TRANSGENIC HERBICIDE TOLERANT COTTON

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Cotton variety development and testing have entered into a new phase and into the 21st century with the advent of biotechnology and transgenic varieties. Genetic engineering techniques allow the introduction of genes from unrelated species, resulting in a new version of an existing variety with a "value added" trait, such as herbicide tolerance. Herbicide tolerant cotton is becoming a reality across the US cotton belt with the introduction of Roundup Ready and BXN varieties. As this technology develops, herbicide tolerant cotton will become common place in California production systems.

The development of transgenic tolerant cotton varieties takes a number of years due to the process and steps necessary in molecular genetics. Once a gene of value is identified (Roundup or Buctril tolerance) and its structure is mapped, molecular biologists use enzymes to cutout the DNA segment and insert it into DNA of an individual cotton cell. This process is called transformation. During the regeneration stage, transformed cotton cells are grown on a nutrient medium in petri dishes forming a mass of undifferentiated tissue or callus. The callus is then induced to differentiate into an entire cotton plant which contains the new trait.

Regeneration is only the beginning as screening is necessary to eliminate undesirable plants. All transgenic cotton varieties are regenerated using Cocker 312, an older variety that produces lesser yields and quality than newer varieties. Cocker 312 is used because it is one of the few varieties that can be easily regenerated.

A considerable amount of time (4 to 6 generations) is then needed to conventionally backcross the transformed trait into desired varieties. More screening and testing are needed before seed increases can begin. Once a progeny line is selected, seed companies then increase seed for commercial use. This entire process can take up to 6 to 8 years.

In the San Joaquin Valley, cotton varietal development and release is controlled by state law and administered through the San Joaquin Valley Cotton Board, made up of grower representatives

within the six cotton producing counties of the San Joaquin Valley. Prospective cotton varieties are tested for a 3 year period. If they meet or exceed the yield and quality traits of the Board's standard variety (Maxxa since 1990) they then are released for grower use. As approved varieties are transformed with herbicide tolerance, making them different than their recurring parent, they again must be tested for three years before approval. The additional testing is to insure that its yield and quality characteristics have not been compromised and inferior Cocker 312 traits are not expressed in the new herbicide tolerant variety.

At present, three Roundup Ready cotton varieties are being tested and evaluated by the San Joaquin Valley Cotton Board. If these varieties meet board standards, the first commercial herbicide tolerant cotton varieties will be available to California cotton growers in 2000.

As this technology is developed and made available to the California grower, a number of questions and concerns arise, the most important being the issue of weed resistance or weed species shifts. If weed control programs are developed which rely solely on one herbicide, weed resistance may become a problem. Since plants only have one reproductive cycle per year, it normally takes several years to develop a resistant population. But, growers need to implement resistance management strategies including crop rotation, herbicide rotation and control of weed escapes by tillage in order to prevent resistance from developing.

A number of studies were conducted to evaluate Roundup Ready and BXN (Buctril) transgenic cotton varieties. Studies evaluated control of annual morningglory and cotton tolerance when Roundup Ultra and Buctril were applied to their respective varieties at various rates and stages of growth.

Roundup Ready Studies

Roundup Ultra applied to morningglory in Roundup Ready DP6100RR cotton provided excellent season long control up through harvest when applied to seedling morningglory over the top of 2 to 3 leaf cotton followed by one post directed treatment. A second post directed treatment did not enhance control.

Evaluations of Roundup Ultra applied over the top of DP6100RR cotton at various rates and stages of cotton growth showed the extreme importance of limiting over the top application to no more

than the 4 leaf stage. No visual injury symptoms were noted when Roundup Ultra was applied over the top at any rate or stage of cotton growth. But, final plant mapping data indicated significantly lower boll retention levels in most treatments when compared to a single over the top application at the two leaf stage. Seed cotton yields were numerically less with all Roundup Ultra treatments and significantly lower at the 9 and 12-node stage of application when compared to a single over the top application at the two leaf stage. Post direct treatments of Roundup Ultra at the 8 and 17-node stage of cotton had no detramental effect on yield.

Preharvest or late season applications of Roundup Ultra at 8 NAWF (nodes above white flower), 5 NAWF (cutout), 8 NACB (nodes above cracked boll), and 4 NACB showed no adverse effect to cotton growth and development except at the 8 NAWF application. Roundup Ultra applied at 8 NAWF significantly lowered percent boll retention in the 95 percent zone and seed cotton yield.

When Roundup Ultra was applied to DP6100RR cotton in combination with Staple there was no adverse effect to cotton growth, development and yield. Staple applied at all rates over the top of 3 to 4 leaf cotton produced the same visual symptoms as when applied to non Roundup Ready cotton varieties. Yellowed, crinkled leaves appeared 3 to 5 days after application, but were almost nonexistent at 14 days after treatment.

BXN Studies

Buctril applied to seedling annual morningglory over the top of BXN Stoneville 47 cotton provided acceptable control for 35 days when followed by a post directed treatment of Buctril. Either a single over the top or single later post directed treatment provided unacceptable control of morningglory. At 90 days after treatment, control was also unacceptable with the over the top followed by a post directed treatment. Additional studies indicated no visible, detrimental effects to cotton when Buctril was applied to BXN Stoneville 47 at any stage of growth. There were no differences in yield when compared to a standard weed control program of Staple applied to Maxxa cotton.

In summary, herbicide tolerant cotton, if properly managed, will provide growers with a viable weed management strategy for effective, economic weed control. Presently available transgenic varieties will be the forerunners of future transgenic varieties

which will provide the grower with greater application flexibility and with multiple traits including herbicide tolerance and insecticidal properties. But, as this technology is developed and integrated into production systems a number of concerns must be addressed including:

1. Effects on herbicide use - if a crop is tolerant to a non selective herbicide such as Roundup, can all other herbicides in the system by eliminated? Will it be necessary to use preplant, preemergence, post emergence or over the top selective herbicides? Will herbicide tolerant crops allow replacement of herbicides that are used in higher doses with those used at lower doses? Will growers be able to wait to determine if a weed problem develops then apply a non selective herbicide?

   On the other hand, will herbicide tolerant crops cause growers to solely rely on herbicides for their weed problems, resulting in greater herbicide use?

2. Can cultivation and hand weeding be reduced or eliminated? Will minimum and/or no till production systems be developed in California? Will herbicide tolerant crops allow the elimination of hand weeding and what will be the economic "trade off?"

3. Crop productivity, quality and safety - the implications of genetic engineering as a process in developing herbicide tolerant crops, raises the question of maintaining current yield and quality levels as well as food safety?

4. Weed Resistance - Will herbicide tolerant crops lead to weed resistance or shifts to hard to control perennials?

5. Environmental Effects - What effect will herbicide tolerant crops have on air, water and soil quality? The San Joaquin Valley is a non attainment area for PM_{10} and ozone levels in the atmosphere. Will herbicide tolerant crops result in less cultivation, ultimately reducing the amount of dust and PM_{10} particles released into the atmosphere. Will soil and water quality be effected by the elimination of soil, residual herbicides which have a potential of effecting subsequent rotational crops and movement into the ground water supplies.

6. Economic effects - Will herbicide tolerant crops result in more economical weed strategies for growers? If cropping systems are developed that rely only on a few non selective herbicides; what effect will that have on the development and commercialization of new alternative herbicides? Will this technology lead to a complete restructuring of the ag chemical marketing system?