

:DVWH LPPRELOLJDWLRQ DQG HQYLURQPHQWDO VX
JODJHV GHYHORSPhQW

0 5HEHQ 0 .RVPDO 1 3DFJ\ VND^D DQG 3IEKQDFJ\N

\$*+ 8QLYHUVLW\ RI 6FLHQFH DQG 7HFKQRORJ\)DFXOW\ RI 0DWHULD0V 6FLHQFH DQG &H
,QVWLWXWH RI &HUDPLFV DQG %XLOGLQJ 0DWHULD0V 'LYLVLRQ RI *ODVV LQ &UDFRZ /

\$EVWUDXHWFXUUHQW ZRUN LQYHVWLJDWHG WKH IRUPXODWLRQ RI JODJHV XV
JODVV SRZGHU PL[HG ZLWK EDVDOW NDROLQ DQG RWKHU DGGLWLYHV 1HZ
LPSURYH WKH PHFKDQLFDO DQG FKHPLFDO SURSHUWLHV RI IDVW ILUHJ JO
UHVLVWDQFH WR DEUDVLRQ

,QWURGXFWLRQ

3 .HWERRQUXDQJ VWXGLHG WKH SRV
VROLG ZDVWH 06: VRGD OLPH VLO

*ODJHV FDQ EH GHILQH G DV D VWUDXHWFXUUHQW ZRUN LQYHVWLJDWHG WKH IRUPXODWLRQ RI JODJHV XV
WR FHUPLF HDUWKHQZDUH DQG TRUPHUUORZHWG DQHE ARFBRRILQJWU
R[LGHV RU PLQHDOV DSSOLHG WRGLPHOHGGRRIGWKH@VXKIDFHKQGHU
RI FHUPLF REMHFWV 7KH ODUJHUHQFFUOHQJFLXO GHWDZQLFRUZWLOHQRW
ZLWK LPSURYHG DQG DGYDQFHG ESURSHO DOWRVXIFEXPM WKKH VWUHV
UHVLVWDQFH WR DEUDVLRQ KLJKHUFKDDGLFHJVDJWRZHODVORVHIGXQ
SRURVLW\ DQG LPSURYHG FKHPLDQG SURSHUWLHV LVRBERHYUHQKHU
> @ JODVV FHUPLF JODJH PXVWFSDXHWGZKISEKH EXUPRUH IRULD QXLVDQ
ZKLFK LV WHFKQLFDOO\ DQG FRPHXVFLRQO WKRP SDXISROH ZRWKWKLV
WKH IDEULFDWLRQ FRQGLWLRQVWRUPRPSR VXWLRQLDQLGXMHFULRO &
SURGXFWLRQ ZKHUH JODJHV VKRXOGHWRREWRRHQJODJHIDRREWVWLHU
ILULQJ SURFHVV 'HQVLILFDWLRQKLVHDFYKLUHQFHGEWVQQWSDIEWJRIWK
LQ WKH SUHVHQFH RI D YLVFRXV SORZSDXWWDHUPSHUFRPSXUHVGVOLWKKWQH
KLJKHU WKDQ WKH JODVV WUDQNLWYRQZLVQHPSHFUDMRQINQRZIQ DV W
UHVXOWLQJ LQ D FRPSDFW OD\RU QHDOEDIEBHLRP SRUVRQLWXP JO
'XULQJ IDVW ILULQJ SURFHVV DQGLKHWQHFN\VDVOLLERWLQRIZKL
RFFXUV ,W UHVXOWHG LQ WKH DQGLFUDQDEVRUREFG\YWDQOUDGLDQVRC
LQ JODJH REWDLQH > @ ORUHQYHUHWKQVSKRVSFRPSRQLRQJODVV
DQG VWUXFWXUH GHYHORSPhQRXQGDHJOMAKHWKHWHWLUHQHFDHWHVU
DUH YHU\ LPSURXODQW VDWLFWORUHFRVHUPSHVFLILF JODVV FRPSRV
LQ WKH OLQHDU H[SDQVLRQ FRHILFOLHQW LQI WKKH JODVV GLXFGXLRV
7KH JUHDWHU WKH GLIIHUHQFH RIQFRQMDVKHURDOGRPSHQWLLRQJODVV
RI WKH FHUPLF VXSSRUW DQG WKHUXQJHG WKKHIDVWVWUHVWHHWVHQ
ZLOO DSSHODJH> @XVSHQVLRQV DUHFEXORVHGRQWKHOBWKHU KDQ
RI GLIIHUHQWVSHUVRQVWZFKDWH SRPDVQLXDFWXUHV RI &57 JODV
QRQ SODVLFGLWLYHV 3ODVWLF@PDKHUXDVRILQ50XGH OHW DV D
FOD\V H J NDROLQ DQG EHQRQLQVZHQGHQVQKSDQRQSDVWVFSU
PDWHULDOR[ERGLVSWJRHWV IHGSRSDVLDQDQGQILWMDWLYH DV LW ZL
7KH DGGLWLYHV DUWKHGHVLRQJRSRFRHWDLQDEOH GHYHORSPhQW F
DUH GLVSHUVLQJ DQG GELORFXQDQWLQGLDWHZVQ HQKDQFH WK
DQG GHIDPHQWV @RWHQWLDQDQGLDSDRFLQJWDLQ WKH HQYLURQPH
QDWXUDO FRPSRQHQWV LQ FHUPLFV JODJH SURGXFWLRQ
ZLWK ZDVWHV LV ZHOOGFRFXPHQWHG LQ OLWHUDWXUH > @
5HSODFLQJ IOXJHV ZLWK FXOOHW KDV EHHQ UHSRUWHG LQ <RXVVHI
DQG 7DUYRUQSDQLFK > @

^D&RUUHVSRQGLQJ DXWKRU QDWDOLD SDOFJ\QVND#ZS SO

([SHULPHQWDO 'HWHUPLQDWLRQ RI ZDWHU DEVRUSW
RI WKH WRWDO S :DWHU VDWXUI
7KH FKHPLFDO FRPSRVLWLRQV RI V&T JOD]HV JOD]HV JOD]HV WKH
EDVDOW ERURVLOLFDWH JODVV LQGLQHG ZDWHU DZHD SUHMHG WKH GL
LQ WDEOH &KHPLFDO FRPSRVLWLRQV RI JOD]HV JOD]HV JOD]HV WKH
LQ WKLV H[SHULPHQW ZDV DQDO\VLV WKH ELTXLQ ZDWHU VFKROHV \$IWHU
;5) ZLWK XVH RI VSHFWURPHWHU ZLWK H[S]DQVLRQ;
3\$DO\WLFDO 7KH WKHUPDO OLQHDU H[SDQVLRQ FRHIILFLHQW
ZDV PHDVXUHG RQ WKH EORFNV SUHSDUHG IURP WKH SRZGHU
JOD]HV DQG IULWV MXVW DV VKRZ LQ WDEOH DQG 7KH GLODWLRQ
RI WKH PDWHULDOV ZDV PHDVXUHG XVLQJ GLODWRPWHU %DKU
7KHUPR \$QDO\VLV / / *HUPDQ ZLWK D KLDMXLOOHU ZDV XVHG LQ
. PLQ7KH NLQG RI FUI\WDOOLQH SKDVHV ZKRVK ZHOOH FRPSRVLW
IRUPHG YLD WKH WKHUPDO WUHD\PHQW WLVXWHH WKH QLVWDOO IHG
DW WKH WHP SHUZHWHU H[DPLQHG EGH' LQHG DQG DV D SDUWLDO VX
PHWKRQ ZLWK XVH RI 3KLOLSV ; FRPSRVLWLRQV LQ FWRPHWHU JOD]
ZLWK &XJGLDWLRQ VRXUFH 7KH PRGSRQV LQHO JODVV LV D W
RI FUI\WDOOLQH SKDVHV GHYHORS LQGHEDUJPHV QILUQRWL
ZHUH H[DPLQHG E\ VFDQQQLQJ WHPFRWRO\WLFDO VFRSHWK D ORZ PH
6(0 1RYD 1DQR 6(0)(&RPSRQZ VFDWHQV DQG WUDQVLWLRQ V
ZHUH SHUIRUPHG ZLWK DQ DWWDFKPHQW IRU FKHPEDQ DQDQ\WKHUP
RI VSHFLPHQV LQ PLFUR DUHDV ZKRVK H[HQWALV SHUVZKH [KDJK YD
VSHFWURVFRS\ ('\$; 7KH REVHUYDWLRQV ZHUH DQALYHG RQ FRHIIL
RXW LQ ORZ YDFXXP FRQGLWLRQV RQ WKH DORZWR\HGHFKURQLQ
PRGH 7KH VDP SOHV ZHUH FRYHSHU ZLWK RQDFRQJOD]HV FRPSRVL
7KH DEUDVLRQ UHVLVWDQFH ZDV GHWHUPLQHG RZFRVGDQJ GH
WR WKH (1 ,62 VWDQGDUG RZPHWRQKH\$SUVH RQH RI NDROLQ
WHVW ZDV EDVHG RQ D YLVXDOW\WLFHQW\RI MKDQHMHFW EXV
LQ WKH JOD]HG VXUIDFH DQGD ZKHUHQ WKH RQ WDWLRQ DQZ PD
PRYHPHQW PRYLQJ WKH VKHDULQW RQ RQ D VHWWHU DJUHHPHQW
WLPHV LQ FRPSDULVRQ ZLWK WKH ERXU\DFHWRWKW\WLFH FRHIILFLHQW
GLIHHUHQW IRUPXODWLRQV XVLQJ &5
UDQJLQJ LQ ± DQG ± ZW U
SUHSDUHG ,W SHUPLWWHG WR RE
FKDUDFWHUL]HG E\ WKH E\ D ORZH
FRHIILFLHQW)AJ

)LXUH70\$ H[SDQVLRQ FXUYHV RI VWXGLHG JOD]HV

5DZ PDWHULDOV IRU WKH SURGXFWLRQ RI JOD]HV ZHUH
VKUHGGHG DQG PL]HG WKHQ PLOOHG LQ D SRUFHODLQ EDOO PLOO
7KH UDZ PDWHULDOV ZHUH ZHW PLOOHG IRU PLQXWHV
DQG WKH PLOOLQJ WLPV ZDV FKR VHQ H[SHULPHQWDOO\ WR REWDLQ
H[SHFWHG VLHYH UHVLGXH RI OHVVWKDQ H[SDQVLRQ UHVLGXH
PL]WXUH ZDV DSSOLHG WR D FHUDDLQ WLOH E\ KDQG DQG KHDWHG
DW D UDWH RI XS WR WKH ILU&QJ WHP SRQV SUHSDUHG FRQWDLQV
7KH HQWLUH ILULQJ F\FOH ODVWHG YXEV\WLVXWHG RQV E\ W&5 JOD]V
ZHUH FRROHG ZLWK WKH IXUQDFR ERFDPHW WKXPWH RZREWDLQ JOR
H[DPLQHG YLVXDQO\ LQ WHUPV RI VXUIDFH GHYHUVLVXUHV ZDV GH
VPRRWKQHVV DQG JORVV)RU WKH GHWHUPLQDWLRQ WKH EDVLF
SK\VLFDQ DQG FKHPLFDO SURSHUWLHV VSHFWURPHWHU JOD]HV ZW
WKH ZDWHU DEVRUSWLRQ DQG DEUDVLRQV LQ WDEOH JOD]V DQG W
'HWHUPLQDWLRQ RI ZDWHU DEVRUSWLRQ ZDV H[SDQVLRQ FRHIILFL
DFFRUGLQJ WR WKH PHWKRQ GHYHUVLVXUHV LQ WKH VWDQGDUG ZW
>31 (1 ,62 &HUDPLQ WLOH VURVLOLFDWH JOD]V)LJ

7DEOH7KHPLFDO FRPSRVLWLRQ RI JODJHV FRPSRQHQWV >ZW @

&RPSRQHQW	W&57 JODVV	FXOOHW)HOGVSDU)ORDW %ODVV	FXOOHW
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&D2					
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7DEOH7KH FRPSRVLWLRQV RI JODJHV GHVLJQHG

7KH FRPSRVLWLRQV RI GHVLJQHG JODJHV >ZW @						
6\PERO RI &57 JODJHV	JODVV FXOOHW	*ODVV)HOGVSDU)ORDW FXOOHW	JODJHV %ODVV	WULQJ SDUDPHWHUV DQG DSSHDUDQFH
						°& K ODWW JODJHV
						°& K *ODJHV ZLWK JORVV

%RURVLOLFDWH JODVVHV DUH NQRZQ IURU WKH JODJHV FRPSRVLWLRQV
 FRHIILFLHQWV RI WKH JODJHV RI WKH JODJHV RI WKH JODJHV RI WKH JODJHV
 PDNLQJ WKHP UHVLVWDQW WR WKH JODJHV RI WKH JODJHV RI WKH JODJHV
 RWKHU FRPPRQ JODVV > @ % \ RI WKH JODJHV RI WKH JODJHV RI WKH JODJHV
 %2 FRQWULEXWHV WR WKH GHQVH RI WKH JODJHV RI WKH JODJHV RI WKH JODJHV
 PDNLQJ WKHP PRUH FKHP LFDOO \ UHVLVWDQW)LQ WKH SUHVHQW
 7KH WHQG HQF \ WR FU \ VWDOOL]DWLQJ WKH JODJHV RI WKH JODJHV RI WKH JODJHV
 7KH NLQG RI WKH FU \ VWDOOL]DWLQJ
 E \ WKH ;5' WHFKQLTXH 7KH ;5' SDWV

ILUHG DW UHYHDOHG WKH SUHVHQFH RI D WKUHH
 FU\WDOOLQH2SKDVH6DQGLQH -&3'6
 1R 6L2 6LOOLPDQLWH -&3'6
 1R DQ612%D\$3DUDFHQVLDQ
 -&3'6 1R 7KH LQWHQVLRW\ RI OLQHV
 FRUHVSRQGLQJ WRG6L261SKDVHV
 DUH QDUURZ LQGLFDWLQJ WKH H[LVWHQFH RI ZHOOGHYHORSHG

FU\WDOV)LJ

)LJXUH5' SDWWHUQ RI JODJH QR DIWHU ILULQJ DW
 7KH DSSHDUDQFH RI QRW VLLQLILFDQW DPRXQW RI %D\$O
 FDQ EH H[SODLQ E\ LWV DQ H[WHQVLYH SROLPRUSKLV > @
 8QGHU ;5' WKH FU\WDOOLQH SKDVHV LQ JODJH ZHUH
 QRW GHWHFWHG HQDEOHV XV WR FRQFOXGH WKDW JODJH PRVW
 SUREDEO\ EHLQJ DPRUSKR XV)LJ

)LJXUH6(0 SKRWRJUDSK DQG ('6 DQDO\VLV
 WKH DQDO\VLV SHUIRUPHG LQ SRLQW

6(0 DQDO\VLV GLG QRW VKRZ DQ\ FU
 UHYHDOHG PRUH &D DQG 1D FRQWHQ
 LQ WKH JODJH FRPSRVLWLRQ 7KH UH
 WR PHFKDQLFDO GDPDJH UHVXOWL
 RI WKH DEUDVLYH IDFWRU ZDV WHVW
 LQWR DEUDVLRQ UHVLVWDQFH JUDG
 QXPEHU RI URWDWLRQV RI WKH GHY
 RI WKH JODJHG WLOHV DIWHU ZKLF
 RI DEUDVLRQ EFRPH YLVLEOH %DY
 WKH JODJH LV DVVLJQHG WR WKH FC
 DQG JODJH QXPEHU RI UR
 WR WKH FODVV *ODJH FDQ EH
 IRU IORRULQJ LQ GRPHVWLF KRXLQJ
 DQG QRUPDO IRRWZDUH ZKHU VPDC
 RFDVVLRRQDOO\ EH FDUULHG RXW *C
 IRU PRUH IUHTXHQW SHGHVWULDQ W
 DEVRUSWLRQ DUH SUHVHQWHG LQ 7D

)LJXUH;5' SDWWHUQ JODJH QR& DIWHU ILULQJ DW
 0RUSKRORJ\ RI JODJH &DQGLQH2SKDVH6DQGLQH
 E\ 6(0 VKRZV VPRRWK VXUIDFH ZLWK YHU\ ILQH FU\WDOV
 RQ WKH VXUIDFH DV VKRZQ LQ)LJXUH N6Lm\$0 DQG . ZHUH (1)
 WKH PDMRU HOHPHQWV DQDO\JHG E\ ('6 7KDW FRQVLVWHQW
 ZLWK WKH UHVXOWV RI SKDVH DQDO\VLV E\ ;5' WKDW VKRZV
 FU\WDOOLQH2SKDVH6DQGLQH2SKDVH6DQGLQH2SKDVH6DQGLQH
 DPRXQW 612%D\$3DUDFHQVLDQ)LJ *ODJH PDVVLRQ WKH GULHG VDP SOH > J@
 DW °& VKRZV JODVV\ VXUIDFH)LJ PDVV RI WKH VDP SOH VDWXUDWHQ

7DEOHDWHU DEVRUSWLRO

7\SH RI1XPEHU :DWHU :DWHU VDPSOHVLOHV DEVRUSW DEVRUSW DYHUDJH			
*OD]H			
*OD]H			

&RQFOXVLRQ

7KH DLP RI WKH VWXG\ ZDV WR VXBWUHQV ZDWHU DQGHQWURPDQRXFW
SRLQW RI YLHZ WKH UHF\FOLQJ YDOLJLWV IRU QGWHU FDZDZDWHULDO
VXFFHVIXOO\ H[SHULPHQWV WKH WKH &57 SDQHO JODVV
FHUDPLF LQG XVWU\ &57 FXOOHW XVHG DV D UDZ PDWHULDO LQ
JOD]H IRU ORZ ILUHG SURGXFWV ZHUH UHQGHV
JODVV UHF\FOLQJ *OD]HV IRU ORZ ILULQJ DUHD ZLWK ILULQJ
WHPSHUDW\ &XVHG XWR ZW &57
SDQHO JOD]H GHOVWLIWQLWLRQQLW SHUFHQWV *OD]H
LV UHODWHG WRIW\RLSSQJ VHQHQVLYV OXVPH
FUDFNLQJ EXEOLQJ ORUHRYHU WKH DQGHQWURPDQRXFW

WRZDUG WKH WKHUPDO H[SDQVLRQ
WR EH HOHYDWHG 7KH UH PRGXODW
LQ IRUPXODWLQJ WKH JOD]H FRP
IXQGDPHQWDO WR REWDLQ DFFHVS
SDUDPHWHU 7KH PDWW DQG DPRUSK
YHU\ VLPLODU WR RULJLQDOV QRW F
RQ WKH VXUIDFH DEUDVLRQ WHVW
WKH LQWURGXFWRQ RI &57 SDQHO J
PHHWV WKH RHTXLHUWPDQRXFW SURG
UHVHDUFK FRQGXFWHG KDYH EHHG
IRU WKH VWXG\ ZLWK WKH HQYL
RI WHFKRORJLHV IRU WKH SURGXF
DQG ZRUWULEXWH WR WKH UDWL
SSWKZDWHU DQGHQWURPDQRXFW
YDOLJLWV IRU QGWHU FDZDZDWHULDO
WKH WKH &57 SDQHO JODVV
ZHUH UHQGHV
ILULQJ DUHD ZLWK ILULQJ
5DVVWHLUR 7 *DVPDQ 5 6D
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:DVDQDSLDUQSRQJ 3 6XMDULC
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6HULHV 0DWHULDOV 6FLHQFH DQ

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\$QGUHROD / %DUELHUL (.DUDP
0 3HOLQR &HUDP± ,QW
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&DQQLOOR 7 0DQIUHGLQL 0 0RQ
\$ 6ROD 0DWHU (QJ
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7VXQJ 6KXQH &HUDP ,QW

)LJXUH(0 SKRWRJUDSK DQG ('6 DQDO\VLV RI JOD]H
WKH DQDO\VLV SHUIRUPHG LQ SRLQW