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The antioxidant potential:

factor of abiotic stress tolerance in cotton

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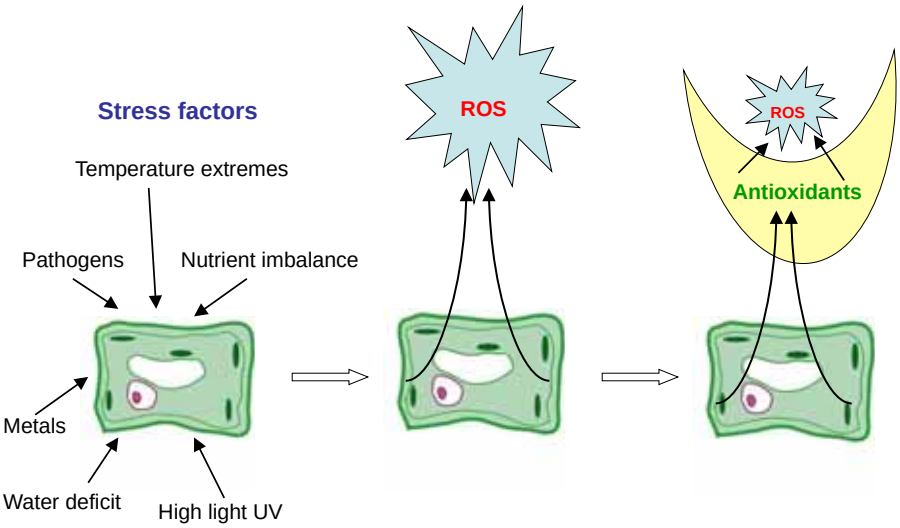
It is commonly accepted that the primary event induced by
various stress factors in plants is

the burst of reactive oxygen species

ROS

i.e. a state of oxidative stress
that can have deleterious effect on cell function and structure.

Plants elaborated a diversified network of antioxidants (ROS scavengers) to regulate the oxidative stress.
The antioxidant potential is deployed as a response to stress inflict.



Enzymes

Peroxidase
Catalase
Superoxidedismutase
Glutathione reductase
Etc.

Non-enzymatic compounds

Carotenoids
Tocopherols
Polyphenols
Proline
Polyamnines
Etc.

The antioxidant defense of plants involves compounds of diverse chemical types

In our long-term research on cotton stress physiology we examined

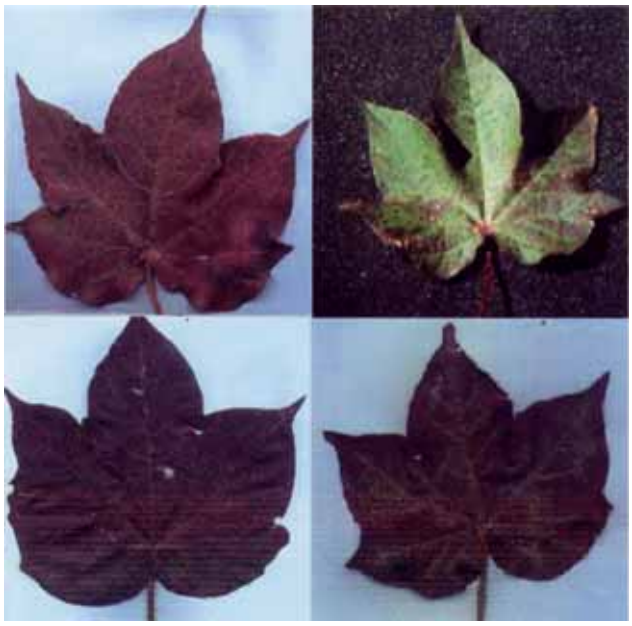
two cases of cotton- stress factor interactions:

- Nutrient (K/Na) imbalance
  (leaf reddening)
- Water deficit

In both cases abiotic constraints induce

a state of oxidative stress

Cotton reddening



Red cotton leaves

Experimental

•Three **locations** in Aegean region:
Söke, Menemen, Bergama

•**Cotton plants:**
Nazilli 84 cv.

♦ Leaves of green plants (controls)
Leaves with symptoms of reddening:
♦ Light symptoms
♦ Severe symptoms

•**Soils:**
♦Under green plants
♦Under reddening plants

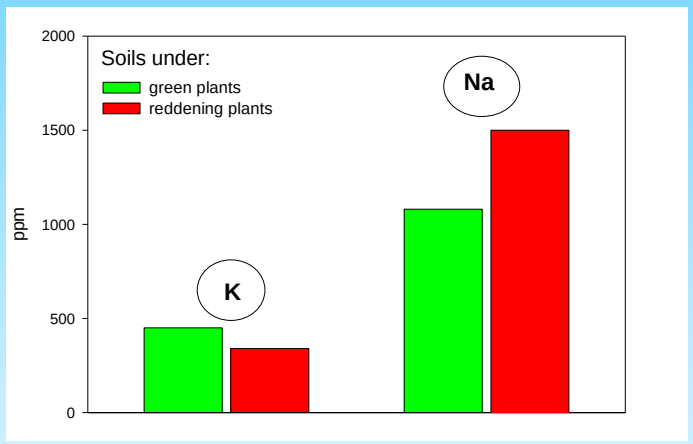
We have established that

reddening of cotton leaves

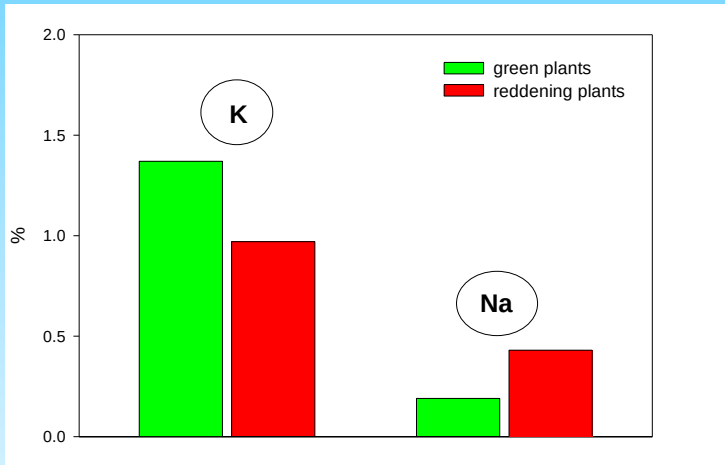
is provoked by

K deficiency in the soil and K/Na imbalance

leading to overaccumulation of Na in the leaves



K and Na content (ppm) of soils on which
green and reddening plants are grown

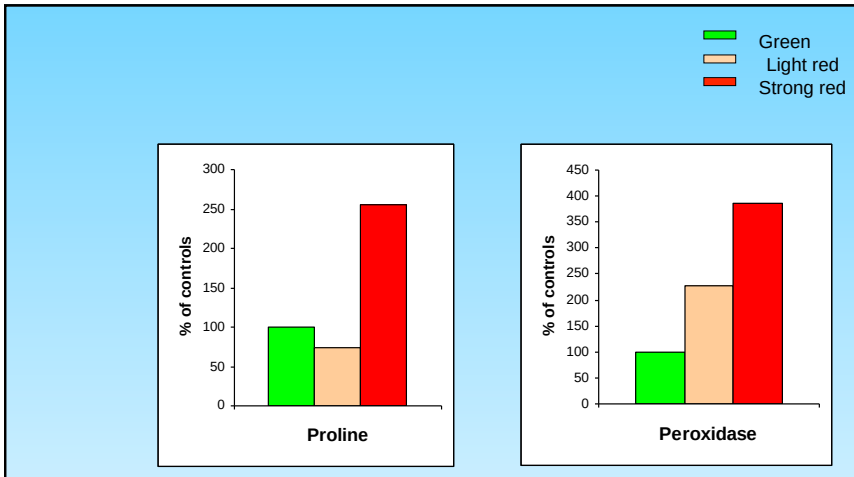


K and Na content (%) in leaves
of green and reddening plants

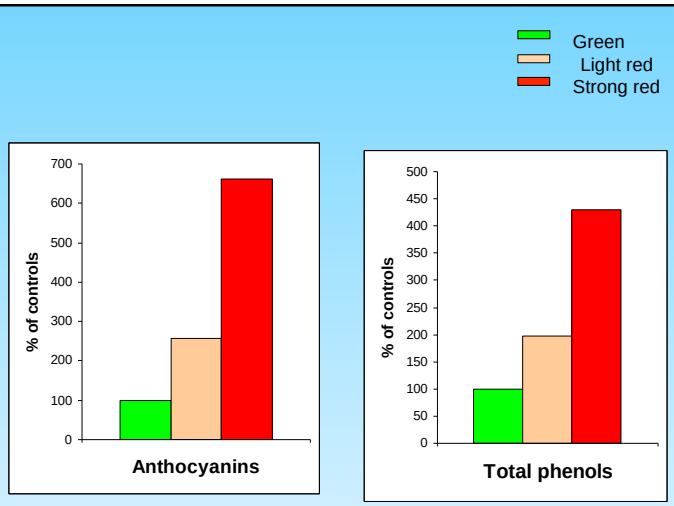
Plants make better use of Na in case of K deficiency

Excess of Na induces over-accumulation of toxic
OH• free radicals in plants, i.e.
a state of oxidative stress (Alia et al. 1993).

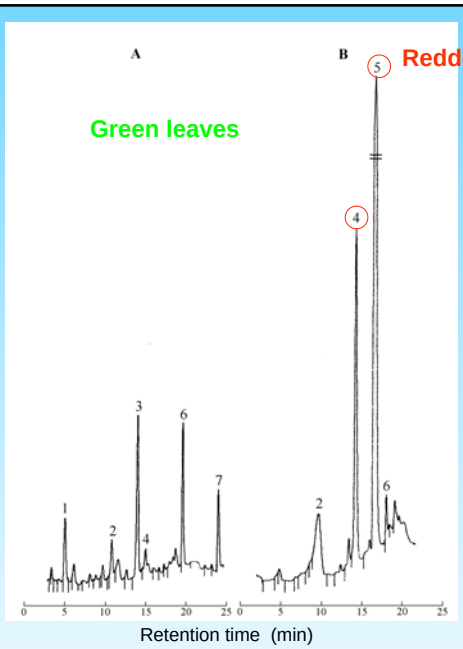
Biochemical changes related to cotton reddening



Increase of non-enzymatic (proline) and enzymatic (peroxidase) antioxidants in reddening leaves



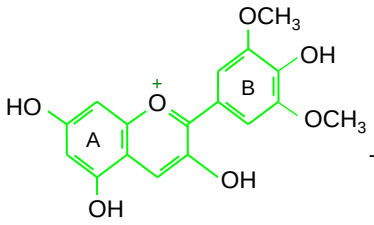
Dramatic increase of anthocyanins and total phenols in the reddening leaves



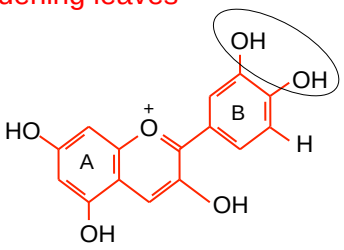
Retention time (min)

HPLC of anthocyanins (C6-C3-C6+) in green and reddening cotton leaves
Peaks 4 and 5 are identified as cyanidin glycosides

Green leaves



Reddening leaves



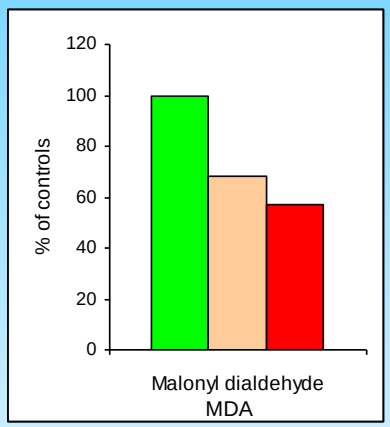
Malvidin
- Low antioxidant/antiradical activity
- Predominant aglycone in green leaves

Cyanidin
- High antioxidant activity
(due to the o-OH grouping in the B-ring)
- Predominant aglycone in reddening leaves

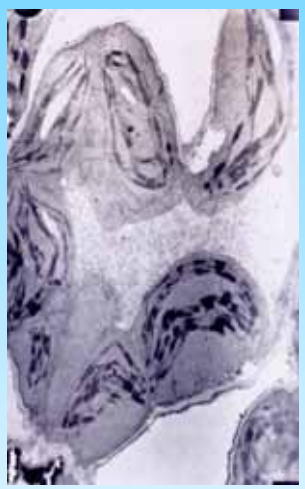
❖The shift from malvidin to cyanidin in reddening leaves determines a stronger protective potential against oxidative stress.

The efficacy of the antioxidant defense in reddening leaves is evidenced by the low damage of membrane integrity as shown by the

- Malonyl dialdehyde (MDA) test
- Transmission electron microscopy



MDA test
Low membrane damage in reddening leaves

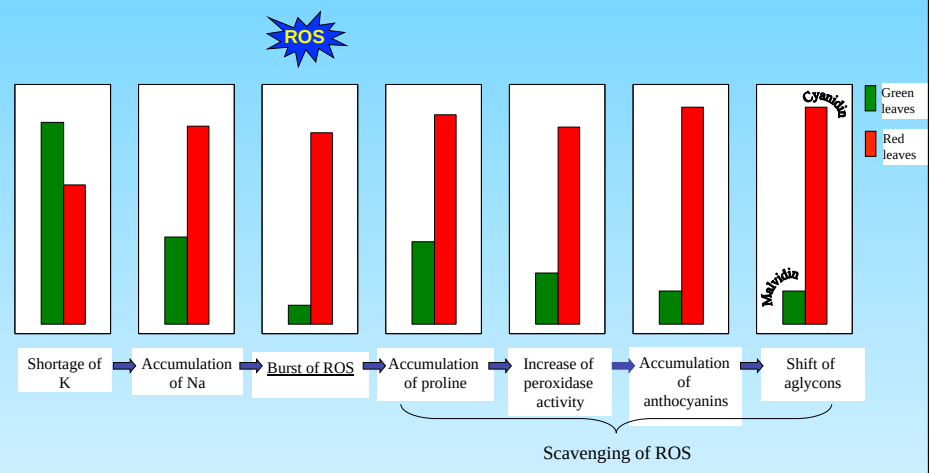


Green leaves

Reddening leaves

Transmission electron microscopy

Preserved membrane integrity in reddening leaves



Antioxidant protection in reddening cotton leaves: general proposed scheme

Drought tolerance

Experimental design

Nazilli 84-S
Drought sensitive (S)

Şahin 2000
Drought tolerant (T)

Irrigation regimes

- Field capacity (normal water supply)
- 1/3 field capacity (drought stress)

Locality

- Söke, Aegean region of Turkey

Parameters

Biochemical

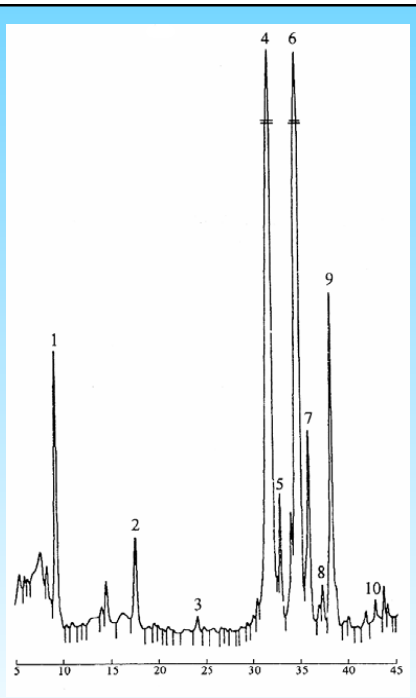
- Non-enzymatic antioxidants
  - Polyphenols
  - Proline
  - Carotenoids
- Markers of membrane damage
  - Malonyldialdehyde (MDA)

Physiological

- Photosynthesis
- Water use efficiency (WUE)
- Max photochemical activity of PSII
- Relative water content (RWC)

Non-enzymatic antioxidants

- **Polyphenols**
- **Proline**
- **Carotenoids**

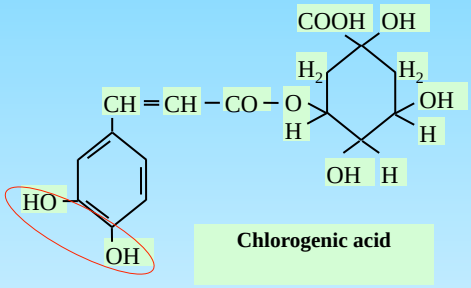


HPLC pattern of polyphenols in the leaves of cotton genotype Nazilli 84-S.

1, 2, 3 – isomers of chlorogenic acid:
- 1 – 5-O-caffeoyl quinic acid
- 2 – 3-O-caffeoyl quinic acid
- 3 – 4-O-caffeoyl quinic acid

4 – 10 – flavonoids:
- 4 – isoquercitrin glycoside
- 6 – rutin
- 8 – quercitrin
- 9 – kaempferol-3-rutinoside
- 10 – quercetin

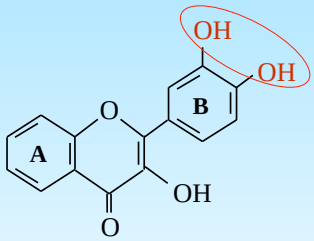
Main polyphenols in cotton leaves



Chlorogenic acid

Cinnamic acid derivatives

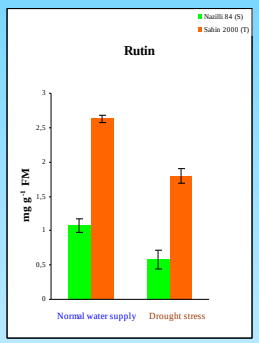
Flavonoids: quercetine derivatives

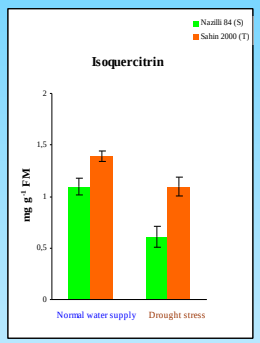


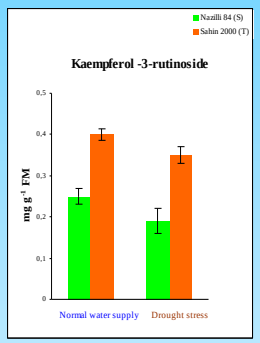
Quercetin

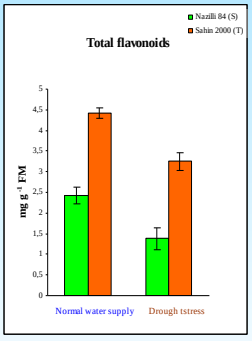
Both types have high antioxidant activity due to the presence of o-dihydroxy grouping

Quercetin derivatives (rutin, isoquercitrin) are the major flavonoids in cotton leaves

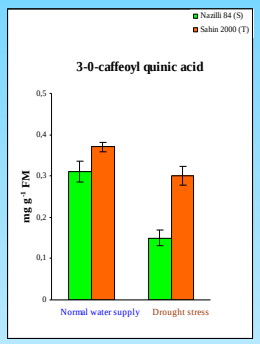


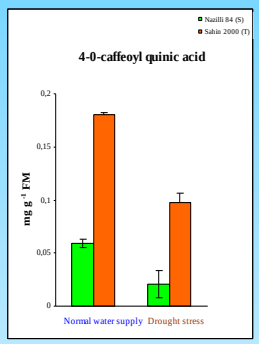


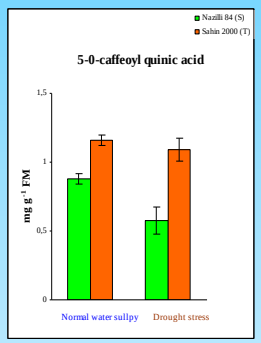


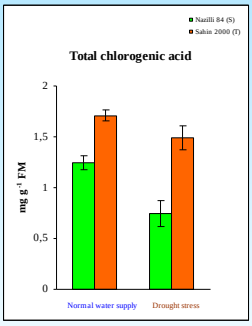


Higher content of flavonoids in the drought-tolerant ( ) than in the sensitive ( ) genotype:
-at normal water supply
-at drought





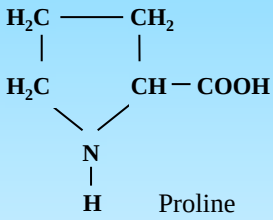




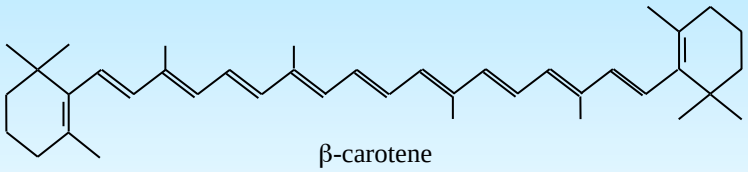
Higher content of chlorogenic acid isomers in the drought-tolerant (■) than in the sensitive (■) genotype:
-at normal water supply
-at drought

Non-enzymatic antioxidants

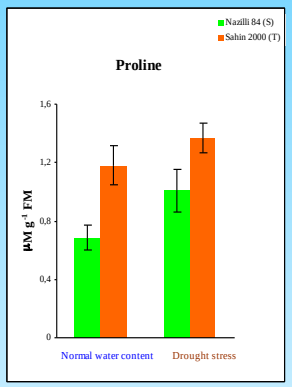
Proline
Carotenoids

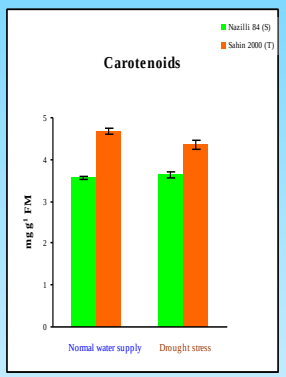


Proline



β-carotene



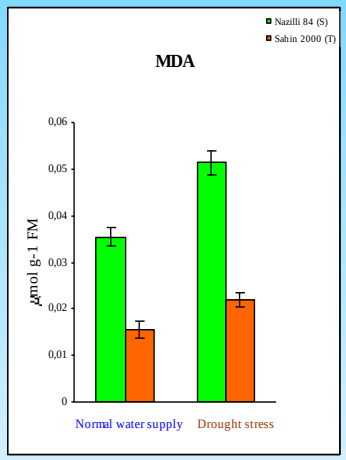


Higher content of proline and carotenoids in the drought-tolerant (■) than in the sensitive (■) genotype:
-at normal water supply
-at drought

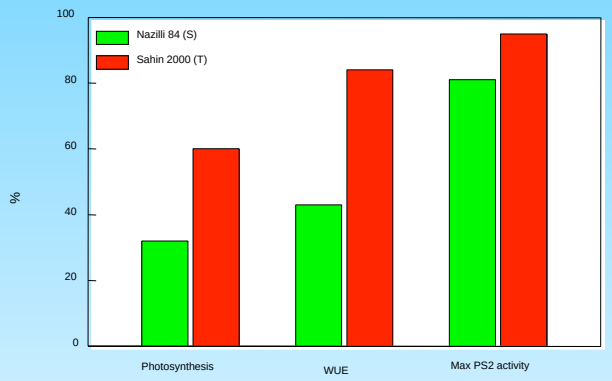
The efficacy of the antioxidant defense in the drought-tolerant genotype is evidenced by:

- ❖ lower membrane damage
- ❖ better physiological performance

as compared to the sensitive genotype

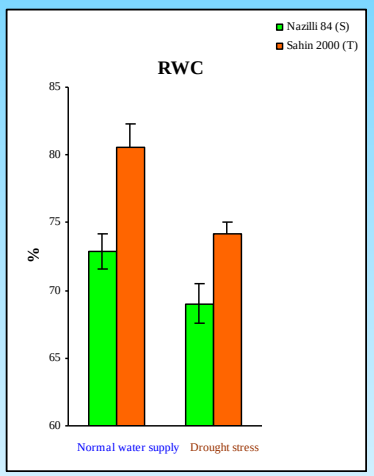


Lower membrane damage (malonyl dialdehyde content, MDA) in the drought-tolerant (■) than in the sensitive (■) genotype at:
- normal water supply
- drought



Photosynthetic parameters in drought-subjected plants as % of the plants grown at normal water supply

Better photosynthetic performance in the drought-tolerant (■) than in the sensitive (■) genotype



Higher relative water content (RWC) in the drought-tolerant ( ) than in the sensitive ( ) genotype at:
- normal water supply
- drought

Conclusion

✓ Cotton plants employ an effective versatile network of antioxidant compounds for defense against various abiotic stress constraints.

✓ The data obtained contribute to the understanding of the biochemical bases of abiotic stress tolerance in plants.

✓ They can serve as a rationale in modeling and engineering abiotic stress tolerant cotton crops.

Acknowledgements

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Thank you