSICUM			UC Davis	PBI
122	265	LA3869		SOLANUM	LYCOPERSICUM			UC Davis	PBI
123	266	LA3870		SOLANUM	LYCOPERSICUM			UC Davis	PBI
124	267	LA3871		SOLANUM	LYCOPERSICUM			UC Davis	PBI
125	268	LA3874		SOLANUM	LYCOPERSICUM			UC Davis	PBI
126	269	LA3875		SOLANUM	LYCOPERSICUM			UC Davis	PBI
127	270	LA3876		SOLANUM	LYCOPERSICUM			UC Davis	PBI
128	271	LA3878		SOLANUM	LYCOPERSICUM			UC Davis	PBI
129	272	LA3879		SOLANUM	LYCOPERSICUM			UC Davis	PBI
130	273	LA3882		SOLANUM	LYCOPERSICUM			UC Davis	PBI
131	274	LA3883		SOLANUM	LYCOPERSICUM			UC Davis	PBI
132	275	LA3886		SOLANUM	LYCOPERSICUM			UC Davis	PBI
133	276	LA3889		SOLANUM	LYCOPERSICUM			UC Davis	PBI
134	277	LA3892		SOLANUM	LYCOPERSICUM			UC Davis	PBI
135	278	LA3893		SOLANUM	LYCOPERSICUM			UC Davis	PBI
136	279	LA3906		SOLANUM	LYCOPERSICUM			UC Davis	PBI
137	280	LA4230		SOLANUM	LYCOPERSICUM			UC Davis	PBI
138	281	LA4231		SOLANUM	LYCOPERSICUM			UC Davis	PBI
139	282	LA4232		SOLANUM	LYCOPERSICUM			UC Davis	PBI
140	283	LA4233		SOLANUM	LYCOPERSICUM			UC Davis	PBI
141	284	LA4234		SOLANUM	LYCOPERSICUM			UC Davis	PBI
142	285	LA4235		SOLANUM	LYCOPERSICUM			UC Davis	PBI
143	286	LA4236		SOLANUM	LYCOPERSICUM			UC Davis	PBI
144	287	LA4237		SOLANUM	LYCOPERSICUM			UC Davis	PBI
145	288	LA4247		SOLANUM	LYCOPERSICUM			UC Davis	PBI
146	289	LA4248		SOLANUM	LYCOPERSICUM			UC Davis	PBI
147	290	LA4249		SOLANUM	LYCOPERSICUM			UC Davis	PBI
148	291	LA4252		SOLANUM	LYCOPERSICUM			UC Davis	PBI
149	292	LA4256		SOLANUM	LYCOPERSICUM			UC Davis	PBI
150	293	LA4257		SOLANUM	LYCOPERSICUM			UC Davis	PBI
151	294	LA4272		SOLANUM	LYCOPERSICUM			UC Davis	PBI
152	295	LA4273		SOLANUM	LYCOPERSICUM			UC Davis	PBI
153	296	LA4283		SOLANUM	LYCOPERSICUM			UC Davis	PBI
154	297	LA4284		SOLANUM	LYCOPERSICUM			UC Davis	PBI
155	298	S240		SOLANUM	LYCOPERSICUM			Diggers Australia	PBI
156	299	S219		SOLANUM	LYCOPERSICUM			Diggers Australia	PBI
157	300	S225		SOLANUM	LYCOPERSICUM			Diggers Australia	PBI
158	301	S227		SOLANUM	LYCOPERSICUM			Diggers Australia	PBI
159	302	S228		SOLANUM	LYCOPERSICUM			Diggers Australia	PBI
160	303	S231		SOLANUM	LYCOPERSICUM			Diggers Australia	PBI
161	304	S232		SOLANUM	LYCOPERSICUM			Diggers Australia	PBI
162	305	S235		SOLANUM	LYCOPERSICUM			Diggers Australia	PBI

163	306	S237		SOLANUM	LYCOPERSICUM			Diggers Australia	PBI
164	307	S241		SOLANUM	LYCOPERSICUM			Diggers Australia	PBI
165	308	S242		SOLANUM	LYCOPERSICUM			Diggers Australia	PBI
166	309	S244		SOLANUM	LYCOPERSICUM			Diggers Australia	PBI
167	310	S285		SOLANUM	LYCOPERSICUM			Diggers Australia	PBI
168	311	S288		SOLANUM	LYCOPERSICUM			Diggers Australia	PBI
169	312	S289		SOLANUM	LYCOPERSICUM			Diggers Australia	PBI
170	313	S290		SOLANUM	LYCOPERSICUM			Diggers Australia	PBI
171	314	S292		SOLANUM	LYCOPERSICUM			Diggers Australia	PBI
172	315	S294		SOLANUM	LYCOPERSICUM			Diggers Australia	PBI
173	316	S364		SOLANUM	LYCOPERSICUM			Diggers Australia	PBI
174	317	S365		SOLANUM	LYCOPERSICUM			Diggers Australia	PBI
175	318	S2171		SOLANUM	LYCOPERSICUM			Diggers Australia	PBI
176	319	S2211		SOLANUM	LYCOPERSICUM			Diggers Australia	PBI
177	320	S2212		SOLANUM	LYCOPERSICUM			Diggers Australia	PBI
178	321	S2213		SOLANUM	LYCOPERSICUM			Diggers Australia	PBI
179	322	S2217		SOLANUM	LYCOPERSICUM			Diggers Australia	PBI
180	323	S2302		SOLANUM	LYCOPERSICUM			Diggers Australia	PBI
181	324	S2351		SOLANUM	LYCOPERSICUM			Diggers Australia	PBI
182	325	S2822		SOLANUM	LYCOPERSICUM			Diggers Australia	PBI
183	326	S2832		SOLANUM	LYCOPERSICUM			Diggers Australia	PBI
184	327	S2902		SOLANUM	LYCOPERSICUM			Diggers Australia	PBI
185	328	S2992		SOLANUM	LYCOPERSICUM			Diggers Australia	PBI
186	329	S239F		SOLANUM	LYCOPERSICUM			Diggers Australia	PBI
187	330	S284F		SOLANUM	LYCOPERSICUM			Diggers Australia	PBI
188	11	VI005898	L00493	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
189	12	VI005904	L00499	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
190	13	VI005906	L00501	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
191	14	VI005907	L00502	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
192	15	VI005930	L00525	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
193	16	VI005976	L00571	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
194	17	VI005977	L00572	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
195	18	VI005978	L00573	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
196	19	VI005979	L00574	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
197	20	VI005992	L00587	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
198	61	VI006780	L01376	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
199	62	VI006802	L01398	TM:SOLANUM	LYCOPERSICUM	Australia		AVRDC	UAF
200	63	VI006889	L01485	TM:SOLANUM	LYCOPERSICUM	Australia		AVRDC	UAF
201	64	VI006890	L01486	TM:SOLANUM	LYCOPERSICUM	Australia		AVRDC	UAF
202	65	VI006891	L01487	TM:SOLANUM	LYCOPERSICUM	Australia		AVRDC	UAF

203	66	VI006977	L01574	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
204	67	VI007105	L01702	TM:SOLANUM	LYCOPERSICUM	Australia		AVRDC	UAF
205	68	VI007106	L01703	TM:SOLANUM	LYCOPERSICUM	Australia		AVRDC	UAF
206	69	VI007107	L01704	TM:SOLANUM	LYCOPERSICUM	Australia		AVRDC	UAF
207	70	VI007119	L01716	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
208	71	VI007127	L01724	TM:SOLANUM	LYCOPERSICUM	Australia		AVRDC	UAF
209	72	VI007132	L01729	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
210	73	VI007292	L01890	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
211	74	VI007293	L01891	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
212	75	VI007356	L01955	TM:SOLANUM	LYCOPERSICUM	Pakistan		AVRDC	UAF
213	76	VI007357	L01956	TM:SOLANUM	LYCOPERSICUM	Pakistan		AVRDC	UAF
214	77	VI007358	L01957	TM:SOLANUM	LYCOPERSICUM	Pakistan		AVRDC	UAF
215	78	VI007529	L02128	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
216	79	VI007530	L02129	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
217	80	VI007531	L02130	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
218	91	VI009383	L03988	TM:SOLANUM	LYCOPERSICUM	Sri Lanka		AVRDC	UAF
219	92	VI009428	L04034	TM:SOLANUM	LYCOPERSICUM	Australia		AVRDC	UAF
220	93	VI009429	L04035	TM:SOLANUM	LYCOPERSICUM	Australia		AVRDC	UAF
221	94	VI010089	L04769	TM:SOLANUM	LYCOPERSICUM	Australia		AVRDC	UAF
222	95	VI010090	L04770	TM:SOLANUM	LYCOPERSICUM	Australia		AVRDC	UAF
223	96	VI010091	L04771	TM:SOLANUM	LYCOPERSICUM	Australia		AVRDC	UAF
224	97	VI010147	L04845	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
225	98	VI029711	L04849	TM:SOLANUM	LYCOPERSICUM	Australia		AVRDC	UAF
226	99	VI029712	L04850	TM:SOLANUM	LYCOPERSICUM	Australia		AVRDC	UAF
227	100	VI029713	L04851	TM:SOLANUM	LYCOPERSICUM	Australia		AVRDC	UAF
228	101	VI029714	L04852	TM:SOLANUM	LYCOPERSICUM	Australia		AVRDC	UAF
229	102	VI029715	L04853-A	TM:SOLANUM	LYCOPERSICUM	Australia		AVRDC	UAF
230	103	VI029716	L04854	TM:SOLANUM	LYCOPERSICUM	Australia		AVRDC	UAF
231	104	VI029717	L04855	TM:SOLANUM	LYCOPERSICUM	Australia		AVRDC	UAF
232	105	VI029749	L04888	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
233	106	VI029750	L04889	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
234	107	VI030145	L05283	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
235	108	VI030153	L05291	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
236	109	VI030158	L05296	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
237	110	VI030159	L05297	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
238	111	VI030595	L05462	TM:SOLANUM	LYCOPERSICUM	Australia		AVRDC	UAF
239	112	VI030340	L05906	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
240	113	VI030356	L05920	TM:SOLANUM	LYCOPERSICUM	Sri Lanka		AVRDC	UAF
241	114	VI030357	L05921	TM:SOLANUM	LYCOPERSICUM	Sri Lanka		AVRDC	UAF
242	115	VI030358	L05922	TM:SOLANUM	LYCOPERSICUM	Sri Lanka		AVRDC	UAF
243	116	VI030359	L05923	TM:SOLANUM	LYCOPERSICUM	Sri Lanka		AVRDC	UAF
244	117	VI030360	L05924-A	TM:SOLANUM	LYCOPERSICUM	Sri Lanka		AVRDC	UAF
245	118	VI030368	L05931	TM:SOLANUM	LYCOPERSICUM	Australia		AVRDC	UAF
246	119	VI043616	L06178	TM:SOLANUM	LYCOPERSICUM	Australia		AVRDC	UAF
247	120	VI045748	L06194-I	TM:SOLANUM	LYCOPERSICUM	Australia		AVRDC	UAF

248	121	VI041364	L06195	TM:SOLANUM	LYCOPERSICUM	Australia		AVRDC	UAF
249	122	VI043638	L06215	TM:SOLANUM	LYCOPERSICUM	Australia		AVRDC	UAF
250	123	VI036337	TL00938	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
251	124	VI036339	TL00940	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
252	125	VI036340	TL00941	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
253	126	VI036342	TL00943	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
254	127	VI036343	TL00944	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
255	128	VI036345	TL00946	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
256	129	VI036346	TL00947	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
257	130	VI036347	TL00948	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
258	131	VI036348	TL00949	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
259	132	VI036349	TL00950	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
260	133	VI036350	TL00951	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
261	134	VI036355	TL00956	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
262	135	VI036358	TL00959	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
263	136	VI036361	TL00962	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
264	137	VI036364	TL00965	TM:SOLANUM	LYCOPERSICUM	India		AVRDC	UAF
265	138	VI037959	TL01240	TM:SOLANUM	LYCOPERSICUM	Sri Lanka		AVRDC	UAF
266	139	VI051126	TL01891	TM:SOLANUM	LYCOPERSICUM	Sri Lanka		AVRDC	UAF
267	140	VI051127	TL01892	TM:SOLANUM	LYCOPERSICUM	Sri Lanka		AVRDC	UAF
268	141	VI051128	TL01893	TM:SOLANUM	LYCOPERSICUM	Sri Lanka		AVRDC	UAF
269	142	VI051129	TL01894	TM:SOLANUM	LYCOPERSICUM	Sri Lanka		AVRDC	UAF
270	143	VI051130	TL01895	TM:SOLANUM	LYCOPERSICUM	Sri Lanka		AVRDC	UAF
271	144	AVTO9311		TM:SOLANUM	LYCOPERSICUM		CL1131-0-0-13-0-6	Hanson AVRDC	UAF
272	145	AVTO9317		TM:SOLANUM	LYCOPERSICUM		CL1131-0-0-38-4-0	Hanson AVRDC	UAF
273	146	AVTO9609		TM:SOLANUM	LYCOPERSICUM		CL1131-7-2-0-9	Hanson AVRDC	UAF
274	147	AVTO9318		TM:SOLANUM	LYCOPERSICUM		CL11d-0-2-1	Hanson AVRDC	UAF
275	148	AVTO9319		TM:SOLANUM	LYCOPERSICUM		CL143-0-10-3-0-1-10	Hanson AVRDC	UAF
276	149	AVTO9320		TM:SOLANUM	LYCOPERSICUM		CL2729-0-2-1-12-0	Hanson AVRDC	UAF
277	150	AVTO9001		TM:SOLANUM	LYCOPERSICUM		CL5915-206D4-2-2-0	Hanson AVRDC	UAF
278	151	AVTO9314		TM:SOLANUM	LYCOPERSICUM		CL5915-206D4-2-2-0-4	Hanson AVRDC	UAF
279	152	AVTO9321		TM:SOLANUM	LYCOPERSICUM		CL5915-206D4-2-5-0	Hanson AVRDC	UAF
280	153	AVTO9322		TM:SOLANUM	LYCOPERSICUM		CL5915-223D4-2-1-0	Hanson AVRDC	UAF
281	154			TM:SOLANUM	LYCOPERSICUM		CL5915-93D4	Hanson AVRDC	UAF
282	155	AVTO9323		TM:SOLANUM	LYCOPERSICUM		CL5915-93D4-1-0	Hanson AVRDC	UAF
283	156			TM:SOLANUM	LYCOPERSICUM		CL5915-93D4-1-12	Hanson AVRDC	UAF
284	157	AVTO9304		TM:SOLANUM	LYCOPERSICUM		CL5915-93D4-1-0-3	Hanson AVRDC	UAF
285	158	AVTO9315		TM:SOLANUM	LYCOPERSICUM		CL5915-93D4-1-0-C-1	Hanson AVRDC	UAF
286	159	AVTO9324		TM:SOLANUM	LYCOPERSICUM		CL8d-0-7-1	Hanson AVRDC	UAF
287	160	AVTO9602		TM:SOLANUM	LYCOPERSICUM		CLN1460A	Hanson AVRDC	UAF
288	161	AVTO9601		TM:SOLANUM	LYCOPERSICUM		CLN1462A	Hanson	UAF

								AVRDC	
289	162	AVTO9603		TM:SOLANUM	LYCOPERSICUM		CLN1462B	Hanson AVRDC	UAF
290	163	AVTO9604		TM:SOLANUM	LYCOPERSICUM		CLN1463A	Hanson AVRDC	UAF
291	164	AVTO9610		TM:SOLANUM	LYCOPERSICUM		CLN1463B	Hanson AVRDC	UAF
292	165	AVTO9604		TM:SOLANUM	LYCOPERSICUM		CLN1464A	Hanson AVRDC	UAF
293	166	AVTO9605		TM:SOLANUM	LYCOPERSICUM		CLN1464B	Hanson AVRDC	UAF
294	167	AVTO9611		TM:SOLANUM	LYCOPERSICUM		CLN1466A	Hanson AVRDC	UAF
295	168	AVTO9612		TM:SOLANUM	LYCOPERSICUM		CLN1466B	Hanson AVRDC	UAF
296	169	AVTO9613		TM:SOLANUM	LYCOPERSICUM		CLN1466C	Hanson AVRDC	UAF
297	170	AVTO9614		TM:SOLANUM	LYCOPERSICUM		CLN1466D	Hanson AVRDC	UAF
298	171	AVTO9615		TM:SOLANUM	LYCOPERSICUM		CLN1466E	Hanson AVRDC	UAF
299	172	AVTO9712		TM:SOLANUM	LYCOPERSICUM		CLN1621C	Hanson AVRDC	UAF
300	173	AVTO9701		TM:SOLANUM	LYCOPERSICUM		CLN1621E	Hanson AVRDC	UAF
301	174	AVTO9803		TM:SOLANUM	LYCOPERSICUM		CLN1621F	Hanson AVRDC	UAF
302	175	AVTO9713		TM:SOLANUM	LYCOPERSICUM		CLN1621H	Hanson AVRDC	UAF
303	176	AVTO9714		TM:SOLANUM	LYCOPERSICUM		CLN1621I	Hanson AVRDC	UAF
304	177			TM:SOLANUM	LYCOPERSICUM		CLN1621J	Hanson AVRDC	UAF
305	178	AVTO9801		TM:SOLANUM	LYCOPERSICUM		CLN1621L	Hanson AVRDC	UAF
306	179	AVTO9806		TM:SOLANUM	LYCOPERSICUM		CLN2026C	Hanson AVRDC	UAF
307	180	AVTO9802		TM:SOLANUM	LYCOPERSICUM		CLN2026D	Hanson AVRDC	UAF
308	181	AVTO9813		TM:SOLANUM	LYCOPERSICUM		CLN2026E	Hanson AVRDC	UAF
309	182	AVTO9325		TM:SOLANUM	LYCOPERSICUM		CLN236BC1F2-26-3-3-15	Hanson AVRDC	UAF
310	183	AVTO0301		TM:SOLANUM	LYCOPERSICUM		CLN2498D	Hanson AVRDC	UAF
311	184	AVTO0304		TM:SOLANUM	LYCOPERSICUM		CLN2498E	Hanson AVRDC	UAF
312	185	AVTO1228		TM:SOLANUM	LYCOPERSICUM		CLN3212A-23	Hanson AVRDC	UAF
313	186	AVTO1229		TM:SOLANUM	LYCOPERSICUM		CLN3212A-25	Hanson AVRDC	UAF
314	187	AVTO1227		TM:SOLANUM	LYCOPERSICUM		CLN3212B	Hanson AVRDC	UAF
315	188	AVTO9302		TM:SOLANUM	LYCOPERSICUM		CLN475BC1F2-265-12-9-1	Hanson AVRDC	UAF
316	189	AVTO9312		TM:SOLANUM	LYCOPERSICUM		CLN475BC1F2-265-4-19	Hanson AVRDC	UAF
317	190	AVTO9326		TM:SOLANUM	LYCOPERSICUM		CLN475BC1F2-265-9-0	Hanson AVRDC	UAF
318	191	AVTO9313		TM:SOLANUM	LYCOPERSICUM		CLN65-349D5-2-0	Hanson AVRDC	UAF
319	192			TM:SOLANUM	LYCOPERSICUM		CLN65-553D4-6-6-0	Hanson AVRDC	UAF
320	193	AVTO9327		TM:SOLANUM	LYCOPERSICUM		CLN657BC1F2-267-0-3-1-4	Hanson AVRDC	UAF
321	194	AVTO9328		TM:SOLANUM	LYCOPERSICUM		CLN657BC1F2-274-0-15-0	Hanson AVRDC	UAF
322	195	AVTO9305		TM:SOLANUM	LYCOPERSICUM		CLN657BC1F2-274-0-15-4	Hanson AVRDC	UAF

323	196	AVTO9329		TM:SOLANUM	LYCOPERSICUM		CLN657BC1 F2-285-0-21	Hanson AVRDC	UAF
324	197	AVTO9511		TM:SOLANUM	LYCOPERSICUM		CLN698BC1 F2-358-4-13	Hanson AVRDC	UAF
325	248	Rio Grand Rich Pro		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF
326	249	Rio Grande Quantum		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF
327	250	Rio Grande California		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF
328	251	Tima France		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF
329	252	Tomato 3383 F1		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF
330	253	CM Selection		TM:SOLANUM	LYCOPERSICUM			VRI, FSD Pakistan	UAF

Appendix 2: List of the okra genotypes used in the project

S No.	ID/Name	Genus	Species	Pedigree	Origin	Source	Entry rcvd at
1	VI039622	ABELMOSCHUS	ESCULENTUS	CHOITALI	Bangladesh	AVRDC	UAF/PBI
2	VI039638	ABELMOSCHUS	ESCULENTUS	LOCAL	Bangladesh	AVRDC	UAF/PBI
3	VI039643	ABELMOSCHUS	ESCULENTUS	DESHI	Bangladesh	AVRDC	UAF/PBI
4	VI039651	ABELMOSCHUS	ESCULENTUS	LOCAL	Bangladesh	AVRDC	UAF/PBI
5	VI039652	ABELMOSCHUS	ESCULENTUS	P.S.TYPE	Bangladesh	AVRDC	UAF/PBI
6	VI040649	ABELMOSCHUS	ESCULENTUS	KRACHIAPKHIEO	Thailand	AVRDC	UAF/PBI
7	VI040770	ABELMOSCHUS	ESCULENTUS	KRA-CHIAP-KHIEO	Thailand	AVRDC	UAF/PBI
8	VI040865	ABELMOSCHUS	ESCULENTUS	KRACHIAPKHIEO	Thailand	AVRDC	UAF/PBI
9	VI041139	ABELMOSCHUS	ESCULENTUS	THUA LEA	Thailand	AVRDC	UAF/PBI
10	VI041215	ABELMOSCHUS	ESCULENTUS		Philippines	AVRDC	UAF/PBI
11	VI041461	ABELMOSCHUS	ESCULENTUS		Philippines	AVRDC	UAF/PBI
12	VI041462	ABELMOSCHUS	ESCULENTUS		Philippines	AVRDC	UAF/PBI
13	VI041763	ABELMOSCHUS	ESCULENTUS	SEL-2	India	AVRDC	UAF/PBI
14	VI044233	ABELMOSCHUS	ESCULENTUS		Philippines	AVRDC	UAF/PBI
15	VI044241	ABELMOSCHUS	ESCULENTUS		Philippines	AVRDC	UAF/PBI
16	VI044244	ABELMOSCHUS	ESCULENTUS		Philippines	AVRDC	UAF/PBI
17	VI037997	ABELMOSCHUS	ESCULENTUS		Thailand	AVRDC	UAF/PBI
18	VI037995	ABELMOSCHUS	ESCULENTUS		Thailand	AVRDC	UAF/PBI
19	VI037994	ABELMOSCHUS	ESCULENTUS		Thailand	AVRDC	UAF/PBI
20	VI033773	ABELMOSCHUS	ESCULENTUS	LADY'S FINGER	Malaysia	AVRDC	UAF/PBI
21	VI033775	ABELMOSCHUS	ESCULENTUS	MK BE 1	Malaysia	AVRDC	UAF/PBI
22	VI033781-A	ABELMOSCHUS	ESCULENTUS	BENDIR LIMA SEGI	Malaysia	AVRDC	UAF/PBI
23	VI033781-B	ABELMOSCHUS	ESCULENTUS	BENDIR LIMA SEGI	Malaysia	AVRDC	UAF/PBI
24	VI033784	ABELMOSCHUS	ESCULENTUS	LOCAL 5-ANGLED OKRA	Malaysia	AVRDC	UAF/PBI
25	VI033785	ABELMOSCHUS	ESCULENTUS	MALAYSIA OKRA 5-ANGLED	Malaysia	AVRDC	UAF/PBI
26	VI033786	ABELMOSCHUS	ESCULENTUS	MALAYSIA OKRA 5-ANGLED	Malaysia	AVRDC	UAF/PBI
27	VI033791	ABELMOSCHUS	ESCULENTUS		Malaysia	AVRDC	UAF/PBI
28	VI033803	ABELMOSCHUS	ESCULENTUS		Philippines	AVRDC	UAF/PBI
29	VI033805	ABELMOSCHUS	ESCULENTUS		Philippines	AVRDC	UAF/PBI
30	VI033810	ABELMOSCHUS	ESCULENTUS		Philippines	AVRDC	UAF/PBI
31	VI033824	ABELMOSCHUS	ESCULENTUS		Philippines	AVRDC	UAF/PBI
32	VI036201	ABELMOSCHUS	ESCULENTUS		Philippines	AVRDC	UAF/PBI
33	VI036203	ABELMOSCHUS	ESCULENTUS	OKRANG TAGALOG	Philippines	AVRDC	UAF/PBI
34	VI036211	ABELMOSCHUS	ESCULENTUS		Philippines	AVRDC	UAF/PBI
35	VI036212	ABELMOSCHUS	ESCULENTUS		Philippines	AVRDC	UAF/PBI
36	VI036213	ABELMOSCHUS	ESCULENTUS		Philippines	AVRDC	UAF/PBI
37	VI036215	ABELMOSCHUS	ESCULENTUS		Philippines	AVRDC	UAF/PBI
38	VI046536	ABELMOSCHUS	ESCULENTUS	KRACHIAP KHIEO	Thailand	AVRDC	UAF/PBI
39	VI046537	ABELMOSCHUS	ESCULENTUS	KRACHIAP KHIEO	Thailand	AVRDC	UAF/PBI
40	VI046544	ABELMOSCHUS	ESCULENTUS	KRACHIAP KHIEO	Thailand	AVRDC	UAF/PBI
41	VI046554	ABELMOSCHUS	ESCULENTUS		Thailand	AVRDC	UAF/PBI

42	VI046556	ABELMOSCHUS	ESCULENTUS		Thailand	AVRDC	UAF/PBI
43	VI046559	ABELMOSCHUS	ESCULENTUS		Thailand	AVRDC	UAF/PBI
44	VI046562	ABELMOSCHUS	ESCULENTUS		Thailand	AVRDC	UAF/PBI
45	VI046563	ABELMOSCHUS	ESCULENTUS		Thailand	AVRDC	UAF/PBI
46	VI046566	ABELMOSCHUS	ESCULENTUS	OK5	Thailand	AVRDC	UAF/PBI
47	VI047672	ABELMOSCHUS	ESCULENTUS		Bangladesh	AVRDC	UAF/PBI
48	VI047751	ABELMOSCHUS	ESCULENTUS	DHEROS/VENDI	Bangladesh	AVRDC	UAF/PBI
49	VI047808	ABELMOSCHUS	ESCULENTUS	DESHI DHELEOSH	Bangladesh	AVRDC	UAF/PBI
50	VI048154	ABELMOSCHUS	ESCULENTUS		Bangladesh	AVRDC	UAF/PBI
51	VI048291	ABELMOSCHUS	ESCULENTUS		Bangladesh	AVRDC	UAF/PBI
52	VI048596	ABELMOSCHUS	MOSCHATUS		Taiwan	AVRDC	UAF/PBI
53	VI048692	ABELMOSCHUS	MOSCHATUS	CHID CHOR	Thailand	AVRDC	UAF/PBI
54	VI049632	ABELMOSCHUS	ESCULENTUS		Thailand	AVRDC	UAF/PBI
55	VI049954	ABELMOSCHUS	ESCULENTUS	HARITHA	Thailand	AVRDC	UAF/PBI
56	VI049961	ABELMOSCHUS	ESCULENTUS	MAHNCO ARKA ABHHAY	India	AVRDC	UAF/PBI
57	VI050145	ABELMOSCHUS	MOSCHATUS		Taiwan	AVRDC	UAF/PBI
58	VI050150	ABELMOSCHUS	ESCULENTUS		Taiwan	AVRDC	UAF/PBI
59	VI050170	ABELMOSCHUS	ESCULENTUS		Taiwan	AVRDC	UAF/PBI
60	VI050549	ABELMOSCHUS	ESCULENTUS		Thailand	AVRDC	UAF/PBI
61	VI051038	ABELMOSCHUS	ESCULENTUS	OKRA	Philippines	AVRDC	UAF/PBI
62	VI051039	ABELMOSCHUS	ESCULENTUS		Philippines	AVRDC	UAF/PBI
63	VI051042	ABELMOSCHUS	ESCULENTUS	OKRA	Philippines	AVRDC	UAF/PBI
64	VI051047	ABELMOSCHUS	ESCULENTUS		Philippines	AVRDC	UAF/PBI
65	VI051048	ABELMOSCHUS	ESCULENTUS		Philippines	AVRDC	UAF/PBI
66	VI051062	ABELMOSCHUS	ESCULENTUS	OKRA	Philippines	AVRDC	UAF/PBI
67	VI051077	ABELMOSCHUS	ESCULENTUS	OKRA/SALUYOT	Philippines	AVRDC	UAF/PBI
68	VI051114	ABELMOSCHUS	ESCULENTUS	UTONG	Philippines	AVRDC	UAF/PBI
69	VI054546	ABELMOSCHUS	ESCULENTUS	OKRA	Philippines	AVRDC	UAF/PBI
70	VI054562	ABELMOSCHUS	ESCULENTUS	OKRA	Philippines	AVRDC	UAF/PBI
71	VI054563	ABELMOSCHUS	ESCULENTUS	OKRA	Philippines	AVRDC	UAF/PBI
72	VI054565	ABELMOSCHUS	ESCULENTUS	OKRA	Philippines	AVRDC	UAF/PBI
73	VI054566	ABELMOSCHUS	ESCULENTUS		Philippines	AVRDC	UAF/PBI
74	VI054568	ABELMOSCHUS	MOSCHATUS	OKRA	Philippines	AVRDC	UAF/PBI
75	VI055017	ABELMOSCHUS	ESCULENTUS		Philippines	AVRDC	UAF/PBI
76	VI055018	ABELMOSCHUS	ESCULENTUS		Philippines	AVRDC	UAF/PBI
77	VI055110	ABELMOSCHUS	ESCULENTUS	KACANG LI (LENDIR)	Malaysia	AVRDC	UAF/PBI
78	VI055119	ABELMOSCHUS	ESCULENTUS		Myanmar	AVRDC	UAF/PBI
79	VI055219	ABELMOSCHUS	ESCULENTUS	KACANG BENDI	Malaysia	AVRDC	UAF/PBI
80	VI055220	ABELMOSCHUS	ESCULENTUS	KACANG BENDI	Malaysia	AVRDC	UAF/PBI
81	VI055578	ABELMOSCHUS	ESCULENTUS	LEIN MEUANANG	Lao	AVRDC	UAF/PBI
82	VI055582	ABELMOSCHUS	MOSCHATUS		Lao	AVRDC	UAF/PBI
83	VI055884	ABELMOSCHUS	ESCULENTUS	MAK LAEP MEUANANG	Lao	AVRDC	UAF/PBI
84	VI055996	ABELMOSCHUS	ESCULENTUS	PHAK PANG	Lao	AVRDC	UAF/PBI
85	VI056069	ABELMOSCHUS	ESCULENTUS		Cambodia	AVRDC	UAF/PBI
86	VI056079	ABELMOSCHUS	ESCULENTUS		Cambodia	AVRDC	UAF/PBI

87	VI056081	ABELMOSCHUS	ESCULENTUS		Cambodia	AVRDC	UAF/PBI
88	VI056401	ABELMOSCHUS	ESCULENTUS		Philippines	AVRDC	UAF/PBI
89	VI056402	ABELMOSCHUS	ESCULENTUS		Philippines	AVRDC	UAF/PBI
90	VI056404	ABELMOSCHUS	ESCULENTUS		Philippines	AVRDC	UAF/PBI
91	VI056407	ABELMOSCHUS	MOSCHATUS		Philippines	AVRDC	UAF/PBI
92	VI056447	ABELMOSCHUS	MOSCHATUS		Philippines	AVRDC	UAF/PBI
93	VI056448	ABELMOSCHUS	ESCULENTUS	COWHORN	USA	AVRDC	UAF/PBI
94	VI056449	ABELMOSCHUS	ESCULENTUS	BURGUNDY	USA	AVRDC	UAF/PBI
95	VI056450	ABELMOSCHUS	ESCULENTUS	CLEMSON SPINELESS 80	USA	AVRDC	UAF/PBI
96	VI056451	ABELMOSCHUS	ESCULENTUS	LEE DWARF	USA	AVRDC	UAF/PBI
97	VI056452	ABELMOSCHUS	ESCULENTUS	SILVER QUEEN	USA	AVRDC	UAF/PBI
98	VI056453	ABELMOSCHUS	ESCULENTUS	CHOPPEE	USA	AVRDC	UAF/PBI
99	VI056454	ABELMOSCHUS	ESCULENTUS	CAFÉ QUETZAL	Guatemala	AVRDC	UAF/PBI
100	VI056455	ABELMOSCHUS	ESCULENTUS	YUMA RED	USA	AVRDC	UAF/PBI
101	VI056456	ABELMOSCHUS	ESCULENTUS	CAJUN JEWEL	USA	AVRDC	UAF/PBI
102	VI057245	ABELMOSCHUS	ESCULENTUS		Cambodia	AVRDC	UAF/PBI
103	VI057249	ABELMOSCHUS	ESCULENTUS		Cambodia	AVRDC	UAF/PBI
104	VI060131	ABELMOSCHUS	MOSCHATUS	GOMBO PAYSAN	Mali	AVRDC	UAF/PBI
105	VI060132	ABELMOSCHUS	ESCULENTUS	GancR/08	Mali	AVRDC	UAF/PBI
106	VI060133	ABELMOSCHUS	ESCULENTUS	GancR/CS0708	Mali	AVRDC	UAF/PBI
107	VI060206	ABELMOSCHUS	ESCULENTUS	BHENDI	Australia	AVRDC	UAF/PBI
108	VI060313	ABELMOSCHUS	ESCULENTUS	TZ-SMN-86	Tanzania	AVRDC	UAF/PBI
109	VI060314	ABELMOSCHUS	ESCULENTUS	TZ-SMN-9-5	Tanzania	AVRDC	UAF/PBI
110	VI060315	ABELMOSCHUS	ESCULENTUS	TZ-SMN-98	Tanzania	AVRDC	UAF/PBI
111	VI060316	ABELMOSCHUS	ESCULENTUS	TZ-SMN-103	Tanzania	AVRDC	UAF/PBI
112	VI060317	ABELMOSCHUS	ESCULENTUS	RCA 1	Tanzania	AVRDC	UAF/PBI
113	Sabzpari	ABELMOSCHUS	ESCULENTUS		Pakistan	VRI, Faisalabad	UAF/PBI
114	Diksha	ABELMOSCHUS	ESCULENTUS		India	VRI, Faisalabad	UAF/PBI
115	MS-04	ABELMOSCHUS	ESCULENTUS		Pakistan	VRI, Faisalabad	UAF/PBI
116	Pusa Sawani	ABELMOSCHUS	ESCULENTUS		India	VRI, Faisalabad	UAF/PBI
117	Green Wounder	ABELMOSCHUS	ESCULENTUS		India	VRI, Faisalabad	UAF/PBI
118	OH-152	ABELMOSCHUS	ESCULENTUS		Thailand	VRI, Faisalabad	UAF/PBI
119	MD-02	ABELMOSCHUS	ESCULENTUS		Pakistan	VRI, Faisalabad	UAF/PBI
120	China Red	ABELMOSCHUS	ESCULENTUS		China	VRI, Faisalabad	UAF/PBI
121	Punjab Selection	ABELMOSCHUS	ESCULENTUS		India	VRI, Faisalabad	UAF/PBI
122	Pharbhani Karanti	ABELMOSCHUS	ESCULENTUS		India	VRI, Faisalabad	UAF/PBI
123	OH-139	ABELMOSCHUS	ESCULENTUS		Pakistan	VRI, Faisalabad	UAF/PBI
124	OH-713	ABELMOSCHUS	ESCULENTUS		Pakistan	VRI, Faisalabad	UAF/PBI
125	Super Star	ABELMOSCHUS	ESCULENTUS		India	VRI, Faisalabad	UAF/PBI
126	OH-597	ABELMOSCHUS	ESCULENTUS		Pakistan	VRI, Faisalabad	UAF/PBI
127	OH-2324	ABELMOSCHUS	ESCULENTUS		Pakistan	VRI, Faisalabad	UAF/PBI
128	PMS-55	ABELMOSCHUS	ESCULENTUS		Pakistan	VRI, Faisalabad	UAF/PBI

129	PMF Beauty	ABELMOSCHUS	ESCULENTUS		Pakistan	VRI, Faisalabad	UAF/PBI
130	Ikra-3	ABELMOSCHUS	ESCULENTUS		Pakistan	VRI, Faisalabad	UAF/PBI
131	Okra-1548	ABELMOSCHUS	ESCULENTUS		Pakistan	VRI, Faisalabad	UAF/PBI
132	Sanam	ABELMOSCHUS	ESCULENTUS		India	VRI, Faisalabad	UAF/PBI
133	Okra-7080	ABELMOSCHUS	ESCULENTUS		Pakistan	VRI, Faisalabad	UAF/PBI
134	Kiran	ABELMOSCHUS	ESCULENTUS		India	VRI, Faisalabad	UAF/PBI
135	Sitara-9101	ABELMOSCHUS	ESCULENTUS		Pakistan	VRI, Faisalabad	UAF/PBI
136	Okra-7100	ABELMOSCHUS	ESCULENTUS		Pakistan	VRI, Faisalabad	UAF/PBI
137	Click-5769	ABELMOSCHUS	ESCULENTUS		USA	VRI, Faisalabad	UAF/PBI
138	Laxmy	ABELMOSCHUS	ESCULENTUS		India	VRI, Faisalabad	UAF/PBI
139	JKOH-456	ABELMOSCHUS	ESCULENTUS		Pakistan	VRI, Faisalabad	UAF/PBI
140	JK Tetra-6	ABELMOSCHUS	ESCULENTUS		Pakistan	VRI, Faisalabad	UAF/PBI
141	Lush Green	ABELMOSCHUS	ESCULENTUS		India	VRI, Faisalabad	UAF/PBI
142	Rama Krishna	ABELMOSCHUS	ESCULENTUS		India	VRI, Faisalabad	UAF/PBI
143	Garnier	ABELMOSCHUS	ESCULENTUS			VRI, Faisalabad	UAF/PBI
144	Tokita	ABELMOSCHUS	ESCULENTUS			VRI, Faisalabad	UAF/PBI
145	Green Gold	ABELMOSCHUS	ESCULENTUS		Pakistan	VRI, Faisalabad	UAF/PBI
146	NSSL 6372 01 SD	ABELMOSCHUS	ESCULENTUS		USA	USDA	PBI
147	NSSL 6373 01 SD	ABELMOSCHUS	ESCULENTUS		USA	USDA	PBI
148	NSSL 6374 01 SD	ABELMOSCHUS	ESCULENTUS		USA	USDA	PBI
149	NSSL 6375 01 SD	ABELMOSCHUS	ESCULENTUS		USA	USDA	PBI
150	NSSL 6376 01 SD	ABELMOSCHUS	ESCULENTUS		USA	USDA	PBI
151	NSSL 6377 01 SD	ABELMOSCHUS	ESCULENTUS		USA	USDA	PBI
152	NSSL 6652 01 SD	ABELMOSCHUS	ESCULENTUS		USA	USDA	PBI
153	NSSL 6653 01 SD	ABELMOSCHUS	ESCULENTUS		USA	USDA	PBI
154	NSSL 6679 01 SD	ABELMOSCHUS	ESCULENTUS		USA	USDA	PBI
155	NSSL 22639 01 SD	ABELMOSCHUS	ESCULENTUS		USA	USDA	PBI
156	NSSL 22646 02 SD	ABELMOSCHUS	ESCULENTUS		USA	USDA	PBI
157	NSSL 26529 01 SD	ABELMOSCHUS	ESCULENTUS		USA	USDA	PBI
158	NSSL 28694 02 SD	ABELMOSCHUS	ESCULENTUS		USA	USDA	PBI
159	NSSL 28695 03 SD	ABELMOSCHUS	ESCULENTUS		USA	USDA	PBI
160	NSSL 28696 02 SD	ABELMOSCHUS	ESCULENTUS		USA	USDA	PBI
161	NSSL 28697 01 SD	ABELMOSCHUS	ESCULENTUS		USA	USDA	PBI
162	NSSL 28699 03	ABELMOSCHUS	ESCULENTUS		USA	USDA	PBI

	SD						
163	NSSL 31338 01 SD	ABELMOSCHUS	ESCULENTUS		USA	USDA	PBI
164	NSSL 31567 01 SD	ABELMOSCHUS	ESCULENTUS		USA	USDA	PBI
165	NSSL 32797 01 SD	ABELMOSCHUS	ESCULENTUS		USA	USDA	PBI
166	NSSL 32806 01 SD	ABELMOSCHUS	ESCULENTUS		USA	USDA	PBI
167	NSSL 37032 02 SD	ABELMOSCHUS	ESCULENTUS		USA	USDA	PBI
168	NSSL 76065 01 SD	ABELMOSCHUS	ESCULENTUS		Turkey	USDA	PBI
169	NSSL 378790 01 SD	ABELMOSCHUS	ESCULENTUS		Russian Federation	USDA	PBI
170	NSSL 378791 01 SD	ABELMOSCHUS	ESCULENTUS		Russian Federation	USDA	PBI
171	NSSL 378792 01 SD	ABELMOSCHUS	ESCULENTUS		Russian Federation	USDA	PBI
172	NSSL 378793 01 SD	ABELMOSCHUS	ESCULENTUS		Russian Federation	USDA	PBI
173	NSSL 378794 01 SD	ABELMOSCHUS	ESCULENTUS		Russian Federation	USDA	PBI
174	NSSL 378795 01 SD	ABELMOSCHUS	ESCULENTUS		Russian Federation	USDA	PBI
175	Grif 12989	ABELMOSCHUS	ESCULENTUS		India	USDA	PBI
176	PI 105442 01 SD	ABELMOSCHUS	ESCULENTUS		Turkey	USDA	PBI
177	PI 109215 01 SD	ABELMOSCHUS	ESCULENTUS		Turkey	USDA	PBI
178	PI 117095 01 SD	ABELMOSCHUS	ESCULENTUS		Turkey	USDA	PBI
179	PI 120660 01 SD	ABELMOSCHUS	ESCULENTUS		Turkey	USDA	PBI
180	PI 120661 01 SD	ABELMOSCHUS	ESCULENTUS		Turkey	USDA	PBI
181	PI 120826 01 SD	ABELMOSCHUS	ESCULENTUS		Turkey	USDA	PBI
182	PI 124977 01 SD	ABELMOSCHUS	ESCULENTUS		Mexico	USDA	PBI
183	PI 127417 01 SD	ABELMOSCHUS	ESCULENTUS		Afghanistan	USDA	PBI
184	PI 138507 01 SD	ABELMOSCHUS	ESCULENTUS		Iraq	USDA	PBI
185	PI 138508 01 SD	ABELMOSCHUS	ESCULENTUS		Iran	USDA	PBI
186	PI 140316 01 SD	ABELMOSCHUS	ESCULENTUS		Iran	USDA	PBI
187	PI 140317 01 SD	ABELMOSCHUS	ESCULENTUS		Iran	USDA	PBI
188	PI 140318 01 SD	ABELMOSCHUS	ESCULENTUS		Iran	USDA	PBI
189	PI 142784 01 SD	ABELMOSCHUS	ESCULENTUS		Iran	USDA	PBI
190	PI 142785 01 SD	ABELMOSCHUS	ESCULENTUS		Iran	USDA	PBI
191	PI 142786 01 SD	ABELMOSCHUS	ESCULENTUS		Iran	USDA	PBI
192	PI 155295 01 SD	ABELMOSCHUS	ESCULENTUS		Yemen	USDA	PBI
193	PI 169696 01 SD	ABELMOSCHUS	ESCULENTUS		Turkey	USDA	PBI

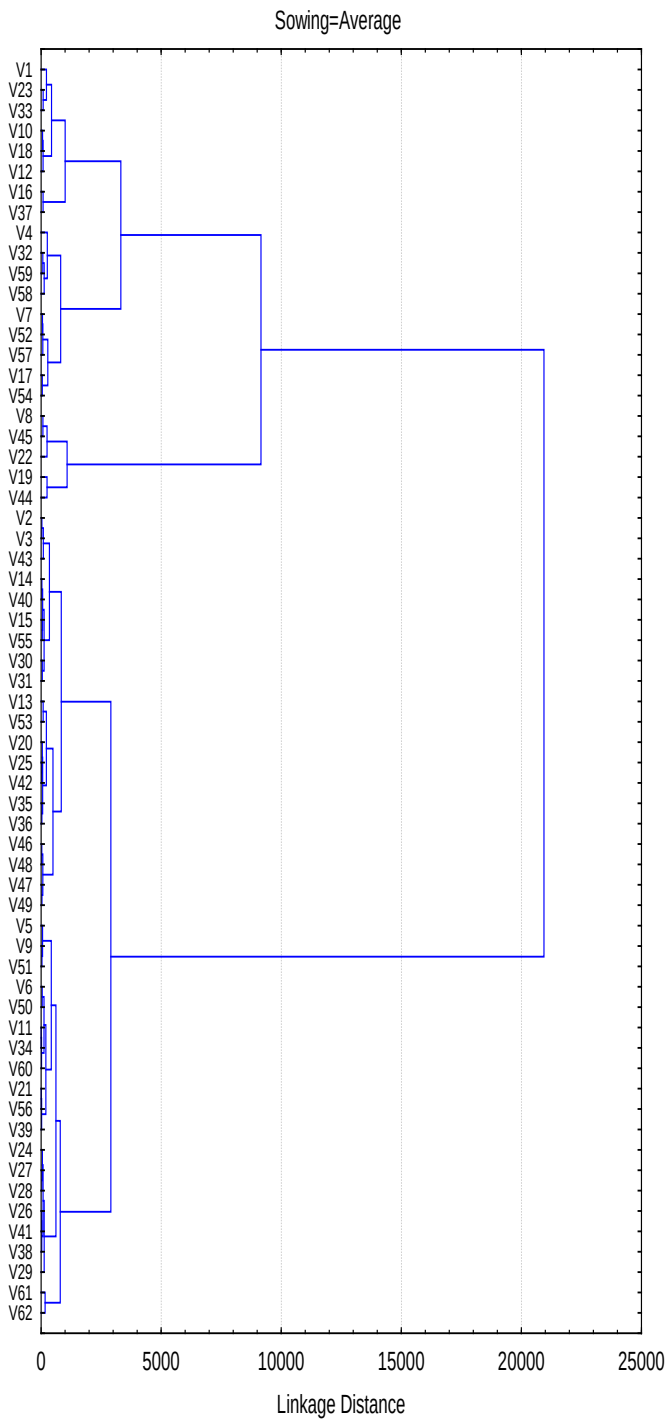
Appendix 3: Tomato and okra entries shortlisted after the first round of screening

Shortlisted tomato entries in the first round of screening at UAF			**Shortlisted okra entries in the first round of screening at UAF**		
S No.	Tomato Genotype	Description	S No.	Okra Genotype	Description
1	CLN-2366 A	Tolerant stage 1 screening	1	VI039622	Tolerant stage 1 screening
2	Polar Beauty	Tolerant stage 1 screening	2	VI036211	Tolerant stage 1 screening
3	Forme De Coeur	Tolerant stage 1 screening	3	VI056455	Tolerant stage 1 screening
4	Kaldera	Tolerant stage 1 screening	4	VI056453	Tolerant stage 1 screening
5	Caro Rich Tomato	Tolerant stage 1 screening	5	OH-152	Tolerant stage 1 screening
6	Spekled Siberian	Tolerant stage 1 screening	6	VI060313	Tolerant stage 1 screening
7	Northern Delight	Tolerant stage 1 screening	7	VI033773	Tolerant stage 1 screening
8	L00090	Tolerant stage 1 screening	8	VI036203	Tolerant stage 1 screening
9	Manitoba	Tolerant stage 1 screening	9	VI046554	Tolerant stage 1 screening
10	Anahu	Tolerant stage 1 screening	10	VI033805	Tolerant stage 1 screening
11	Nagina	Tolerant stage 1 screening	11	VI060133	Tolerant stage 1 screening
12	Subarctic-A	Tolerant stage 1 screening	12	VI051048	Tolerant stage 1 screening
13	L00091	Tolerant stage 1 screening	13	VI044241	Tolerant stage 1 screening
14	L01301	Tolerant stage 1 screening	14	VI033781-B	Tolerant stage 1 screening
15	CLN2498E	Tolerant stage 1 screening	15	VI033775	Tolerant stage 1 screening
16	L00525	Tolerant stage 1 screening	16	VI054566	Tolerant stage 1 screening
17	L01213	Tolerant stage 1 screening	17	VI056456	Tolerant stage 1 screening
18	L01214	Tolerant stage 1 screening	18	VI037997	Tolerant stage 1 screening
19	L00184	Tolerant stage 1 screening	19	VI046537	Tolerant stage 1 screening
20	VI036349	Tolerant stage 1 screening	20	VI046566	Tolerant stage 1 screening
21	L01202	Tolerant stage 1 screening	21	VI050549	Tolerant stage 1 screening
22	L00587	Tolerant stage 1 screening	22	OH-713	Tolerant stage 1 screening
23	L00602	Tolerant stage 1 screening	23	OH-139	Tolerant stage 1 screening
24	L01212	Tolerant stage 1 screening	24	VI051114	Sensitive stage 1 screening
25	CLN475BC1F2-265-4-19	Tolerant stage 1 screening	25	VI033803	Sensitive stage 1 screening
26	L00263	Tolerant stage 1 screening	26	VI039652	Sensitive stage 1 screening
27	L05931	Tolerant stage 1 screening	27	VI060206	Sensitive stage 1 screening
28	L00266	Tolerant stage 1 screening	28	VI060315	Sensitive stage 1 screening
29	L00451	Tolerant stage 1 screening	29	Tokita	Sensitive stage 1 screening
30	L00501	Tolerant stage 1 screening			
31	L00574	Tolerant stage 1 screening			
32	L00491	Tolerant stage 1 screening			
33	L00493	Tolerant stage 1 screening			
34	L01201	Tolerant stage 1 screening			
35	L05291	Tolerant stage 1 screening			
36	L00571	Tolerant stage 1 screening			
37	L04845	Tolerant stage 1 screening			
38	L00603	Tolerant stage 1 screening			
39	L05923	Tolerant stage 1 screening			

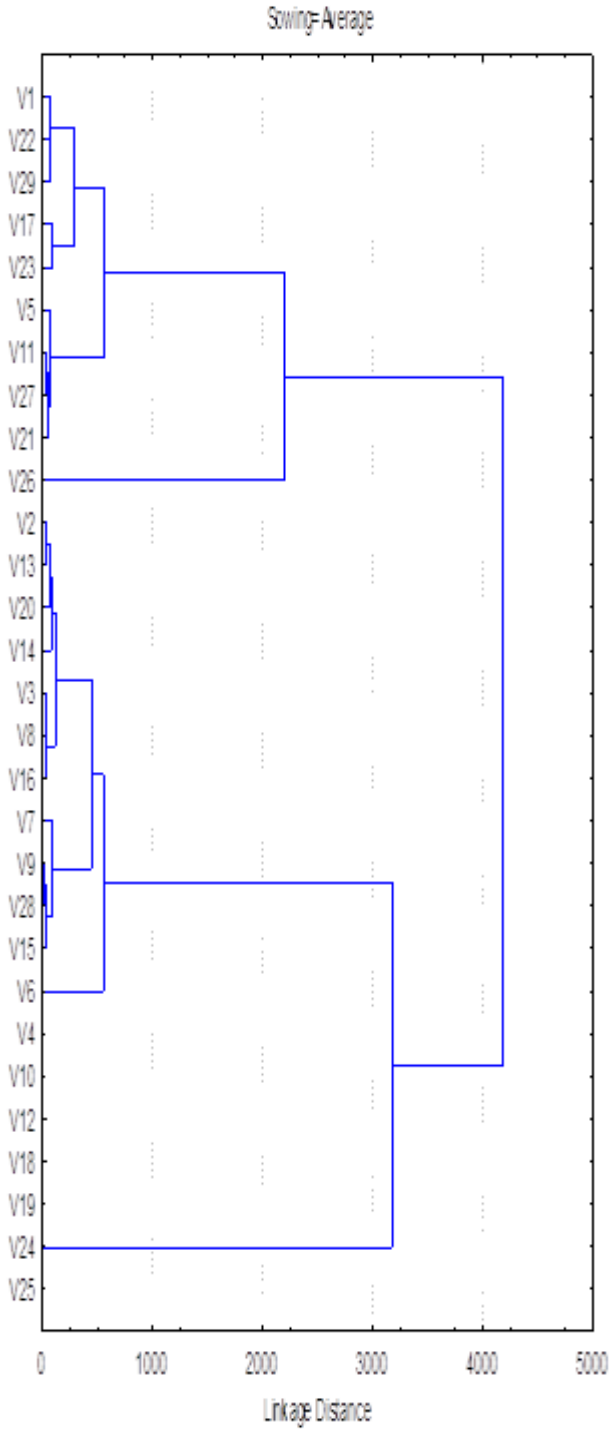
40	L01062	Tolerant stage 1 screening			
41	L05906	Tolerant stage 1 screening			
42	VI036350	Tolerant stage 1 screening			
43	VI036347	Tolerant stage 1 screening			
44	L00492	Tolerant stage 1 screening			
45	L01225	Tolerant stage 1 screening			
46	L01344	Tolerant stage 1 screening			
47	L04888	Tolerant stage 1 screening			
48	L00572	Tolerant stage 1 screening			
49	L01217	Tolerant stage 1 screening			
50	Iles Yellow Latvian	Sensitive stage 1 screening			
51	Pakit	Sensitive stage 1 screening			
52	UC-134	Sensitive stage 1 screening			
53	CLN1621I	Sensitive stage 1 screening			
54	L01216	Sensitive stage 1 screening			
55	L04853	Sensitive stage 1 screening			
56	CLN1466D	Sensitive stage 1 screening			
57	VI036339	Sensitive stage 1 screening			
58	VI036346	Sensitive stage 1 screening			
59	L01200	Sensitive stage 1 screening			
60	L05920	Sensitive stage 1 screening			
61	CLN1462A	Sensitive stage 1 screening			
62	CLN1466E	Sensitive stage 1 screening			

Appendix 4: Shortlisted tomato and okra entries ranked (Ward, 1963) on the basis of physiological and agronomic data in the field at UAF with two sowing dates (Highest performers are at the top).

Tomatoes lines = 62



Okra lines = 29

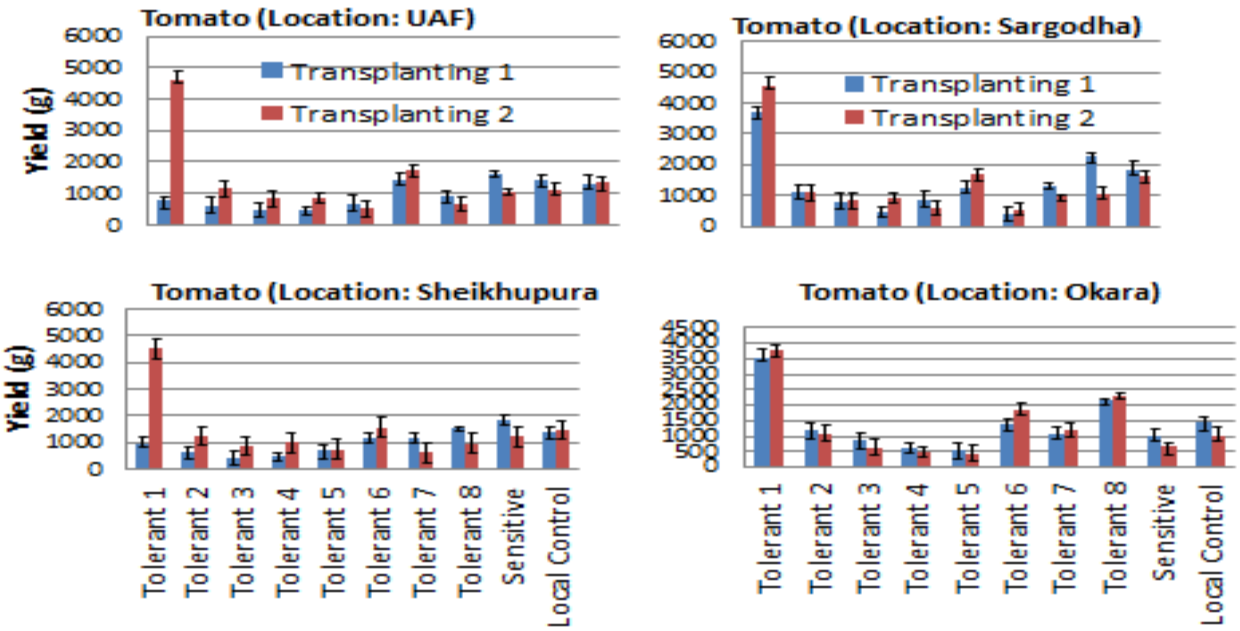


Appendix 5: Tomato and okra elite entries selected for multi-location testing in Punjab

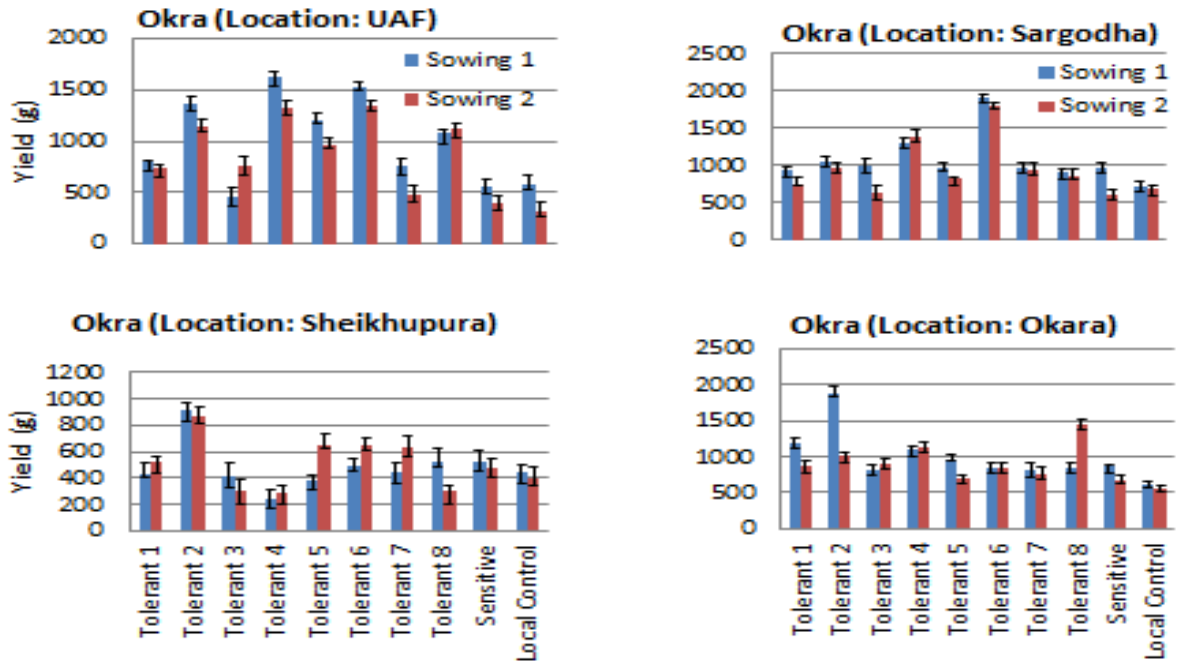
Tomato lines selected for multi-location testing in Punjab Pakistan				Okra lines selected for multi-location testing in Punjab Pakistan			
S No.	**Genotype**	**Description**	**Remarks**	**S No.**	**Genotype**	**Description**	**Remarks**
1	Subarctic-A	Tolerant S1 & S2 screening	Mod tolerant in tunnel at PBI	1	VI039622	Tolerant S1 & S2 screening	Mod tolerant in tunnel at PBI
2	L00525	Tolerant S1 & S2 screening	NA	2	VI056456	Tolerant S1 & S2 screening	Mod tolerant in tunnel at PBI
3	L04845	Tolerant S1 & S2 screening	NA	3	OH-139	Tolerant S1 & S2 screening	Mod tolerant in tunnel at PBI
4	CLN-2366 A	Tolerant S1 & S2 screening	Tolerant in tunnel at PBI	4	Tokita	Tolerant S1 & S2 screening	Mod tolerant in tunnel at PBI
5	L00493	Tolerant S1 & S2 screening	NA	5	OH-713	Tolerant S1 & S2 screening	Mod tolerant in tunnel at PBI
6	L00602	Tolerant S1 & S2 screening	NA	6	VI060206	Tolerant S1 & S2 screening	Mod tolerant in tunnel at PBI
7	L01214	Tolerant S1 & S2 screening	NA	7	OH-152	Tolerant S1 & S2 screening	Mod tolerant in tunnel at PBI
8	Anahu	Tolerant S1 & S2 screening	Mod tolerant in tunnel at PBI	8	VI060133	Tolerant S1 & S2 screening	NA
9	S Siberian	Sensitive in field screening	Mod tolerant in tunnel at PBI	9	VI046566	Sensitive in field screening	Mod tolerant in tunnel at PBI
10	Rio Grand	Standard	Mod tolerant in tunnel at PBI	10	Sabazpari	Standard	NA

Appendix 6: Yield performance of elite entries in the multi-location trials in Punjab

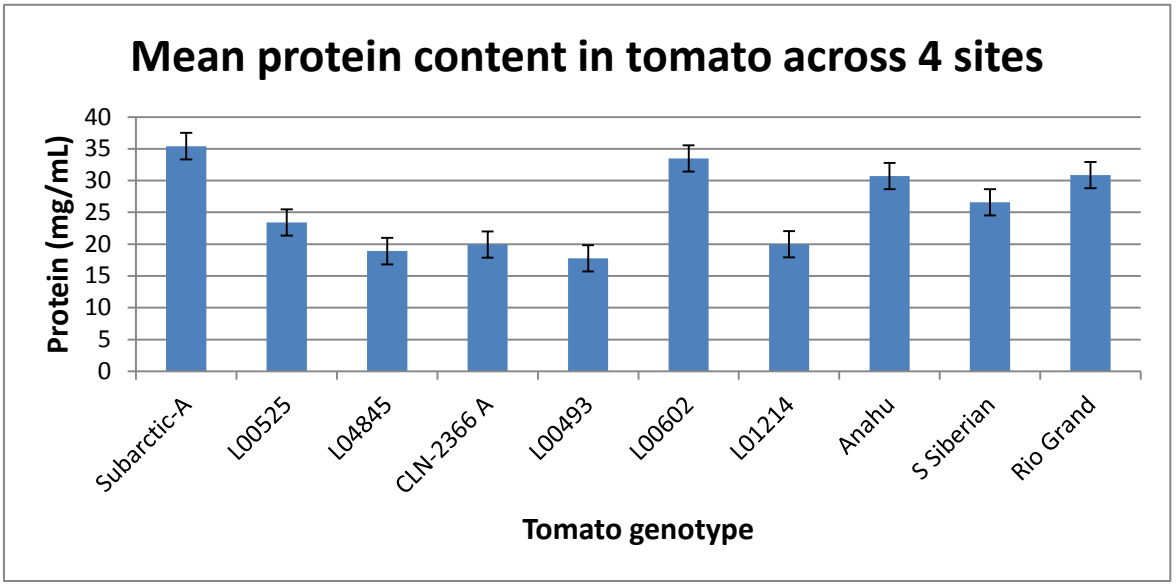
A) Tomato multi-location trials

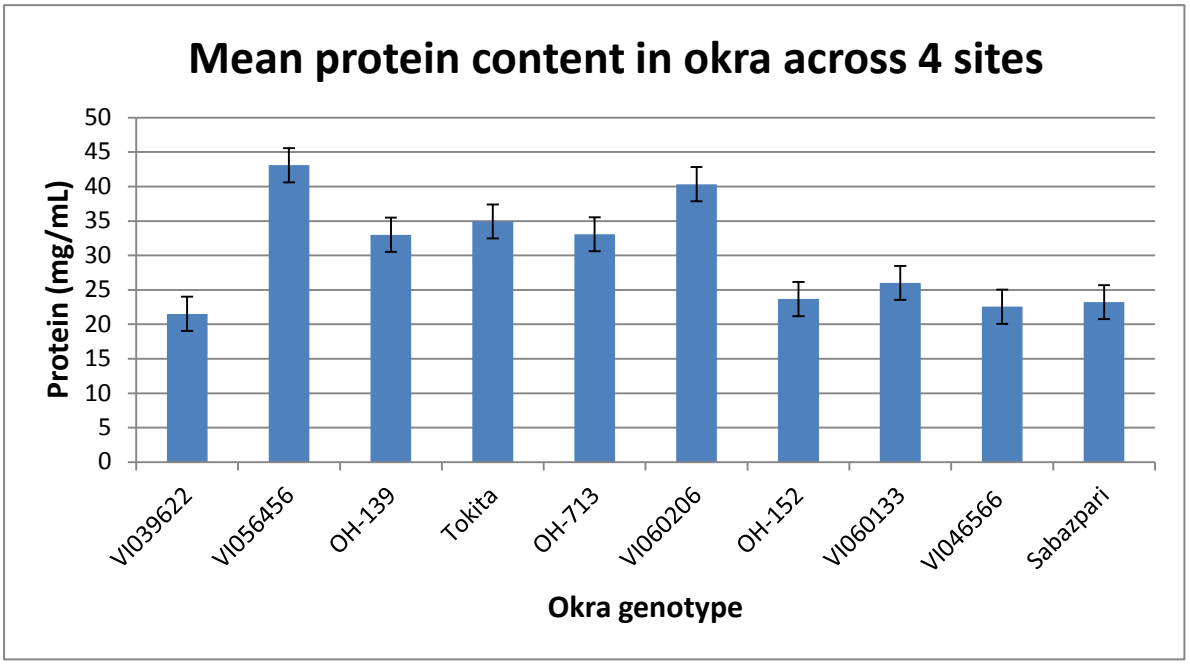


B) Okra multi-location trials

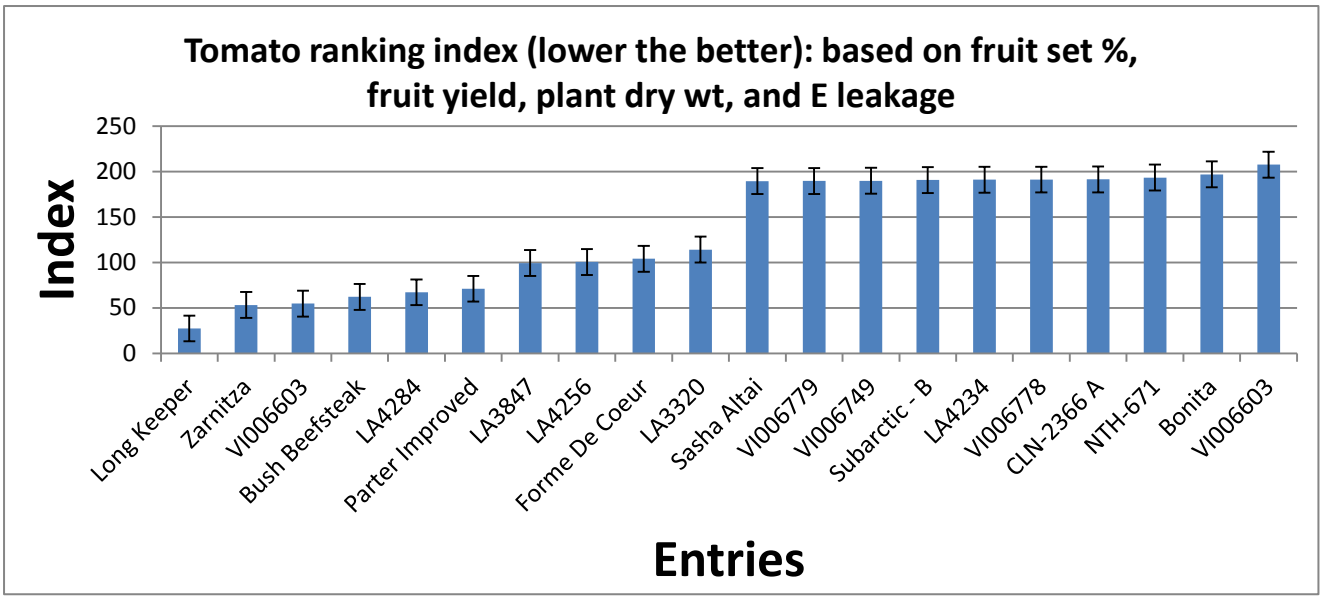


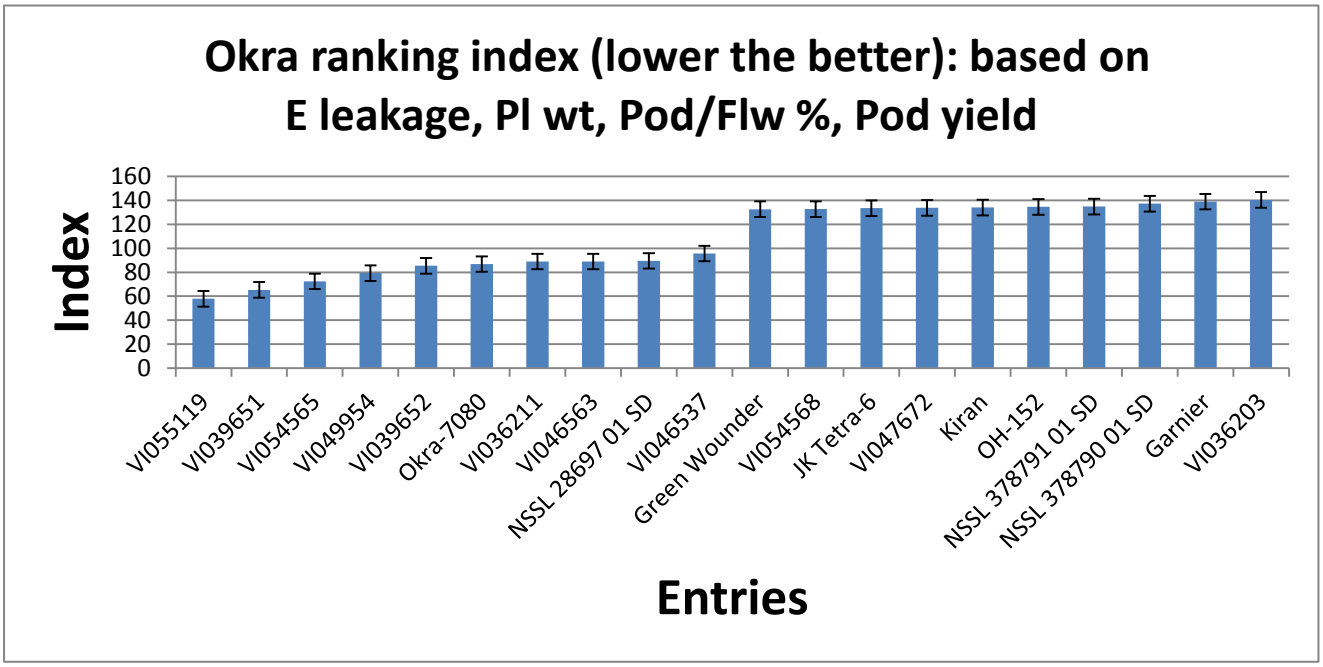
Appendix 7: Mean protein content in tomato and okra fruit across four sites in Punjab, Pakistan





Appendix 8: Tomatoes and okra entries (top ten and bottom ten) ranked (Gomez-Pando et al. 2009) on the basis of their performance in tunnel house at PBI





Appendix 9: Marker trait associations in tomato and okra (DArTseq). The top fifty markers with highest LOD scores influencing each trait are presented in the table.

A) Tomatoes (unpublished Ph.D research data M Alsamir, 2015)

Tomato List Order	DArTseq	Chromosome	Position	Pl dry weight	Electrolyte leakage	Fruit weight	No. inflorescence	No. flowers	No. fruit
				LOD score					
73	7797326	SL2.40ch01	293817	-	-	-	16.27	-	-
101	7795968	SL2.40ch01	915531	-	3.85	-	-	-	-
115	4694528	SL2.40ch01	1061171	-	-	-	4.55	-	-
123	7983855	SL2.40ch01	1281642	-	4	-	-	-	-
131	7759934	SL2.40ch01	1401506	-	-	-	-	3.48	-
133	7941163	SL2.40ch01	1476749	-	-	-	4.04	-	-
147	7864535	SL2.40ch01	1882405	-	-	-	4.73	-	-
152	7988409	SL2.40ch01	1946685	-	-	-	16.27	-	-
184	7851559	SL2.40ch01	2441031	-	13.59	-	-	-	-
224	7768210	SL2.40ch01	3051633	-	3.87	-	-	-	-
228	4705377	SL2.40ch01	3105176	4.39	-	-	-	-	-
256	8018472	SL2.40ch01	4265331	-	-	-	16.27	-	-
335	4694767	SL2.40ch01	13207673	-	-	3.55	-	-	-
394	7768033	SL2.40ch01	33900226	-	-	-	16.3	-	-
401	7792131	SL2.40ch01	39211504	-	-	-	16.27	-	-
467	7798066	SL2.40ch01	57854713	-	3.84	-	-	-	-
481	7988386	SL2.40ch01	59257109	-	3.87	-	-	-	-
484	8030242	SL2.40ch01	59717745	-	3.87	-	-	-	-
569	4699897	SL2.40ch01	69133809	-	-	-	-	3.93	-
571	7843195	SL2.40ch01	69150250	-	-	-	16.34	-	-
788	4697879	SL2.40ch01	74902270	-	12.64	-	-	-	-
1090	7988306	SL2.40ch01	80109436	10.94	-	-	-	-	-
1274	7793528	SL2.40ch01	81538102	-	-	3.24	-	-	-
1325	8030159	SL2.40ch01	81998292	-	-	-	11.61	-	-
1340	7988909	SL2.40ch01	82251525	-	-	-	9.65	-	-
1350	7959573	SL2.40ch01	82392517	-	-	3.23	-	-	-
1381	7942590	SL2.40ch01	83085140	6.93	-	-	-	-	-
1382	7840609	SL2.40ch01	83085140	7.15	-	-	-	-	-
1447	7844207	SL2.40ch01	84149429	11.83	-	-	-	-	-
1770	7844233	SL2.40ch02	7761474	-	-	-	-	-	4.8
1836	7941895	SL2.40ch02	17832837	-	-	-	-	4.07	-
1894	4695827	SL2.40ch02	28088359	11.6	-	-	-	-	-
2004	8029788	SL2.40ch02	32247548	4.61	-	-	3.76	-	-
2013	7942806	SL2.40ch02	32474518	4.61	-	-	3.76	-	-

2154	7947551	SL2.40ch02	36962281	-	7.8	3.24	-	-	-
2211	8005347	SL2.40ch02	38244251	-	-	3.27	-	-	-
2217	4701591	SL2.40ch02	38284212	-	-	-	-	-	5.02
2377	7844195	SL2.40ch02	41897525	-	-	3.25	-	-	-
2450	7798060	SL2.40ch02	43649492	-	-	-	-	-	4.65
2525	7764459	SL2.40ch02	44840434	-	-	3.21	-	-	-
2526	4701537	SL2.40ch02	44840488	-	-	-	-	-	4.61
2527	7853280	SL2.40ch02	44848958	-	-	3.28	-	-	-
2529	7834963	SL2.40ch02	44876345	-	-	-	-	-	4.55
2596	7755217	SL2.40ch02	45581686	-	-	3.21	-	-	-
2605	4702307	SL2.40ch02	45721210	-	-	-	-	-	4.62
2668	7759378	SL2.40ch02	47114191	-	-	-	-	-	4.59
2669	4694828	SL2.40ch02	47114257	-	-	-	-	-	4.47
2782	7844882	SL2.40ch02	49240436	-	-	3.51	-	-	-
2890	4697371	SL2.40ch03	1176225	-	-	-	-	-	4.57
2996	7941411	SL2.40ch03	7942835	-	-	-	-	3.21	-
2997	7760887	SL2.40ch03	7942835	-	-	-	-	3.32	-
3128	7997588	SL2.40ch03	25649988	-	-	-	16.27	-	-
3161	8041340	SL2.40ch03	39185501	-	3.87	-	-	-	-
3192	7940949	SL2.40ch03	45421344	-	-	3.26	-	-	-
3273	7754993	SL2.40ch03	48281029	-	-	-	8.28	-	-
3327	7846311	SL2.40ch03	51508987	-	-	3.29	-	-	-
3424	4695741	SL2.40ch03	55692361	-	-	-	-	-	4.84
3470	4700570	SL2.40ch03	56783847	-	-	3.25	-	-	-
3478	4697461	SL2.40ch03	56961907	5.66	-	-	-	-	-
3492	7759863	SL2.40ch03	57219025	-	3.83	-	-	-	-
3517	7942552	SL2.40ch03	57616782	-	-	-	2.95	-	-
3731	4695260	SL2.40ch03	61128810	-	-	-	-	-	4.5
3733	7959054	SL2.40ch03	61163245	-	3.75	-	-	-	-
3745	7844641	SL2.40ch03	61310825	-	-	-	4.3	-	-
4098	4697432	SL2.40ch04	3531930	-	-	-	-	3.28	-
4252	7835074	SL2.40ch04	19183845	-	-	-	-	-	5.16
4280	7759319	SL2.40ch04	25884155	-	-	-	5.4	-	-
4287	4696227	SL2.40ch04	29694793	-	-	-	-	-	5.14
4331	4697958	SL2.40ch04	41169853	-	3.1	3.3	-	-	-
4337	4702319	SL2.40ch04	41240594	-	-	-	-	-	4.6
4342	7941861	SL2.40ch04	42473749	-	-	-	-	3.36	-
4359	7984872	SL2.40ch04	44262955	-	4	-	-	-	-
4371	4704060	SL2.40ch04	45503548	7.31	-	-	-	-	-
4387	7755152	SL2.40ch04	48010526	-	-	-	3.09	-	-
4433	4697146	SL2.40ch04	52500996	-	-	-	2.97	-	-
4500	7941911	SL2.40ch04	54754830	-	-	3.27	-	-	-
4663	7765636	SL2.40ch04	60211531	-	-	-	-	-	5.02
4695	4700691	SL2.40ch04	61282615	-	13.1	-	-	-	-
4758	7942772	SL2.40ch04	62545646	-	-	-	3.55	-	-
4828	7988170	SL2.40ch04	63239364	4.61	-	-	3.76	-	-

4847	7796769	SL2.40ch04	63501449	-	4.07	3.23	-	-	-
4880	7940885	SL2.40ch04	63647310	-	-	3.26	-	-	-
4953	7838042	SL2.40ch05	282135	-	-	3.42	-	-	-
5078	7756090	SL2.40ch05	1756348	4.99	-	-	-	-	-
5140	4701734	SL2.40ch05	2990004	-	-	-	-	-	4.62
5173	4703366	SL2.40ch05	4093160	-	-	-	-	4.9	-
5232	4699809	SL2.40ch05	6269669	-	8.12	-	-	-	-
5272	7984498	SL2.40ch05	8516007	-	4	-	-	-	-
5529	8019081	SL2.40ch05	58514813	-	7.6	-	-	-	-
5586	7940937	SL2.40ch05	60332420	-	-	3.26	-	-	-
5696	7797850	SL2.40ch05	63907458	-	-	-	-	-	4.98
5713	4698030	SL2.40ch05	64101422	-	-	-	-	-	4.67
5729	8042814	SL2.40ch05	64189018	-	10.02	3.2	-	-	-
5730	7838397	SL2.40ch05	64189018	-	-	-	-	-	4.7
5732	4702038	SL2.40ch05	64223277	-	-	3.2	-	-	-
5739	4696734	SL2.40ch05	64357014	-	-	-	-	-	4.65
5767	7798527	SL2.40ch05	64764445	-	-	-	-	-	5
5844	7834844	SL2.40ch06	1001239	-	-	-	-	-	4.67
5854	8037652	SL2.40ch06	1312135	17.24	-	-	-	-	-
5863	7942743	SL2.40ch06	1469696	-	-	-	3.74	-	-
5868	7941044	SL2.40ch06	1596253	-	-	-	-	-	4.91
5869	7996598	SL2.40ch06	1596294	-	-	-	-	-	4.5
5881	7765350	SL2.40ch06	1694655	-	-	-	-	-	4.51
5886	4702799	SL2.40ch06	1728893	-	-	3.32	-	-	-
5938	7839690	SL2.40ch06	2755646	-	-	-	3.72	-	-
5998	8038225	SL2.40ch06	6292426	-	-	-	16.27	-	-
6066	7992344	SL2.40ch06	21752312	-	-	-	3.45	-	-
6180	4702910	SL2.40ch06	30040332	-	-	3.35	-	-	-
6189	7864944	SL2.40ch06	30346640	-	-	3.2	-	-	-
6326	8004972	SL2.40ch06	35505015	-	-	3.18	-	-	-
6410	4702711	SL2.40ch06	37567085	-	-	-	-	3.97	-
6526	7986044	SL2.40ch06	40588726	-	4	-	-	-	-
6572	4702676	SL2.40ch06	41809750	-	3.07	-	-	-	-
6589	7853588	SL2.40ch06	42309607	-	-	3.25	-	-	-
6591	7945834	SL2.40ch06	42333191	-	-	3.25	-	-	-
6668	4696737	SL2.40ch06	44788666	-	-	-	5.41	-	-
6687	4698504	SL2.40ch06	45092199	-	-	-	5.69	-	-
6699	4699355	SL2.40ch06	45427891	-	-	-	-	3.25	-
6715	7989086	SL2.40ch07	28562	-	-	-	11.61	-	-
6771	4704673	SL2.40ch07	2236523	-	-	-	-	-	4.47
6798	4694702	SL2.40ch07	3147935	-	-	-	-	-	4.79
6846	4697807	SL2.40ch07	5212963	-	-	-	-	-	4.81
6979	4700378	SL2.40ch07	51248149	-	-	3.23	-	-	-
6996	8001698	SL2.40ch07	53001174	4.34	-	-	-	-	-
7156	7853255	SL2.40ch07	59892231	8.33	-	-	-	-	-
7185	4698929	SL2.40ch07	60582720	-	-	-	-	3.49	-

7187	7941880	SL2.40ch07	60599925	-	-	3.22	-	-	-
7219	4698794	SL2.40ch07	61647980	16.88	-	-	-	-	-
7227	7835887	SL2.40ch07	62020437	-	-	-	26.95	-	-
7461	8005865	SL2.40ch07	64714675	-	4	-	-	-	-
7481	7853983	SL2.40ch07	64893587	7.99	-	-	-	-	-
7508	4697169	SL2.40ch08	49737	-	-	-	-	-	5.08
7536	4694548	SL2.40ch08	1027930	-	-	-	-	-	5.44
7821	7959615	SL2.40ch08	53215750	-	4.07	3.23	-	-	-
7833	7966718	SL2.40ch08	53664035	-	3.05	-	-	-	-
7961	8004577	SL2.40ch08	56943468	12.63	-	-	-	-	-
7994	4699398	SL2.40ch08	57682782	5.9	-	-	-	-	-
8057	7997340	SL2.40ch08	59669014	-	-	3.23	-	-	-
8166	7834091	SL2.40ch09	327607	-	-	-	-	3.68	-
8167	7839877	SL2.40ch09	334400	-	-	-	-	3.48	-
8168	4695869	SL2.40ch09	344812	-	-	-	-	3.4	-
8170	4700650	SL2.40ch09	360552	-	-	-	-	3.39	-
8181	7765780	SL2.40ch09	624363	-	-	-	-	3.37	-
8182	7765277	SL2.40ch09	624414	-	-	-	-	3.49	-
8183	4697385	SL2.40ch09	625072	-	-	-	-	3.4	-
8232	7997198	SL2.40ch09	1752299	-	4	-	-	-	-
8241	7959057	SL2.40ch09	1958489	-	3.75	-	-	-	-
8441	7987133	SL2.40ch09	18096583	-	12.76	-	-	-	-
8444	4697778	SL2.40ch09	19187269	-	-	-	-	3.66	-
8532	4702958	SL2.40ch09	40120517	-	-	-	-	4.8	-
8868	7852577	SL2.40ch09	65015732	14.86	-	-	2.95	-	-
9057	4705578	SL2.40ch10	1172132	4.75	-	-	-	-	-
9221	7838763	SL2.40ch10	13407409	-	-	-	-	-	5.57
9241	4700387	SL2.40ch10	19393703	-	9.86	3.2	-	-	-
9266	4701839	SL2.40ch10	29639424	-	-	-	-	4.07	-
9335	7857014	SL2.40ch10	45522308	-	-	-	-	3.43	-
9359	4699144	SL2.40ch10	50737423	-	13.61	-	-	-	-
9375	7760216	SL2.40ch10	52373018	-	-	-	-	3.17	-
9376	7759266	SL2.40ch10	52373084	-	-	-	-	3.52	-
9426	7958632	SL2.40ch10	58850741	-	-	-	-	-	4.62
9484	7766439	SL2.40ch10	60743919	-	-	-	-	3.92	-
9491	4702816	SL2.40ch10	61052302	-	-	-	-	3.53	-
9492	4700756	SL2.40ch10	61064081	-	-	-	-	3.48	-
9622	4695837	SL2.40ch10	64431853	14.93	-	-	2.78	-	-
9726	8029752	SL2.40ch11	900645	-	-	3.26	-	-	-
9869	4701939	SL2.40ch11	4775637	-	-	-	-	3.44	-
9879	7988214	SL2.40ch11	5243715	-	-	-	-	3.34	-
9880	7941932	SL2.40ch11	5243782	-	-	-	-	3.26	-
9885	7835784	SL2.40ch11	5406226	-	-	-	-	4.08	-
9906	4705806	SL2.40ch11	6250494	-	-	-	-	3.92	-
9910	7941956	SL2.40ch11	6461311	-	-	-	-	3.41	-
9911	4695064	SL2.40ch11	6461311	-	-	-	-	3.74	-

9915	4696510	SL2.40ch11	6569810	-	-	-	-	3.54	-
9933	7941953	SL2.40ch11	7141790	-	-	-	-	3.8	-
9934	7756905	SL2.40ch11	7141790	-	-	-	-	3.26	-
9948	4700862	SL2.40ch11	7865440	-	-	-	-	3.28	-
9967	7757000	SL2.40ch11	8636585	-	-	-	-	3.37	-
10011	7942913	SL2.40ch11	14003457	5.22	-	-	-	-	-
10028	7982679	SL2.40ch11	17673373	-	4	-	-	-	-
10038	4700034	SL2.40ch11	19833195	-	3.23	-	-	-	-
10039	4696716	SL2.40ch11	19833245	-	3.11	-	-	-	-
10155	7941032	SL2.40ch11	45458119	-	-	3.26	-	-	-
10300	4699558	SL2.40ch11	50820180	-	-	-	-	5.35	-
10301	7759053	SL2.40ch11	50820246	-	-	-	-	4.95	-
10592	7944314	SL2.40ch12	3782241	-	10.84	-	-	-	-
10616	8013298	SL2.40ch12	4823614	-	-	3.26	-	-	-
10763	7853678	SL2.40ch12	29974049	-	-	-	-	-	4.94
10828	4699639	SL2.40ch12	38769068	-	-	3.29	-	-	-
10829	4702143	SL2.40ch12	39184662	-	-	3.24	-	-	4.87
10989	7833981	SL2.40ch12	62418091	4.59	-	-	-	-	-
10991	7942884	SL2.40ch12	62446894	5.22	-	-	-	-	-
11034	8030480	SL2.40ch12	62927554	5.22	-	-	-	-	-
11047	7764710	SL2.40ch12	63068112	4.6	-	-	-	-	-
11154	8030410	SL2.40ch12	64433813	5.22	-	-	-	-	-
11158	7842953	SL2.40ch12	64567563	5.85	-	-	-	-	-
11161	8013483	SL2.40ch12	64591135	5.22	-	-	-	-	-
11173	8034799	SL2.40ch12	64664144	5.22	-	-	-	-	-
11179	7942847	SL2.40ch12	64697129	5.22	-	-	-	-	-
11225	8004592	SL2.40ch12	65078077	5.22	-	-	-	-	-
11297	4696098	Unknown	60	-	3.62	-	-	-	-
11330	4696640	Unknown	111	-	-	-	-	-	4.63
11373	4697735	Unknown	178	-	-	-	-	4.36	-
11385	4697940	Unknown	195	-	-	3.24	-	-	-
11411	4698410	Unknown	233	-	-	-	-	3.49	-
11432	4698789	Unknown	263	-	-	-	-	-	5.07
11448	4699059	Unknown	289	-	-	-	-	-	4.56
11503	4700096	Unknown	368	-	-	-	-	3.62	-
11514	4700251	Unknown	383	8.72	-	-	-	-	-
11525	4700385	Unknown	398	-	-	-	-	-	5.51
11576	4701487	Unknown	467	-	-	-	-	3.35	-
11598	4701842	Unknown	496	-	-	-	-	3.19	-
11694	4705318	Unknown	648	-	-	-	-	-	4.76
11733	7758602	Unknown	733	-	-	-	3.72	-	-
11914	7763295	Unknown	1220	-	-	3.21	-	-	4.9
11926	7763401	Unknown	1263	13.35	-	-	2.99	-	-
11939	7763481	Unknown	1292	-	-	-	-	3.46	-
11950	7763553	Unknown	1316	11.13	-	-	3.49	-	-
11995	7763956	Unknown	1450	-	-	-	-	-	4.47

11996	7763965	Unknown	1454	-	3.54	-	-	-	-
12462	7792214	Unknown	2171	-	-	-	11.61	-	-
12584	7796128	Unknown	2481	-	-	-	16.27	-	-
12607	7796353	Unknown	2515	-	-	3.26	-	-	-
12660	7796869	Unknown	2633	-	-	-	-	-	4.98
12706	7797308	Unknown	2723	-	3.87	-	-	-	-
12794	7798262	Unknown	2903	-	-	-	16.37	-	-
12919	7837465	Unknown	3183	-	3.17	-	-	-	-
12972	7842678	Unknown	3313	-	3.94	-	-	-	-
13007	7843119	Unknown	3434	-	-	3.22	-	-	-
13008	7843121	Unknown	3435	-	-	3.44	-	-	5.11
13058	7843659	Unknown	3579	-	-	-	3.07	-	-
13075	7843816	Unknown	3617	-	15.38	-	-	-	-
13115	7844284	Unknown	3753	-	-	-	-	3.88	-
13207	7845156	Unknown	4028	-	-	-	-	-	4.63
13221	7845304	Unknown	4070	7.09	-	-	-	-	-
13238	7845431	Unknown	4111	-	3.93	-	-	-	-
13280	7845841	Unknown	4223	-	11.65	-	-	-	-
13290	7845984	Unknown	4262	4.99	-	-	-	-	-
13320	7846322	Unknown	4363	-	-	3.27	-	-	-
13359	7848312	Unknown	4417	-	4	-	-	-	-
13409	7851671	Unknown	4537	-	-	-	-	-	4.54
13430	7852180	Unknown	4596	-	13.78	-	-	-	-
13453	7852396	Unknown	4649	5.55	-	-	-	-	-
13465	7852510	Unknown	4689	-	-	-	-	3.21	-
13493	7852920	Unknown	4803	-	-	-	-	3.58	-
13564	7853616	Unknown	5003	-	-	3.29	-	-	-
13578	7853745	Unknown	5031	-	15.7	-	-	-	-
13668	7856308	Unknown	5276	-	-	-	-	-	4.64
13707	7856850	Unknown	5398	7.16	-	-	-	-	-
13742	7858148	Unknown	5495	-	-	-	-	-	5.1
13750	7858289	Unknown	5523	-	-	-	16.34	-	-
13752	7858303	Unknown	5530	-	13.76	-	-	-	-
13877	7941017	Unknown	5841	-	-	-	-	-	4.73
13879	7941022	Unknown	5845	-	-	-	2.87	-	-
13893	7941054	Unknown	5863	-	-	3.27	-	-	-
13955	7941218	Unknown	5963	-	-	-	-	-	4.5
14525	7941940	Unknown	6550	-	14.83	-	-	-	-
14806	7942341	Unknown	6886	4.61	-	-	3.76	-	-
14831	7942442	Unknown	6933	-	-	3.17	-	-	-
14858	7942485	Unknown	6960	7.01	-	-	-	-	-
14880	7942525	Unknown	6984	-	-	-	13.81	-	-
14901	7942587	Unknown	7021	-	-	-	3.21	-	-
14920	7942624	Unknown	7040	-	-	3.26	-	-	-
14961	7942756	Unknown	7103	4.65	-	-	3.77	-	-
14966	7942786	Unknown	7126	4.61	-	-	3.76	-	-

14973	7942821	Unknown	7147	-	-	-	3.69	-	-
15011	7942882	Unknown	7190	5.22	-	-	-	-	-
15019	7942897	Unknown	7198	5.22	-	-	-	-	-
15025	7942904	Unknown	7204	5.22	-	-	-	-	-
15034	7942917	Unknown	7213	5.22	-	-	-	-	-
15049	7942934	Unknown	7228	5.22	-	-	-	-	-
15052	7942939	Unknown	7231	5.22	-	-	-	-	-
15081	7943018	Unknown	7273	-	-	-	2.68	-	-
15222	7943226	Unknown	7426	-	-	3.26	-	-	-
15376	7943436	Unknown	7595	-	-	-	16.27	-	-
15503	7943585	Unknown	7729	-	3.87	-	-	-	-
15510	7943593	Unknown	7736	-	-	-	16.27	-	-
15760	7947523	Unknown	10069	-	-	3.25	-	-	-
16105	7958631	Unknown	20307	-	-	-	-	-	4.62
16177	7959055	Unknown	20528	-	3.75	-	-	-	-
16185	7959203	Unknown	20638	-	-	3.26	-	-	-
16249	7959438	Unknown	20799	-	18.49	-	-	-	-

B) Okra (unpublished Ph.D research data M Safdar, 2015)

Okra List Order	DArTseq	Electrolyte leakage	Days to flowering	No. leaf lobes	Pl height	Pl weight	Pod-Flower ratio	Stem diam
		LOD score						
27	17292119	-	-	-	-	4.5	-	-
57	17301521	-	-	-	-	-	6.66	-
113	17303346	-	-	103.45	-	-	-	-
189	100140194	-	-	103.67	-	-	-	-
334	17304930	6.57	-	-	-	-	-	-
367	17275685	-	-	-	-	-	5.74	-
463	17307055	-	-	-	-	41.27	-	-
464	17291756	-	6.81	-	-	-	-	-
528	17290698	-	-	141.18	-	-	-	-
586	17276434	-	-	-	-	-	5.89	-
596	17308897	8.97	-	-	-	-	-	-
654	17277279	-	-	137.03	-	-	-	-
868	17308796	11.05	-	-	-	-	-	-
956	17286982	-	-	-	-	-	-	27.91
966	17308867	-	-	-	-	-	5.86	-
1022	17277646	-	4.85	-	-	-	-	-
1363	17298675	-	-	-	-	30.9	-	-
1555	17304913	7.16	-	-	-	-	-	-
1633	17299346	-	-	103.44	-	-	-	-
1677	17305315	-	-	-	-	-	-	28.01

1698	17300096	-	-	-	-	-	6.24	-
1908	17295015	-	-	144.44	-	-	-	-
1919	17273712	-	-	-	14.59	-	-	-
1944	17286814	-	-	-	-	-	-	27.92
1965	17289539	-	-	-	-	-	6.08	-
2155	17309853	7.28	-	-	-	-	-	-
2238	17276612	-	-	-	-	4.83	-	-
2301	17275304	-	3.43	-	-	-	-	-
2350	17291184	-	-	-	14.9	-	-	-
2361	17290788	-	3.96	-	-	-	-	-
2468	17277868	-	-	-	19.91	-	-	-
2529	17277593	-	-	-	-	5.62	-	-
2561	17305326	-	-	-	-	4.71	-	-
2708	17276521	-	-	-	17.81	-	-	-
2713	17280235	-	-	-	19.84	-	-	-
2779	17305831	-	-	-	-	4.92	-	-
3094	17281268	-	-	-	-	6.25	-	-
3344	17282135	-	-	-	14.79	-	-	-
3523	17277578	-	3.49	-	-	-	-	-
3530	17281771	-	-	-	-	4.16	-	-
3605	17274441	-	-	-	-	4.19	-	-
3832	17281670	-	-	-	-	4.28	-	-
3861	17273421	-	4.77	-	-	-	-	-
3864	17281713	-	3.42	-	-	-	-	-
3936	17308213	-	-	-	-	5.31	-	-
3963	17278210	-	3.94	-	-	-	-	-
4439	17273711	-	-	-	-	4.12	-	-
4524	17281988	-	3.44	-	-	-	-	-
4588	17302252	-	3.56	-	-	-	-	-
4755	17292269	-	-	-	14.51	-	-	-
4905	17288728	-	-	-	18.05	-	-	-
4916	17290425	-	-	-	-	5.98	-	-
4974	17281936	-	3.49	-	-	-	-	-
5015	17303030	-	-	-	-	4.58	-	-
5033	17289169	-	-	-	-	5.4	-	-
5034	17297912	-	-	-	-	5.54	-	-
5157	17275328	-	-	-	-	4.05	-	-
5216	17273445	-	4.15	-	-	-	-	-
5217	17274131	-	-	-	-	4.15	-	-
5272	17275172	-	-	-	-	4.08	-	-
5415	17298127	-	-	-	-	6.92	-	-
5489	17276776	-	-	-	-	4.13	-	-
5522	17278038	-	3.52	-	-	-	-	-
5525	17274158	-	-	-	14.62	-	-	-
5579	17289804	-	-	-	-	4.13	-	-
5721	17277947	-	5.44	-	-	-	-	-

5774	17305058	-	-	-	-	4.08	-	-
5891	17273290	-	-	-	-	-	7.14	-
6234	17294769	-	-	-	-	4.28	-	-
6334	17281702	-	-	-	-	5.45	-	-
6476	17274373	-	-	-	-	5.18	-	-
6547	17273245	-	-	-	-	4.11	-	-
6680	17273281	-	-	-	-	-	6.13	-
6774	17280555	-	-	-	-	4.38	-	-
6923	17279686	-	-	-	-	-	6.09	-
7533	17274713	-	-	-	-	-	5.67	-
7647	17289852	-	-	-	-	-	7.18	-
7650	17307122	-	-	-	-	-	6.29	-
7668	17276446	-	-	-	-	-	6.12	-
7848	17309627	-	-	-	-	-	5.64	-
8054	17274283	-	-	-	-	-	5.88	-
8131	17279746	-	-	-	-	-	7.54	-
8171	17306975	-	-	-	-	-	6.26	-
8266	17279243	-	-	-	-	-	6.84	-
8272	17298499	-	-	-	-	-	6.39	-
8376	17290927	-	-	-	-	-	6.44	-
8490	17287354	-	-	-	-	-	6.63	-
8531	17279739	-	-	-	-	-	6.6	-
8565	17288711	-	-	-	-	-	6.09	-
8581	17280856	-	-	-	-	-	6.77	-
8638	17293878	-	-	-	-	-	7.01	-
8725	17279730	-	-	-	-	-	6.18	-
8737	17311141	-	-	-	-	4.38	-	-
8794	17273089	-	-	-	-	-	6.17	-
8812	17304499	-	-	-	-	-	6.35	-
8866	17278733	-	-	-	-	-	6.34	-
8872	17290987	-	-	-	-	-	5.95	-
8879	17307396	-	-	-	-	-	6.42	-
8894	17277840	-	-	-	-	-	5.91	-
8905	17306904	-	-	-	-	-	6.96	-
8907	17310292	-	-	-	-	-	6.69	-
8953	17278011	-	-	-	-	-	7.34	-
8976	17293637	-	-	-	-	-	6.45	-
9110	17274739	-	-	-	-	-	5.97	-
9266	17303185	-	-	-	-	-	6.69	-
9271	17310803	-	-	-	-	-	5.87	-
9332	17307503	-	-	-	-	-	5.7	-
9347	17277084	-	-	-	-	-	6.57	-
9466	17278609	-	-	-	-	-	6.56	-
9470	17311010	-	-	-	-	-	6.66	-
9799	17290990	-	-	-	-	-	5.88	-
10143	17289236	-	-	-	-	-	5.78	-

15008	17294435	-	3.92	-	-	-	-	-
15807	17308308	-	9.48	-	-	-	-	-
16065	17294291	-	-	-	-	-	6.21	-
17609	17306910	-	4.43	-	-	-	-	-
17840	17291077	-	-	-	-	-	6.63	-
19972	17304595	-	-	147.16	-	-	-	-
20033	17298206	-	-	-	-	-	6.16	-
20204	17294975	-	-	-	-	-	6.55	-
20262	17277697	-	11.47	-	-	-	-	-
20280	17279634	-	-	145.89	-	-	-	-
20459	17299127	-	7.25	-	-	-	-	-
20619	17287221	-	11.71	-	-	-	-	-
23782	17307923	-	-	127.75	-	-	-	-
23795	17294669	-	-	131.61	-	-	-	-
23801	17309195	-	-	132.54	-	-	-	-
23830	17294315	-	-	135.28	-	-	-	-
23832	17301922	-	-	135.28	-	-	-	-
23862	17290053	-	-	137.03	-	-	-	-
23873	17304451	7.76	-	-	-	-	-	-
23875	17308015	-	-	137.03	-	-	-	-
23916	17297442	-	-	-	-	40.18	-	-
23963	17288808	-	11.39	-	-	-	-	-
23967	17291363	-	-	140.38	-	-	-	-
24073	17311009	-	-	141.95	-	-	-	-
24194	17310618	-	-	143.96	-	-	-	-
24216	17301775	-	-	144.45	-	-	-	-
24317	17283195	-	-	-	-	-	-	30.44
24448	17285901	-	-	-	17.19	-	-	-
24572	17309485	-	-	-	17.19	-	-	-
24579	17310478	-	-	-	17.19	-	-	-
24888	17285304	-	12.87	-	-	-	-	-
25151	17293023	-	12.87	-	-	-	-	-
25173	17293186	-	12.87	-	-	-	-	-
25268	17295819	-	12.87	-	-	-	-	-
25358	17301193	-	-	-	-	-	7.2	-
25381	17302696	-	13.2	-	-	-	-	-
25534	17275163	-	5.87	-	-	-	-	-
25535	17276787	-	5.87	-	-	-	-	-
25536	17278913	-	5.87	-	-	-	-	-
25537	17281173	-	5.87	-	-	-	-	-
25632	17285487	-	13.04	-	-	-	-	-
25724	17288804	-	5.87	-	-	-	-	-
25783	17295887	-	5.58	-	-	-	-	-
25852	17305394	-	13.04	-	-	-	-	-
25867	17308109	-	5.87	-	-	-	-	-
25894	17274790	-	-	-	-	-	-	29.56

25900	17276975	7.03	-	-	-	-	-	-
25908	17302161	-	-	-	-	-	-	29.14
25916	17293537	8.8	-	-	-	-	-	-
25922	17296096	6.84	-	-	-	-	-	-
25928	17304865	6.8	-	-	-	-	-	-
25942	17294941	9.34	-	-	-	-	-	-
25955	17293695	6.61	-	-	-	-	-	-
25956	17293790	6.6	-	-	-	-	-	-
25962	17309359	6.73	-	-	-	-	-	-
25976	17298430	6.55	-	-	-	-	-	-
25977	17300241	7.07	-	-	-	-	-	-
25978	17300343	-	-	-	-	43.25	-	-
25981	17303724	6.58	-	-	-	-	-	-
25988	17310305	6.84	-	-	-	-	-	-
25991	17278272	10.99	-	-	-	-	-	-
25992	17278602	9.79	-	-	-	-	-	-
26011	17308099	10.51	-	-	-	-	-	-
26014	17309880	-	-	-	-	7.72	-	-
26038	17302250	17.5	-	-	-	-	-	-
26041	17305918	6.7	-	-	-	-	-	-
26048	17275026	-	-	-	-	30.66	-	-
26078	17305121	-	-	-	-	31.06	-	-
26091	17277993	-	-	103.45	-	-	-	-
26095	17280135	10.31	-	-	-	-	-	-
26101	17287219	-	-	103.45	-	-	-	-
26109	17295107	6.71	-	-	-	-	-	-
26113	17297308	-	-	103.45	-	-	-	-
26123	17303700	-	-	-	-	30.36	-	-
26125	17305609	9.27	-	-	-	-	-	-
26135	17310756	-	-	-	-	30.83	-	-
26143	17287832	-	-	103.54	-	-	-	-
26151	17294220	-	-	103.54	-	-	-	-
26154	17296374	-	-	103.54	-	-	-	-
26165	17304308	-	-	103.54	-	-	-	-
26169	17306506	9.91	-	-	-	-	-	-
26178	17310449	-	-	103.54	-	-	-	-
26196	17294404	-	-	103.61	-	-	-	-
26197	17295062	10.28	-	-	-	-	-	-
26206	17302351	-	-	103.62	-	-	-	-
26208	17306065	-	-	103.61	-	-	-	-
26215	17309536	-	-	103.62	-	-	-	-
26224	17287692	-	-	-	-	7.13	-	-
26226	17288854	-	-	103.67	-	-	-	-
26229	17289452	-	-	-	-	30.72	-	-
26235	17294408	-	-	103.67	-	-	-	-
26248	17307645	8.72	-	-	-	-	-	-

26257	17288640	-	-	103.7	-	-	-	-
26267	17299805	-	-	103.7	-	-	-	-
26268	17299891	-	-	103.7	-	-	-	-
26277	17305236	-	-	103.7	-	-	-	-
26279	17306234	-	-	103.7	-	-	-	-
26281	17307336	-	-	-	-	7.14	-	-
26282	17307932	-	-	103.7	-	-	-	-
26284	17309261	-	-	103.7	-	-	-	-
26289	100121864	-	-	103.7	-	-	-	-
26298	17289195	-	-	103.7	-	-	-	-
26317	17275661	-	-	103.69	-	-	-	-
26320	17280172	-	-	103.7	-	-	-	-
26332	17300068	-	-	-	-	31.48	-	-
26343	17276788	9.19	-	-	-	15.45	-	-
26351	17290235	-	-	103.67	-	-	-	-
26352	17291419	-	-	103.67	-	-	-	-
26353	17293857	6.88	-	-	-	-	-	-
26356	17306471	-	-	103.66	-	-	-	-
26357	17309047	-	-	-	-	30.86	-	-
26372	17300129	-	-	-	-	7.56	-	-
26396	17306724	-	-	103.54	-	-	-	-
26398	17309197	-	-	103.54	-	-	-	-
26401	17290191	8.31	-	-	-	-	-	-
26409	17295146	-	-	103.34	-	-	-	-
26430	17282999	8.38	-	-	-	-	-	-
26476	17282507	8.8	-	-	-	-	-	-
26478	17282512	8.8	-	-	-	-	-	-
26502	17282799	18.85	-	-	-	-	-	-
26525	17282917	9.27	-	-	-	-	-	-
26567	17283171	26.69	-	-	-	-	-	-
26569	17283189	-	9.89	-	-	-	-	-
26641	17284630	-	-	-	-	-	-	28.01
26645	17284677	-	-	-	-	-	-	28.01
26662	17285004	-	-	-	-	-	-	28.01
26664	17285019	-	-	-	-	-	-	28.01
26673	17285239	-	-	-	-	-	-	28.01
26678	17285268	-	-	-	-	-	-	28.01
26681	17285291	-	-	-	-	-	-	28.01
26688	17285407	-	-	-	-	-	-	28.01
26702	17285554	-	-	-	-	-	-	28.01
26722	17285769	-	-	-	-	-	-	28.01
26823	17286387	-	-	-	-	-	-	28.02
26853	17286608	-	-	-	14.31	-	-	-
26854	17286617	-	-	-	14.31	-	-	-
26855	17286618	-	-	-	14.31	-	-	-
26857	17286625	-	-	-	14.31	-	-	-

26859	17286640	-	-	-	14.31	-	-	-
26860	17286642	-	-	-	14.31	-	-	-
26861	17286646	-	-	-	14.31	-	-	-
26862	17286652	-	-	-	14.31	-	-	-
26863	17286656	-	-	-	14.31	-	-	-
26864	17286657	-	-	-	14.31	-	-	-
26865	17286668	-	-	-	14.31	-	-	-
26866	17286676	-	-	-	14.31	-	-	-
26867	17286678	-	-	-	14.31	-	-	-
26868	17286692	-	-	-	14.31	-	-	-
26878	17286749	-	-	-	-	-	-	27.92
26885	17286775	-	-	-	-	-	-	27.92
26886	17286778	-	-	-	-	-	-	27.92
26887	17286779	-	-	-	-	-	-	27.92
26894	17286804	-	-	-	-	-	-	27.92
26898	17286824	-	-	-	-	-	-	27.92
26899	17286829	-	-	-	-	-	-	27.92
26900	17286833	-	-	-	-	-	-	27.92
26901	17286837	-	-	-	-	-	-	27.92
26903	17286848	-	-	-	-	-	-	27.92
26904	17286850	-	-	-	-	-	-	27.92
26932	17292392	-	-	-	-	-	-	28.01
26940	17292438	-	-	-	14.31	-	-	-
26948	17292672	-	-	-	-	-	-	28.01
26985	17293270	-	-	-	-	-	-	28.01
27002	17293464	-	-	-	-	-	-	27.92
27006	17293959	-	-	-	-	-	-	27.92
27010	17295345	-	-	-	14.31	-	-	-
27011	17295349	6.69	-	-	-	-	-	-
27031	17295510	-	-	-	14.31	-	-	-
27039	17295590	9.27	-	-	-	-	-	-
27060	17295903	-	-	-	-	-	-	28.01
27061	17295917	-	-	-	14.31	-	-	-
27063	17295921	-	-	-	14.31	-	-	-
27069	17295943	-	5.23	-	-	-	-	-
27081	17296020	-	-	-	-	-	-	27.92
27088	17296055	-	-	-	14.31	-	-	-
27089	17296074	-	-	-	-	-	-	27.92
27091	17296087	-	-	-	14.48	-	-	-
27095	17296156	-	-	-	-	-	-	27.92
27101	17297120	-	-	-	-	-	-	27.92
27105	17297826	-	-	-	-	-	-	27.92
27144	17301160	-	-	-	-	-	-	28.02
27158	17302453	-	12.25	-	-	-	-	-
27161	17302514	6.71	-	-	-	-	-	-
27168	17302534	-	-	-	14.31	-	-	-

27169	17302546	-	-	-	14.48	-	-	-
27183	17302734	-	-	-	14.31	-	-	-
27184	17302738	-	-	-	14.31	-	-	-
27185	17302747	-	-	-	-	-	-	27.92
27227	17306365	-	-	-	14.31	-	-	-
27269	17308590	-	-	-	-	-	-	27.92
27298	17310096	-	-	-	14.31	-	-	-
27306	17310199	-	-	-	-	-	-	27.92
27320	17277531	-	5.87	-	-	-	-	-
27322	17280960	-	5.87	-	-	-	-	-
27327	17282261	6.66	-	-	-	-	-	-
27328	17282262	6.66	-	-	-	-	-	-
27329	17282264	6.66	-	-	-	-	-	-
27439	17282776	10.15	-	-	-	-	-	-
27530	17283072	8.77	-	-	-	-	-	-
27712	17285809	-	-	-	-	4.7	-	-
27719	17285816	-	-	-	-	4.7	-	-
27739	17285853	-	-	-	-	4.7	-	-
27742	17285862	-	13.42	-	-	-	-	-
27743	17285863	-	13.42	-	-	-	-	-
27745	17285865	-	13.42	-	-	-	-	-
27746	17285867	-	12.29	-	-	-	-	-
27748	17285869	-	13.42	-	-	-	-	-
27751	17285874	-	-	-	-	15.02	-	-
27778	17286003	8.93	-	-	-	-	-	-
27881	17286209	-	6.64	-	-	-	-	-
28025	17286566	-	5.19	-	-	-	-	-
28030	17286571	-	5.19	-	-	-	-	-
28060	17286607	-	-	-	-	-	-	42.4
28077	17286629	-	-	-	-	-	-	42.4
28091	17286648	-	-	-	-	-	-	42.4
28102	17286662	-	-	-	-	-	-	42.4
28111	17286672	-	-	-	-	-	-	42.4
28155	17286728	-	5.58	-	-	-	-	-
28221	17286854	-	-	-	25.38	-	-	-
28225	17286858	9.85	-	-	-	-	-	-
28226	17286859	17.62	-	-	-	-	-	-
28250	17286883	-	-	-	14.28	-	-	-
28251	17286884	-	-	-	14.28	-	-	-
28252	17286885	-	-	-	14.28	-	-	-
28253	17286886	-	-	-	14.28	-	-	-
28254	17286887	-	-	-	14.28	-	-	-
28255	17286888	-	-	-	14.28	-	-	-
28256	17286889	-	-	-	14.28	-	-	-
28257	17286890	-	-	-	14.28	-	-	-
28258	17286891	-	-	-	14.28	-	-	-

28259	17286892	-	-	-	14.28	-	-	-
28602	17295928	-	-	-	-	4.7	-	-
28634	17295996	-	13.42	-	-	-	-	-
28640	17296002	-	-	-	-	-	-	29.76
28675	17296063	-	-	-	-	-	-	42.4
28704	17296152	-	-	-	-	4.7	-	-
29104	17311100	6.66	-	-	-	-	-	-

Appendix 10: Farmer and extension staff trainings

1) Farmer training:

- Number of farmer (male and female) training workshops – 16
- Number of farmers attended – 1050

2) Training of extension workers:

- Training of Field Assistants at IATI Sargodha - 1
- Number of extension staff attended – 35

Vegetable garden training in Okara

Female farmer training in Okara

Appendix 11: Student trainings

1. Ph.D Project at UAF

Student Name: Muhammad Rashid Shaheen **Student ID:** 2004-ag-1175

Project Title: Evaluation of thermo-tolerance and its enhancement in Tomato (*Solanum lycopersicum* L.)

Start date: July, 2013 **Completion date:** July, 2015

Summary of the results:

Tomato (*Solanum lycopersicum* L.) is one of the high value horticultural crops providing opportunities to increase farm income and improving quality of the daily diet. Climate change is intensifying heat events throughout the world affecting crops particularly the horticultural crops like tomato. Heat is the most important constraint adversely affecting vegetative and reproductive growth of tomato and hence reduces the yield as well as quality. The aim of this research was to find new genetic options by introducing genetically diverse and better adapted germplasm while elucidating the genetic and physiological basis of improved adaptation under heat stress and induction of heat tolerance by exogenous application of salicylic acid.

Based on the experiments conducted on genetic variability with the available tomato germplasm and response to various management regimes it was concluded that by using heat tolerant genotypes, the growth period of tomato crop can be expanded in Pakistan. The application of salicylic acid @ 1.5mM has also proved effective in extending the growth period of tomato. By combining genetic and management approaches together the production period of the crop in summer could be extended and a breakthrough in tomato production could be achieved.

2. Ph.D Project at UAF

Student Name: Rashid Hussain **Student ID:** 2004-ag-1947

Project Title: Evaluation of heat tolerance potential and its enhancement in okra (*Abelmoschus esculentus* L. Moench.)

Start date: July, 2013 **Expected completion date:** Sept, 2016

Summary of the proposed research:

Okra (*Abelmoschus esculentus* L.) is recognized as annual herbaceous plant grown in tropical and subtropical areas and serves as a source of carbohydrates, fats,

vitamins and various minerals. In spite of having good nutritional value, its per hectare yield is very low. The low yield is due to drastic effects of abiotic stresses like heat, cold, drought and salinity. Heat stress causes multifarious, and often adverse, alterations in plant growth, development, physiological processes, and ultimately yield.

The results showed strong variation in the germplasm for heat stress tolerance under various crop management regimes. It was concluded that by sowing the heat tolerant genotypes, identified in the research, the crop production period of okra can be expanded in the summer. The application of proline @ 2.5mM proved effective in alleviating the drastic effects of high temperature in okra and growth period of okra can be prolonged by growing the heat tolerant genotypes screened in this research.

3. Masters Project at UAF

Student Name: Araiz Nazir **Student ID**: 2008-ag-1988

Project Title: Effect of Heat stress on Physiological and morphological Attributes of Tomato

Start date: October, 2013 **Completion date**: July, 2015

Summary of the results:

The study was conducted at The Institute of Horticultural Sciences (IHS), University of Agriculture, Faisalabad (UAF). 54 local genotypes of tomato, sourced from from VRI, Ayub Agriculture Research Institute (AARI) were screened to assess the impact of heat stress on various tmato genotypes. The parameters studied were:

1. Number of leaves
2. Root and Shoot length (cm)
3. Root and Shoot fresh weight (g)
4. Root and Shoot dry weight (g)
5. Photosynthetic rate (Pn) (IRGA) µmol m^{-2} s^{-1}
6. Transpiration rate (E) (IRGA) mmol m-2 s^{-1}
7. Water use efficiency (IRGA) (Pn/E)
8. Sub-stomatal CO_2 (IRGA) vpm
9. Leaf Surface Temperature (°C)
10. Chlorophyll contents (Chl. Meter) (SPAD value)

Strong variation for various traits among genotypes indicated strong scope for a meaningful selection for heat stress tolerance from within the materials.

4. Masters Project at UAF

Student Name: Sumeera Asghar **Student ID**: 2008-ag-2431

Project Title: Screening of Okra Genotypes Against Heat Stress Tolerance

Start date: October, 2013 **Completion date**: July, 2015

Summary of the results:

This research was conducted at green house, Institute of Horticultural Sciences, University of Agriculture, Faisalabad, during 2013 for screening of different okra genotypes against heat stress tolerance. Comparative response of 16 selected okra genotypes for heat stress was studied. Data recorded on chlorophyll content, shoot length, shoot fresh and dry weight, root fresh and dry weight, stomatal conductance, leaf temperature, and photo synthesis showed strong variation among genotypes for all the parameters. Variation in genotypic response of okra germplasm promised potential for effective selection against heat stress environments in Pakistan.

5. Masters Project at UAF

Student Name: Muhammad Ali **Student ID**: 2014-ag-1546

Project Title: Physiological and quality response of tomato genotypes at various locations in Punjab, Pakistan

Start date: February, 2014 **Expected completion date**: Sept, 2016

Summary of the proposed research:

A multi-location field trial was conducted in 2015 at four different locations of Punjab i.e University of Agriculture Faisalabad (UAF), Okara, Sheikhupura and Sargodha. Ten tomato genotypes selected from previous trial were grown. Data on gas exchange parameters was captured by using IRGA (InfraRed Gas Analyzer). Fruit quality related attributes were measured at Post harvest lab at The Institute of Horticultural Sciences, University of Agriculture Faisalabad.

Fowling parameters were studied:

(a) Quality related attributes

- Titratable Acidity (%)
- Firmness
- Vitamin C
- Total soluble sugars TSS (Brix)

(b) Gas exchange related attributes

- Photosynthetic rate (Pn) (umol m-2 s-1)
- Transpiration rate (E) (umol m-2 s-1)

- Sub-stomatal CO_2 (vpm)
- Water use efficiency (WUE) (Pn/E)
- Stomatal conductance (Gs) (mmol s-1)

The thesis is due to be submitted in September, 2016.

6. Masters Project at UAF

Student Name: Chand Subhani **Student ID**: 2014-ag-1546

Project Title: Fruit quality and yield response of different tomato genotypes at various locations in Punjab

Start date: February, 2014 **Expected completion date**: Sept, 2016

Summary of the proposed research:

A multi-location field trial was conducted in 2015 at four different locations of Punjab i.e University of Agriculture Faisalabad (UAF) Okara, Sheikhupura and Sargodha. Ten tomato genotypes previous selected from previous experiments were selected for this work.

Fowling parameters were studied

(a) Biochemical parameters

- Super oxide dismutase (SOD) (µg L-1)
- Catalase (CAT) (µg L-1)
- Peroxidase (POD) (µg L-1)
- Protein (mg/ml)
- Electrolyte leakage (%)

(b) Yield attributes

- Fruit yield per plant (kg)
- Average fruit weight (g)
- Fruit diameter (mm)

The thesis is due to be submitted in September 2016.

7. Masters Project at UAF

Student Name: Faisal Hayat **Student ID**: 2014-ag-1546

Project Title: Fruit quality response of different okra genotypes at various locations in Punjab

Start date: February, 2014 **Expected completion date**: Sept, 2016

Summary of the proposed research:

A multi-location field trial was conducted in 2015 at four different locations of Punjab i.e University of Agriculture Faisalabad (UAF), Okara, Sheikhupura and Sargodha. Ten okra genotypes were selected from previous trial were sown on 15th March and 1st April at various locations. Experiment was laid out with three factor factorial arrangement using

RCBD with 4 replications. Quality attributes were measured at Biochemistry Lab, University of Agriculture Faisalabad.

Following quality parameters were studied

- Super oxide dismutase (SOD) (µg L-1)
- Catalase (CAT) (µg L-1)
- Peroxidase (POD) (µg L-1)
- Protein (mg/ml)
- Electrolyte leakage (%)

The thesis is due to be submitted in September 2016.

8. Masters Project at UAF

Student Name: Raja Zulqarnain Zaka **Student ID**: 2014-ag-1506

Project Title: Physiological and yield response of different okra genotypes at various locations of Punjab

Start date: February, 2014 **Expected completion date**: Sept, 2016

Summary of the proposed research:

A multi-location field trial was conducted in March, 2015 at four different locations of Punjab; University of Agriculture Faisalabad (UAF), Okara, Sheikhupura and Sargodha. Ten okra genotypes selected from previous trial were sown on 15th March and 1st April at various locations. Experiment was conducted with three factor factorial arrangement under RCBD with 4 replications. Physiological attributes were measured with the help of IRGA.

Following parameters were studied

(a) Gas exchange related attributes

- Photosynthetic rate (Pn) (umol m-2 s-1)
- Transpiration rate (E) (umol m-2 s-1)
- Sub-stomatal CO_2 (vpm)
- Stomatal conductance (Gs) (mmol s-1)

(b) Yield related attributes

- Fruit yield per plant (kg)
- Individual fruit weight (g)
- Fruit length (mm)
- Fruit diameter (mm)

The thesis is due to be submitted in September 2016.

9. Ph.D Project at USyd

Student Name: Muhammad Alsamir **Student ID**: 309344115

Project Title: Genetic and physiological basis of variation in heat stress tolerance in tomatoes

Start date: March 2013 **Expected completion date**: December 2016

Summary of the proposed research:

Plants are continuously exposed to abiotic stresses during their life cycle and they have evolved mechanisms to overcome those stresses. The defence mechanisms in plants involve accumulation of compatible solutes which are low molecular-weight metabolites with high water solubility in water and non-toxic at high concentrations. Representative compatible solutes, different among species, include certain polyols, sugars, amino acids, betaines and related compounds.

Literature shows that heat stress is increasing, possibly due to climate change. High temperature affects fruit number, fruit weight, and seed number per fruit in tomato and results in deteriorated fruit quality.

Tomato (Lycopersicon esculentum Mill.) belongs to the family solanaceae and is an important vegetable crop all over the world. Tomato thrives well under tropical and subtropical regions. It can grow vigorously and is highly productive within the temperature range of 18 – 28 °C. In many countries the high temperature in summer ceases tomato production resulting in shortage of tomatoes. Lack of tolerance to high temperature in most tomato cultivars presents a major limitation to their production in regions where the temperature during part of the growing season, even for short duration, reaches 38°C or higher. High temperature affects several physiological and biochemical processes leading to tomato yield reduction. High temperature during reproductive development causes significant increase in flower drop and significant decrease in tomato fruit set resulting in significant decreased fruit yield.

A diverse set of tomato germplasm collected from geographically distant regions was used to study physio-genetic mechanisms underpinning improved adaptation of genotypes. Marker-trait association studies will be conducted to identify genetic markers related to individual traits in the germplasm. Investigations on the influence of temperature stress on fruit quality, an important component in these studies, will help explain the role of genetic factors conferring greater resistance to temperature stress.

10. Ph.D Project at USyd

Student Name: Shahnoosh Hayamanesh **Student ID**: 420174600

Project Title: Physiological basis of heat tolerance in diverse okra germplasm

Start date: August 2013 **Expected completion date**: March 2017

Summary of the proposed research:

Environmental stress affects plant productivity, crop quality and importantly the yield. High temperature stress can reduce crop yield and quality and is expected to become more frequent with climate change. High temperature damages the plant photosystem, changes the balance between photosynthesis and respiration and impairs cellular function by damaging membranes and reducing pollen viability; all potentially lowering yield. Okra is an important summer vegetable crop grown in many parts of the world including Australia. High temperature has been shown to influence the germination, growth and yield of okra. The aim of this study was to assess genetic variability for heat-tolerance among Okra genotypes from Pakistan and AVRDC (The World Vegetable Centre).

Some experimental observations were:

• Generally the average plant dry matter significantly decreased in the heat treatment.

• Average electrolyte leakage under heat was generally higher than the control.

• Total number of fruit per genotype (yield) was dramatically reduced under heat stress.

• Pollen was not shed efficiently and the stigma became non receptive under high temperature compared to the control.

• Pollen was flattened under high temperature compared to the control.

• Pollen of heat stressed plants showed no pollen tube germination in vitro whereas pollen of control plants generated pollen tubes.

11. Ph.D Project at USyd

Student Name: Misbah Safdar **Student ID**: 440515944

Project Title: Genetic basis of morphological and biochemical variation under heat stress in okra

Start date: March 2015 **Expected completion date**: December 2018

Summary of the proposed research:

The Earth's surface temperature has risen by more than 0.5°C in the past century mainly due to human activities that have altered the chemical composition of the atmosphere through the build-up of heat trapping greenhouse gases - primarily carbon dioxide, methane, and nitrous oxide. Due to the increase in temperature in warm regions, crop yields can drop ~3– 5% with every 1°C increase in temperature.

Okra *Abelmoschus esculentus* L. (Moench), belongs to the family Malvaceae and is cultivated in temperate, tropical and sub-tropical areas. It is a good source of proteins, fats, carbohydrates, minerals, vitamins, fiber and has medicinal value for various diseases such as urinary disorders, chronic dysentery, ulcers and hemorrhoids. In okra high temperature affects various morphological, phenological, physiological, biochemical and reproductive processes that contribute to reduction in yields and quality or even crop failure.

Significant differences for electrolyte leakage, plant height stem diameter, plant weight and pod/flower ratio were observed in the first year. The data for GWAS DArT and SNPs are being processed.

Data for pollen micromorphology through SEM (scanning electron microscope) for selected genotypes showed significant differences between heat-tolerant and heat-sensitive genotypes.

No significant differences were observed in stomatal conductance data.