Transition to conservation tillage evaluated in

,Q IDOO ZH HVWDEOLVKHG D comparison of conservation and standard tillage in cotton and tomato rotations, with and without winter cover crops, at the University of California West Side Research and Extension &HQWHU LQ)LYH 3RLQWV 7KH REMHF- tives of the study were to compare conservation tillage and conventional tillage practices in crop rotations common to the San Joaquin Valley in terms RI SURGXFWLYLW\ DQG SURÀWDELOLW\ VRLO TXDOLW\ LQGLFDWRUV 9HLW- 2006) and the quantity of dust produced GXFHG :H UHSRUW KHUH RQ WKH the tillage systems performed during WKH ÀUVW \HDUV RI WKH VWXG\

Conventional intercrop tillage practices that knock down and establish new beds following harvest were used LQ WKH VWDQGDUG WLOODJH V\VWHPV WDEOHV DQG 7KH FRQVHUYDWLRQ WLOO- age systems were managed from the general principal of trying to reduce primary, intercrop tillage to the greatest HVW H[WHQW SRVVLEOH 5HGXFHG SUDFWLFHV WKDW UHVWULFW WKH furrows were used in the conservation tillage systems, and planting beds were not moved or destroyed in these systems. WKH ÀHOG WKH HQWLUH

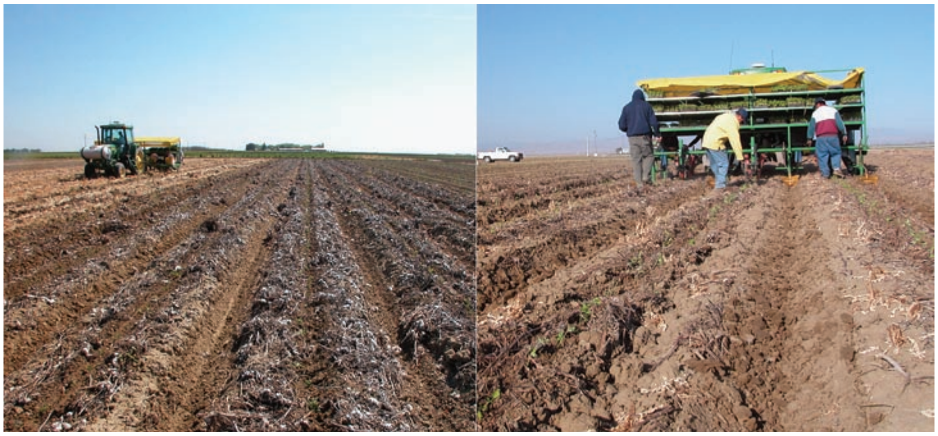
$Q DFUH ÀHOG LQ D RI 3DQRFKH FOD\ ORDP PL[HG VXSHUDFWLYH +DSORFDPELGV $UUR[HV used for the study, and a uniform barley (Hordeum vulgare) crop was grown RYHU WKH HQWLUH ÀHOG WKH WUHDWPHQWV 7KH into two halves with a processing tomato (Lycopersicon esculentum) cotton (Gossypium hirsutum) one half and a cotton-tomato rotation RQ WKH RWKHU 0DQDJHPHQW of standard tillage without cover FURS 6712 VWDQGDUG FRYHU FURS 67&& FRQ- DJH ZLWKRXW FRYHU FURS &712 conservation tillage with cover crop &7&& ZHUH UHSOLFDWHG randomized complete block design on HDFK KDOI RI WKH ÀHOG consisted of six beds, each measuring IHHW E\ IHHW 6L[EHG separated tillage treatments to enable the different tractor operations that ZHUH XVHG IRU HDFK V\VWHP

œ Û i À VÀ cover crop mix of Juan triticale (Triticosecale: LWWP 0HUF ryegrain (Secale cereale) DQG FRPPRQ vetch (Vicia sativa) was planted at a rate RI SRXQGV SHU DFUH WR ÀQH \HOORZ PLQ DQG YHWFK E\ late October in the standard and conservation tillage plus cover crop plots, DQG LUULJDWHG RQFH LQ , the subsequent years, no irrigation was applied to the cover crops, which were planted in advance of any early winter UDLQV 7KH FRYHU FURSV ZHUH LQ PLG 0DUFK RI WKH IROORZLQJ XVLQJ D %XIIDOR 5ROOLQJ 6WDON)OHLVFKHU 1HE ,Q WKH 67&& the chopped cover crop was disked into the soil to a depth of about 8 inches, and 5-foot-wide beds were reformed prior WR WRPDWR WUDQVSODQWLQJ FRYHU FURSV LQ WKH &7&& V\VW sprayed with a 2% solution of glyphosate DQG OHIW RQ WKH VXUIDFH DV

/œ“>Ìœ the tomato-planted half 7KH WUDQVSODQWV SORWWV RI WKH were transplanted in the center of beds at an in-row spacing of 12 inches during LQJ WKH ÀUVW ZHHN RI $SULO XVLQJ D PRGLÀHG WKUHH-URZ WUDQVSODQWHU ÀWWHG FRXOWHU DKHDG RI HDFK WUDQ WUHDWPHQWV UHFHLYHG WKH V

	ST	CT	ST	CT
Shred cotton	8		8	
Undercut cotton	8		8	
Disk	8		8	
Chisel	8		8	
Level (triplane)	8		8	
List beds	8		8	
)NCORPORATE SHAPE BEDS	8		8	
#LEAN FURROWS		8		8
Shred bed		8		8
Spray herbicide trifluralin	8		8	
Incorporate trifluralin – rolling cultivator	8		8	
Spray herbicide glyphosate			8	8
Spray herbicide rimsulfuron	8	8	8	8
Cultivate – sled cultivator	8		8	
Cultivate – high residue cultivator		8		8
Plant tomatoes	8	8	8	8
Fertilize	8	8	8	8
Plant cover crop	8	8		
-OW COVER CROP	8	8		
Custom harvest	8	8	8	8
4OTAL TIMES OVER FIELD	23	12		11

	ST	CT	ST	CT
Disk	8		8	
Chisel	8		8	
Level (triplane)	8		8	
List beds	8		8	
Spray herbicide trifluralin	8		8	
Incorporate trifluralin – rolling cultivator	8		8	
Spray herbicide glyphosate	8	8	8	8
Cultivate – rolling cultivator	8		8	
Chain beds	8	8		
Plant cotton	8	8	8	8
Fertilize	8	8	8	8
Plant cover crop	8	8		
-OW COVER CROP	8	8		
3PRAY INSECTICIDES GROWTH regulator	8	8	8	8
Spray defoliant	8	8	8	8
Spray insecticides	8	8	8	8
Custom harvest	8	8	8	8
4OTAL TIMES OVER FIELD	23			11



Above

applications, with dry fertilizer (11-52-0 NPK) applied preplant at 100 pounds SHU DFUH $GGLWLRQDO side-dress applied at 125 pounds nitrogen per acre in two lines about 7 inches from the transplants and about 6 inches GHHS DERXW ZHHNV DI

Cotton. 7KH RoundUp Ready (glyphosate-resistant) upland cotton (Gossypium hirsutum) variety 'Riata' was used each year in all cotton systems and was established using a John Deere 0ROLQH ,OO 1R WL was planted in two lines on the same IRRW ´SHUPDQHQWµ EH broken down and reshaped following tomatoes, as is customarily done and as we did in our standard tillage plots, which were disked down and reworked into LQFK EHGV IRU FRWWR KHUELFLGH WULÁ XUDOLQ plied and soil-incorporated twice as is the regional custom, to better mix the

FKHPLFDO ZLWK WKH VRLO of 140 pounds of urea fertilizer per acre was made in each year in each V\VWHP XVLQJ D IHUWLOL]HU with an 18-inch coulter to cut residues about 10 inches to the side of plants

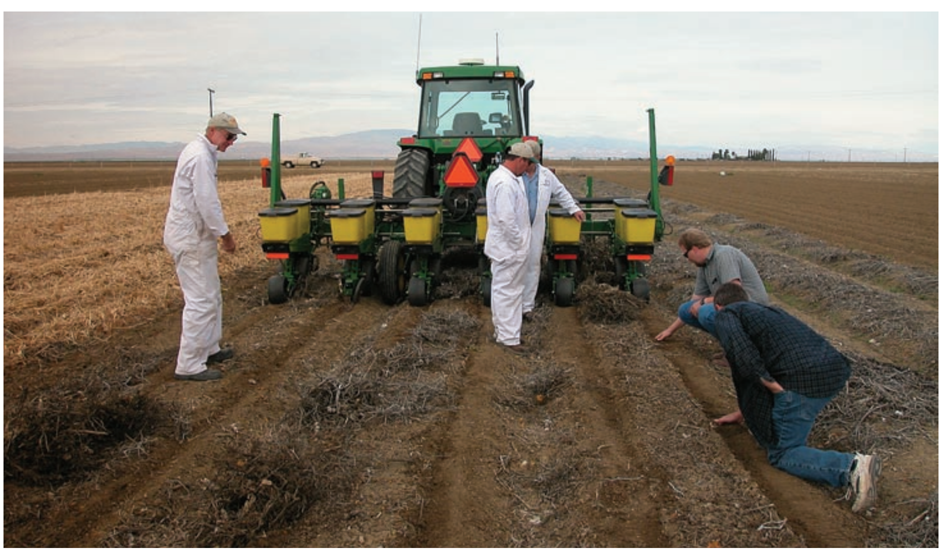
Tractor use. $OO WUDFWRU WUD stricted to the furrows between planting beds in the conservation tillage systems; no tillage was done in the conservation tillage plots following tomatoes and preceding the next cotton crop, and only two tractor passes were conducted following cotton and preceding each VXEVHTXHQW WRPDWR FURS tions included shredding and uprooting the cotton stalks in order to comply with ´SORZ GRZQµ UHJXODWLRQV IRU SLQN EROO worm control in the region and a furrow sweep operation to clean out furrow bottoms to improve irrigation water move- PHQW GRZQ WKH IXUURZV

PLQHG LQ HDFK \HDU XVLQJ gondola trailers following the commercial machine harvest of each entire SORW &RWWRQ OLQW \LHOG using whole-plot seed cotton weights multiplied by gin turnout percentages determined on samples sent through the UC Shafter Research and Education &HQWHU UHVHDUFK JLQ

Dust. 7RWDO GXVW 7' FURPHWHUV@ DHURG\QDPLF UHVSLUDEOH GXVW 5' GLDPHWHU ZHUH FROOHFWH 37)(PHPEUDQH ÀOWHUV V WKH $QGHUVHQ VDPSOHU during each tillage operation in 2001 and 2002, in order to describe relative LQ ÀHOG GXVW SURGXFWLR V\VWHP %DNHU HW DO ZHUH DWWDFKHG WR HDFK À about 15 inches above the ground surface, with the exception of the cotton harvester samples, which were placed at DSSUR[LPDWHO\ IHHW DER 7KH VDPSOHUV ZHUH DWWDF RSHUDWHG SXPSV RSHUDWH RI OLWHUV SHU PLQXWH tions from each tillage or harvest operation were calculated from the mass of GXVW FROOHFWHG RQ SUHZ SXPS DLU ÁRZ UDWHV DQG RI WKH RSHUDWLRQ &XPXO centrations for the four treatments were calculated by summing the mean values of all operations contributing to a particular treatment over a complete cotton- WRPDWR URWDWLRQ

GDWD ZHUH D lyzed as an unbalanced mixed model using SAS statistical software (SAS ,QVWLWXWH 7KLV PRGH account variability associated with switching crops (such as tomato-cotton, cotton-tomato rotation) on experimental SORWV QHVWHG LQ EORFNV 7UHDWPHQWV ZHUH QRW DQ torial combination of cover crop and WLOODJH 7KHUHIRUH VLPS WRULDO HIIHFWV DUH LQIHU

During the 4 years of this study, the QXPEHU RI WUDFWRU WULSV was reduced by about 50% for tomato (table 1) and 40% for cotton (table 2) in the conservation tillage systems rela- WLYH WR VWDQGDUG WLOODJ the tillage intensity between systems



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	2000	ó	2002	õ
	1,000 plants/acre			
Standard tillage no cover crop (STNO)	AB	A	B	A
Standard tillage cover crop (STCC)	AB	AB	B	A
Conservation tillage no cover crop (CTNO)	A	A	A	A
Conservation tillage cover crop (CTCC)	B	B	C	B

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	2000	ó	2002	õ	Average
	tons/acre				
Standard tillage no cover crop (STNO)	AA	61 a,a	B	B	B
Standard tillage cover crop (STCC)	BB	63 a,a	B	B	B
#ONSERVTILLAGENOCOVERCROP#	AB	AA	AB	AB	A
#ONSERVTILLAGECOVERCROP#	CB	61 a,a	B	AB	B

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$FFERENTLETTERSINDICATESTATISTICALSIGNIICANCEATP
o ,AAAPAAAXAAAAACCAXA

were due primarily to reductions in soil-disturbing operations commonly associ-ated with postharvest land preparation, including disking, chiseling, leveling and relisting beds — operations that are W\SLFDOO\ SHUIRUPHG LQ DOO WKH VWDQGDUG V\VWHPV ZLWK

7KH RSHUDWLRQV OLVWHG D DQG 2 represent average sequences for all years; slight differences occurred in FHUWDLQ \HDUV)RU LQVWDQFH performed two operations following cot-ton harvest in the conservation tillage V\VWHPV D RQH SDVV 6KUHGGHU ,QWHUVWDWH 0IJ %DNHUVÀHOG &DOLI WR shred and undercut the cotton plant, and a furrow sweeping operation using D %XIIDOR +LJK 5HVLGXH &XOWLYDWRU)OHLVFKHU 0IJ &ROXPEXV ÀHG DQG ÀWWHG ZLWK PHQWV ,Q KRZHYHU no-till tomato transplanter with furrow ´ULGJLQJ ZLQJV µ DQG WKHUHIRUH FOHDUHG out residues from furrow bottoms at the WLPH RI WUDQVSODQWLQJ

7KH JHQHUDO FRQVHUYDWLRQ WLOODJH approach pursued in this study was to more severely restrict tillage opera-WLRQV WKDQ LV FXVWRPDU\ As a result, more residues accumulated on the soil surface, particularly in the &7&& V\VWHPV DQG WKLV explains the lower numbers of cotton plants that were established in this sys-WHP LQ HDFK \HDU UHODWLYH WR WKH V\VWHP WDEOH

In addition, we were initially con-cerned that residues would interfere with the action of the "over-the-WRSµ WRPDWR KHUELFLGH (Shadeout), which can be sprayed after transplanting and sprinkled in to ac-WLYDWH %\ KRZHYHU conservation tillage cotton, we relied solely on one or two in-season applica-tions of glyphosate; no cultivation was GRQH LQ WKHVH V\VWHPV we typically cultivated two to three times, but based on visual estimates of weed populations, this did not achieve a comparable level of weed control in the conservation tillage systems as in the standard tillage systems in all \HDUV 7KLV WR RQH DVSHFW RI WKH FRQVHU-vation tillage approach that needs to EH LPSURYHG

While the conservation tillage sys-tems we employed in this study dra-matically reduced overall tillage and soil disturbance relative to the standard tillage norms for the San Joaquin Valley, they by no means constitute what is FXVWRPDULO\ FRQVLGHUHG ´QR-WLOOµ RU GXFWLRQ ,Q FODVVLF QR-WLOO V\VWHPV FURSV DUH GLUHFWO\ directly into residues and no additional soil disturbance is generally done prior WR KDUYHVW :H XVHG D PRUH LQWHUPH-diate or incremental tillage reduction strategy in part to clear channels for the movement of irrigation water down furrows and in part to meet California Department of Food and Agriculture (CDFA) mandates for pink bollworm FRQWURO LQ FRWWRQ &XUUHQW lations require uprooting cotton roots postharvest and potentially some UHVLGXH EXULDO 5HFHQW FKDQJHV &')$ 3LQN %ROOZRUP 0DQDJHPHQW Program allow for reduced postharvest WLOODJH LQ FRWWRQ ÀHOGV ZLWKLQ EROOZRUP ÀQGLQJV RU LQ ÀHOGV of a 9-square-mile radius from a pink EROOZRUP WUDSSLQJ ÀQG 7KHVH should make it easier to adopt conser-YDWLRQ WLOODJH SUDFWLFHV

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/œ“>ÌœÊ7RPDWR \LHOGV GXULQJ ÀUVW \HDUV RI WKLV VWXG\ ZHUH ally similar in the conservation tillage and standard tillage systems, with VRPH \HDUV VKRZLQJ VLJQLÀFDQW ferences (positive and negative) (table

3URFHVVLQJ WRPDWR \LHOGV were slightly lower in each of the cover-cropped systems relative to both the standard and conservation tillage V\VWHPV ZLWKRXW FRYHU FURSV have been caused in part by slower Early-season tomato growth that was observed in each of the cover-cropped V\VWHPV :H VSHFXODWH WKDW reduction resulted from nitrogen immo-bilization following cover crop termi-nation each spring, and, in the case of WKH &7&& V\VWHP ORZHU VRLO VXUIDFH DLU WHPSHUDWXUHV testing is now under way to evaluate HDFK RI WKHVH K\SRWKHVHV

Data from the 2001 tomato harvest indicates that yields in conservation till-age both with and without cover crops were similar to those in the standard WLOODJH SORWV ,Q ERWK the highest-yielding system was con-servation tillage without a cover crop, DOWKRXJK \LHOG ZDV VLJQLÀF WKDQ DOO RWKHU WUHDWPHQWV Using a cover crop meant lower yields for the conservation tillage system in EXW WKH RYHUDOO \LHOG ´GUDJ-\LHOG Z FDQWO\ RQO\ ´ZLWK´ HIIHFW RU Interestingly, for the standard tillage system a cover crop increased yields LQ DQG DJDLQ LQ FRPSDUHG WR 67126 WUHDWPHQWV 8VLQJ DJHV IRU WR WKH SHULRG which the tillage systems had become ´HVWDEOLVKHGµ IROORZLQJ WKH VHW XS \HDU &712 KDG VLJQLÀFDQWO\ higher yields than the other treatments WDEOH 7KLV VXJJHVWV D SR

	2000		2002		Average
	pounds lint/acre				
ALLACCVP./	AC	AA	AA	A	Ao
ALLACCVP	A	C	AA	1,336 a,c	B
CONSERVTILLAGENOCOVERCROP#	B	B	B	CB	C
CONSERVTILLAGECOVERCROP#	AC	BA	CB	BB	1,326 d

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o ,AAAPAAAXXAAAACCAXXA

	Total dust	dust
	· · · · · · · · µg/L · · · · · · ·	
ALLACCVP./		
ALLACCVP		
LVACCVP./		
LLACCVP		

CAALALPC FOREACHOPERATION

tillage-system-by-cover-crop interac-
WLRQ ZKHUH FRYHU FURS
lowered tomato yields in the conserva-
tion tillage system but not in the stan-
GDUG WLOODJH V\VWHP
7RPDWR IUXLW TXDOLW\
LGV DQG S+ GDWD ZHUH
in every year of the study and did not
indicate consistent system or treatment
trends when determinations were
made, presumably because similar ir-
rigation water volumes were applied
WR DOO V\VWHPV 7KRXJK ZH GLG QRW
consistently monitor weed populations
during this study, we did generally
observe more weeds with cover crop-
ping, and particularly in the furrows,
IRU ERWK WRPDWR DQG
need to improve weed management in
these systems, particularly late in the
VHDVRQ

Cotton. Cotton yields (table 5) were
low in all systems in 2000 due to a
devastating infestation of mites that
persisted all season, exacerbated by
likely pesticide resistance problems
that developed with repeated miticide
DSSOLFDWLRQV ,Q
\LHOGV ZHUH VLJQLÀFDQWO\
LQ ERWK FRQVHUYDWLRQ
7KH 67&& V\VWHP ZDV F
WKH &712 V\VWHP LQ
DQG :KHQ WKH
WKURXJK LV DYHUDJHG
system yielded 276 pounds more cot-
WRQ OLQW WKDQ WKH &712
While plant populations in these sys-
tems were similar, lower yields in the
&712 V\VWHP PD\ KDYH
reduced early-season crop vigor and a
JUHDWHU LQFLGHQFH RI
ZLWKLQ WKH URZ JUHDWHU
length where no plants emerged) in this
V\VWHP ,Q DGGLWLRQ
may have been due to larger plants with
PRUH EROOV LQ WKH ÀUVW
closest to the main stem on a fruiting

branch), which are typically correlated
ZLWK JUHDWHU \LHOGV
Unlike tomatoes, there seemed to be
no tillage-system-by-cover-crop interac-
WLRQV LQ FRWWRQ 7KH
cover crops consistently had higher
\LHOGV FRPSDUHG ZLWK
Reduced yields in the conservation till-
DJH V\VWHPV DQG WKH
PD\ LQ SDUW EH UHODWHG WR
ties we experienced establishing the
crops in these systems, which resulted in
ORZHU DQG YDULDEOH SODQW
DQG UHGXFHG HDUO\ VHDVRQ
combination of factors may be involved,
however, as prior UC studies of cotton
yield responses to plant population
would not predict yield reductions at
SRSXODWLRQV VKRZQ LQ
DO)XUWKHU ZRUN
prove our planting, establishment, weed
and nutrient management of cotton in
WKHVH V\VWHPV LV XQGHUZD\

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,Q WKH ÀHOG GXVW FRQFHQWUDWLRQV
total and respirable, measured on till-
age and harvest implements were sig-
QLÀFDQWO\ UHGXFHG LQ
tillage treatments compared to standard
tillage for the 2001 to 2002 period of
PHDVXUHPHQWV WDEOH
analysis showed that dust concentra-
WLRQV IRU &712 ZHUH
RI WKHLU 6712 FRXQWHUSDUWV
cumulative total and respirable dust
measured throughout the 2-year rota-
WLRQ SULPDULO\ GXH WR
operations and to the elimination of the
GXVWLHVW RSHUDWLRQV
VRLO GLVNLQJ DQG
that the systems utilized disking and
power incorporation during land prepa-
ration, and these two operations are the
dustiest of all operations (average of 60
WR SRLQWV UHGXFWLRQ
HDFK GLVNLQJ DQG

SRZHU LQFRUSRUDWLRQ
QW WKH 67012 DVVRFLDWHV
dustiest in-season operation in the stan-
GDUG WLOODJH V\VWHPV
V\VWHP FXOWLYDWLRQ
DOVR FRQWULEXWHG VLJQL
dust reduction in the conservation till-
DJH V\VWHPV 3ODQWLQJ DQG
operations, which cause little soil distur-
bance, produced similar amounts of dust
LQ DOO WUHDWPHQWV
7KH WRWDO DQG UHVSLUD
VRLO IRU 6712 DQG 67&&
ZHUH UHVSHFWLYHO\
ÀHOG RSHUDWLRQV 7KH &7
produced about twice as much total
DQG UHVSLUDEOH GXVW
DQ LQFUHDVHG QXPEHU RI
tions to manage the cover crop and
an increased organic fraction in the
GXVW %DNHU HW DO
PHDVXUH 30 DQG 30
matter with aerodynamic diameters
RI DQG —P UHVSHFWLYHO\
WLRQV GRZQZLQG IURP RXU
the effects of the conservation tillage
systems on ambient air quality in rela-
WLRQ WR 8 6 (QYLURQPHQWDO
Agency standards are not completely
FOHDU +RZHYHU RXU GDWD
comparisons of the relative dustiness of
WKH GLIIHUHQW SURGXFWLRQ V\VWHPV
to assume that reduced dust measured
at the implement level would translate
to reduced ambient dust if conserva-
tion tillage practices were adopted
ZLGHO\ $W WKLV SRLQW
whether the reduced dust in conserva-
tion tillage treatments is due solely to a
UHGXFWLRQ LQ WKH ÀHOG
tions, or if it is also related to changes in
soil properties such as aggregation and
VRLO RUJDQLF PDWWHU FRQWHQW

Transitioning to CT

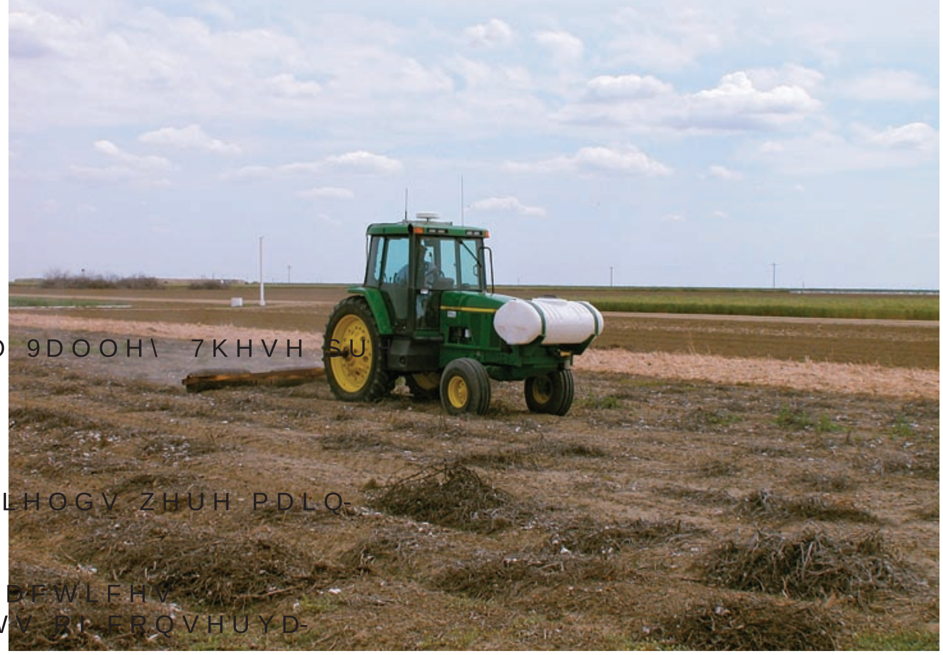
Our results indicate short-term
outcomes and issues associated with a

conversion to conservation tillage production in an irrigated region such as &DOLIRUQLD·V &HQWUDO 9DOOH\ 7KHVH SUH-liminary results suggest that establishing and harvesting processing tomatoes and cotton with conservation tillage is possible given some equipment modi-ÀFDWLRQ ,Q WRPDWR \LHOGV ZHUH PDLQ-tained or even slightly improved with conservation tillage compared with VWDQGDUG WLOODJH SUDFWLFHV

7KH QHJDWLYH LPSDFWV RI FRQVHUYD-tion tillage systems on cotton yields were more problematic during the FRXUVH RI WKLV VWXG\ QXPEHU RI SRV-sible constraints to the adoption of these high-residue production systems ZHUH REVHUYHG GXULQJ WKLV LQLWLDO period and these require further inves-WLJDWLRQ)LUVW WKH accumulation of large quantities of crop residues on the soil surface may eventually present problems in terms of planting, cultivating and harvesting both WRPDWRHV DQG FRWWRQ cultivating tomatoes took more time in WKH &7&& SORWV UHODWLYH WR WKH VWDQGDUG till systems, in part due to the need to GHDO ZLWK UHVLGXHV

Second, although we did not quantify the actual amount of residue picked up by harvesting equipment, it is possible that high surface-residue systems may result in greater "material other than to-PDWRHVµ EHLQJ KDUYHVWHG ZKLFK ZRXOG ultimately require increased cleaning ef-IRUWV DQG SHUKDSV H[SHQVH

7KLUG DOWKRXJK ´]RQH SURGXFWLRQµ theory might suggest that soil compaction constraints may, to a large extent, be avoided by keeping tractor traf-ÀF DZD\ IURP ´FURS JURZWK]RQHVµ 5HFKHO HW DO ORQJHU WHUP VWXGLHV that investigate the implications of reduced till on compaction zones in a bed V\VWHP DUH QHHGHG $Q DGGLWLRQDO DUHD of study worthy of evaluation is the determination of fertilizer application PHWKRGV XQGHU FRQVHUYDWLRQ WLOODJH 7KH DGHTXDF\ RI WKHVH DSSURDFKHV LQ meeting crop requirements will need to be determined for more soluble nutrients (such as nitrogen), as well as for OHVV PRELOH RU KLJKO\ À[HG QXWULHQWV VXFK DV SKRVSKRUXV DQG SRWDVVLXP



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Finally, this transition-phase study KDV LGHQWLÀHG LPSRUWDQW SUREOHPV ZLWK FRWWRQ SURGXFWLYLW\ DQG SURÀWDELOLW\ LQ FRQ-servation tillage that will need to be DGGUHVVHG DQG LPSURYHG $FKLHYLQJ UR-bust and vigorous cotton stands and developing reliable fertility and fertilizer application programs for conservation tillage are important areas that need IXUWKHU DWWHQWLRQ

7KLV VWXG\ ZDV WKH ÀUVW RI LWV NLQG LQ California to systematically compare tillage system alternatives through DQ DJURQRPLF ÀHOG FURS URWDWLRQ 7KH extent to which such alternatives are adopted in this region will ultimately depend on: yield impacts, true input FRVWV DQG KRZ WKHVH DIIHFW SURÀWDELOLW\ equipment costs for alternative systems; decisions about weeding; the management of insect and disease pests over time; and possibly, whether processors DQG XOWLPDWHO\ FRQVXPHUV ÀQG VXIÀ-cient value in these types of production approaches to provide cost offsets to WKH SURGXFHUV IRU WKHLU DGRSWLRQ

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We gratefully acknowledge the help of the California Agriculture *Associate Editors and the anonymous reviewers of this manuscript, as well as staff at the UC West Side Research and Extension Center in Five Points: Ed Scott, Jaime Solorio, Rafael Solorio, Tracy Waltrip and Center Director Bob Hutmacher.*

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