EXPLORING PIMA AND UPLAND CROSS-COMBINATIONS TO IDENTIFY *FUSARIUM OXYSPORUM* F. SP. *VASINFECTUM* RACE 4 RESISTANT COTTONS BY COMBINING ABILITY OF SUPERIOR CULTIVARS

TariLee Frigulti
University of California, Cooperative Extension
Tulare, CA
Mauricio Ulloa
USDA-ARS, PA, CSRL Plant Stress and Germplasm Development Research
Lubbock, TX
Robert B. Hutmacher
Mark Keeley
Univ. of California Davis, Plant Sci. Dept
Davis, CA
Steven D. Wright
University of California, Cooperative Extension
Tulare, CA
John Burke
USDA-ARS, PA, CSRL Plant Stress and Germplasm Development Research
Lubbock, TX
Robert L. Nichols
Cotton Incorporated
Cary, NC
Philip A. Roberts
University of California, Riverside
Riverside, CA

Abstract

An objective of a cotton breeding program is to identify the best performing cultivars or breeding lines which can be used as parents. Multi-cross combinations provide the means to compare the performance of each parent and assess its combining ability through the recombination, a process by which desirable traits are transmitted to their progenies. Knowledge of the combining ability of Upland (*Gossypium hirsutum* L.) and Pima (*G. barbadense* L.) parental-entries resistant to *Fusarium oxysporum* f. sp. *vasinfectum* race 4 (FOV4) is critical for the improvement of FOV4 resistance. In 2014-2016, Pima and Upland cultivars or germplasm lines with known fusarium wilt or FOV4 resistance were selected and crossed in multi-combinations or in diallel and modified diallel designs to develop progeny and new populations and assess FOV4 resistance. The parents and F_1 populations were then grown under FOV4 pressure in the field and greenhouse and evaluated. The FOV4 infection response-results of parents and the F_1 populations were examined to evaluate the performance of selected parental-entries and the combing ability of both selected Upland and Pima cottons. Preliminary analysis of variance revealed significant differences between Pima and Upland parents. Overall Pima by Upland crosses-F_1 or interspecific populations provided plants with low vascular root staining (VRS) values or better tolerance/resistance to FOV4. This trend was supported by the average VRS value, which was observed low in the second generation or F_2 interspecific populations. Within the Upland, except for F_1's of two selected parents, VRS was observed with high VRS values indicating more susceptibility as previously reported in Upland cotton. Germplasm identified or developed from this project will be provided to public and private breeders and will help to broaden the genetic base of fusarium wilt or FOV4 resistance, which is critical to the success and future of the Upland cotton production.

Introduction

Since 2003 cotton production in the San Joaquin Valley of California has been increasingly impacted by *Fusarium oxysporum* f. sp. *vasinfectum* race 4 (FOV4), a race that was new to California. Prior to 2003, fusarium wilt in California was thought to be primarily caused by FOV race 1 (FOV1) - a soil borne pathogen that can survive for long periods in soils, even in the absence of cotton, making it nearly impossible to eradicate from a field. FOV1 is typically found in sandy or sandy loam soils and produces the most severe yield impacts when present in association with root-knot nematodes [*Meloidogyne incognita*] (Bell, 1984; Veech, 1984). FOV4 was identified by UC Davis scientists (Kim et al., 2005) in California soils. Originally, FOV4 was identified in India on Asiatic cottons and was not

previously identified in the U.S. (Kim et al., 2005; Ulloa et al., 2006). This race occurred in clay loam and loam soils, in which root knot nematode populations were absent. Due to the long-term survival potential of FOV4 in field soils in the absence of cotton, host plant resistance has proven to be the most effective means of managing this disease (Hutmacher et al., 2005; Ulloa et al., 2009, 2016). Because one of the most important strategies is a host-plant resistance breeding program in, here we present our approach about how to identify the best performing cultivars which can be used as parents in crosses and evaluate the genetic combining ability of high performing entries for ultimately developing germplasm with improved tolerance / resistance to FOV4.

Materials and Methods

From 2013 through 2016, we evaluated approximately 1500 entries for responses to FOV4 infection. The assessed entries were selected from Upland (*Gossypium hirsutum*), Acala (*G. hirsutum*), and Pima (*G. barbadense*) lines, recombinant inbred lines (RIL), and interspecific progenies including certain mapping populations. The entries were exposed to FOV4 in moderately, highly FOV4 - infested fields in the San Joaquin Valley of California.

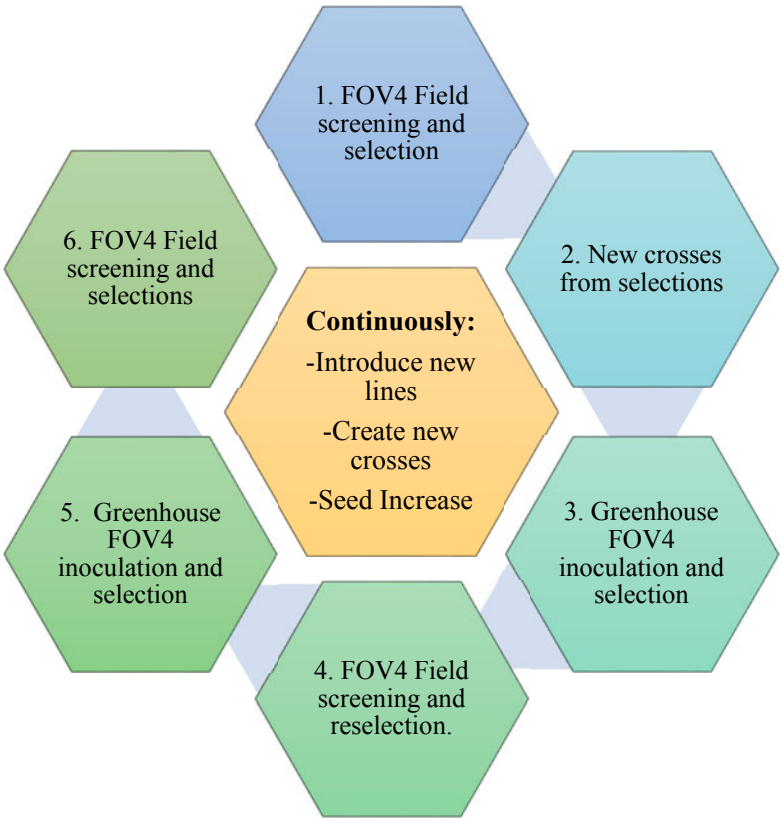

Figure 1. Fusarium wilt (FOV4) evaluation and selection cycle (1-6) under naturally infested FOV4 and artificially greenhouse inoculations.

Plant responses to inoculum were assessed through evaluations of root and stem vascular staining, plant mortality, foliar wilt symptoms and measures of relative plant vigor. Seed increased from these selected entries were re-evaluated under artificial FOV4 inoculation greenhouse tests (Fig. 1).

From all evaluated entries, we selected seven Upland and three Pima experimental entries as parents that showed good levels of resistance to FOV4. Several crosses were performed and multiple (F_1) populations were derived. Results with selected lines presented here are shown to illustrate the response of progenies derived by crossing Pima entries with good levels of resistance with Upland entries and Upland by Upland entries (Table 1). As indicated parents and F_1 populations were assessed in FOV4 infested fields and their progenies subsequently were inoculated with FOV4 and grown under greenhouse conditions for evaluations.

Table 1. Parents and crosses [Upland (U) and Pima (P)] used to assess general and specific combining ability – GCA and SCA, respectively.

Entry	Upland1	Upland2	Upland3	Upland4	Pima1	Pima2	Pima3
Upland1	§	U2xU1	U3xU1	U4xU1	P1xU1	P2xU1	P2xU1
Upland2	U1xU2	§	U3xU2	U4xU2	P1xU2	P2xU2	P3xU2
Upland3	U1xU3	U2xU3	§	U4xU3	P1xU3	P2xU3	P3xU3
Upland4	U1xU4	U2xU4	U3xU4	§	P1xU4	P2xU4	P3xU4
Upland5	U1xU5		U3xU5	U4xU5			
Upland6	U1xU6	U2xU6	U3xU6	U4xU6			
Upland7	U1xU7	U2xU7	U3xU7	U4xU7			
Pima1	U1xP1	U2xP1	U3xP1	U4xP1			
Pima2	U1xP2	U2xP2	U3xP2	U4xP2			
Pima3	U1xP3	U2xP3	U3xP3	U4xP3			

To assess the response of parents and crosses to FOV4, field experiments will typically use a randomized complete block or incomplete block design with three or four replications. When seed availability is a limiting factor, experiments use two replications or use an augmented design. Data were analyzed using SAS 9.4 PROC GLM. Mean separation was performed to compare means of parents and progeny using Waller (SAS Institute Inc., Cary, NC).

Results

During the growing season, plant responses to FOV4 inoculum pressure were assessed through evaluations of root and stem vascular staining levels, plant mortality, foliar wilt symptoms and measures of relative plant vigor. In addition, using vascular root staining (VRS) and foliar rating methods similar to those used in field evaluations, parents and F_1s were also evaluated and subjected to FOV4 root-dip inoculation trials under greenhouse conditions (Figs. 2 and 3). Within Pima parents and progeny, tolerance/resistance is typically set as VRS < 1.0 and within Upland parents and progeny VRS > 2.0.

Figure 2. Foliar examples of greenhouse control entries. Foliar ratings are based on a 0-5 scale (0 = no symptoms, 5 = plant death).

Figure 3. FOV4 vascular root staining (VRS) observation based on a 0-5 scale (0 = no symptoms and 5 = plant death).

Preliminary analysis revealed significant differences between Pima and Upland parents. Overall Pima by Upland crosses-F_1 or interspecific populations produced plants with low VRS values or the appearance of better tolerance/resistance to FOV4 (Figs 4-6). This trend was further supported by observations of low VRS values in the F_2 interspecific populations (Fig. 5). Within the Upland populations, except for F_1's with U6 and U7 parents, VRS was high, suggesting more susceptibility than previously reported (Fig.6).

Analyses are ongoing to further assess the severity of apparent disease symptoms or VRS and identify the best performing germplasm for selection of future parents. Overall, Pima parents and Upland lines U6 and U7 tended to

provided high general combining ability (GCA) while U1-U4 parents were observed with specific combining ability (SCA). Germplasm identified or developed from this project will be provided to public and private breeders and will help to broaden the genetic base of FOV4 resistance, which is critical to the success and future of the Upland cotton production.

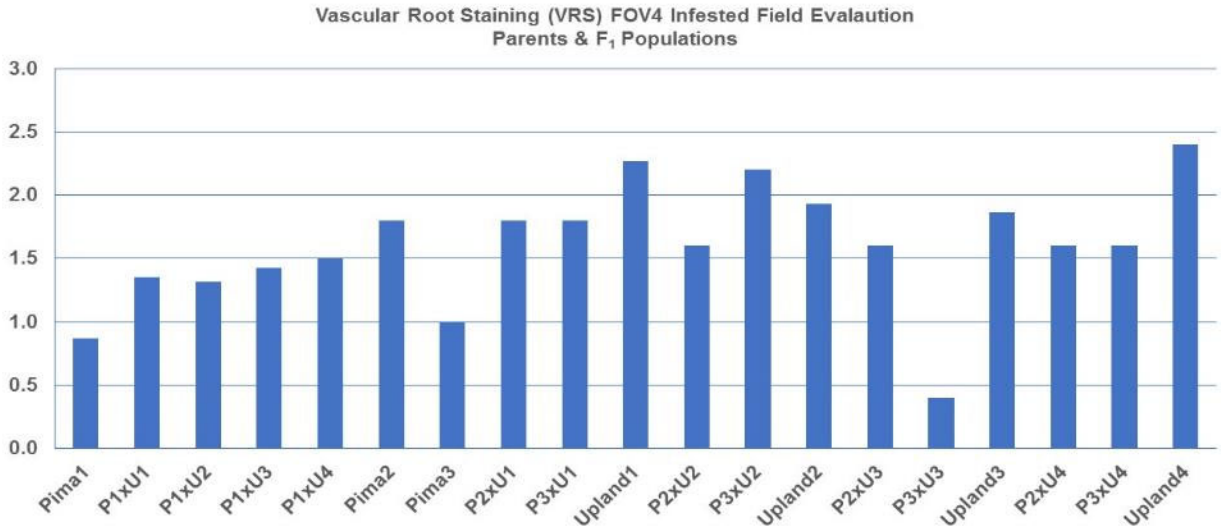

Figure 4. Average VRS of Pima (P), Upland (U) parents, and hybrid (F_1) populations. Minimum significant difference = 0.57.

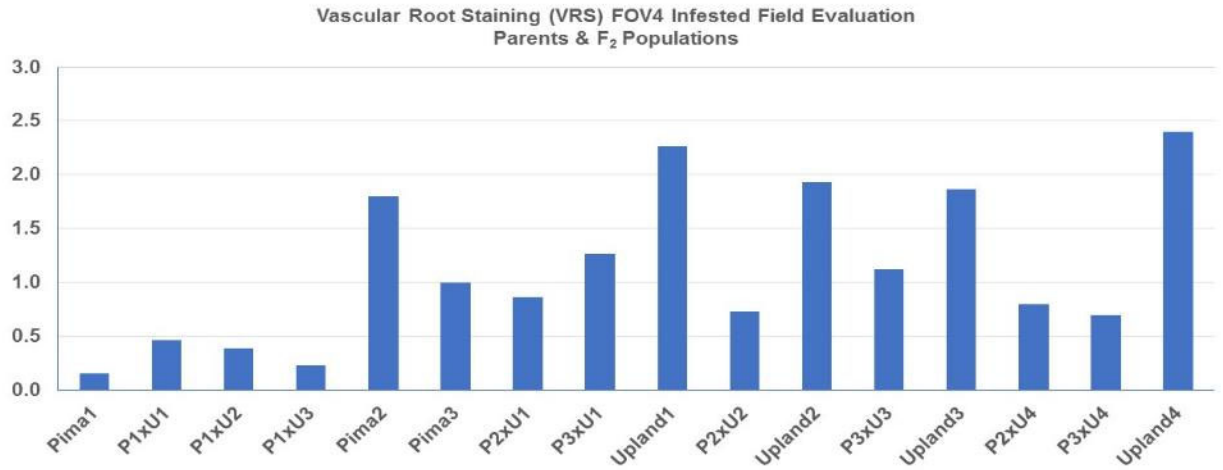

Figure 5. Average VRS of Pima (P), Upland (U) parents, and F_2 populations. Minimum significant difference = 0.32.

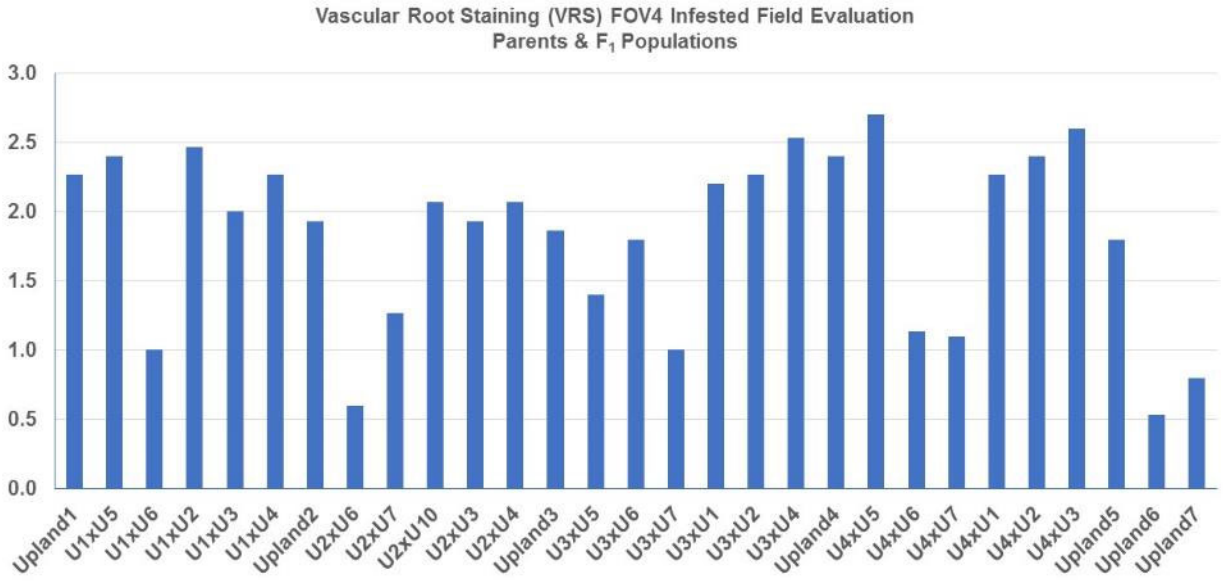

Figure 6. Average VRS of Upland (U) parents, and F_2 populations. Minimum significant difference = 0.67.

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significant difference