

5LFH 5HVH DUFK 2SHQ \$FFHV 2NSDOD HW DO - 5LFH 5HV

5HVH DUFK \$UWLF OH

20, & 6 , QWH

&RPSDULVRQV RI &RRNLQJ DQG (DNLQJ & XQDQ)

1QDHPND (PPDQXHO/2NSDOD) RDQ 6KHX TXDQ = DQJ; LDRTXDQ 4L
.H\ /DERUDWRU\ RI 3ODQW 0ROHFXODU 3K\VLRRJ\ ,QVWLWXWH RI %RWDQ\ &KLQHVH \$FDGHP\ RI 6FLHQF
8QLYHUVLW\ RI &KLQHVH \$FDGHP\ RI 6FLHQFHV %HMLQJ &KLQD
\*XDQJGRQJ .H\ /DERUDWRU\ RI 3ODQW 0ROHFXODU %UHGHLQJ &ROOHJH RI \$JULFXOWXUH 6RXWK &KLQD
&RUUHVSRLQGLQJ JUDQXOH PRUSKRORJ\ ;LDRTXDQ 4L .H\ /DERUDWRU\ RI 3ODQW 0ROHFXODU 3K\VLRRJ\ ,QVWLWXWH
(PDLO [TL#LEFDV DF FQ
5HFHLYHG GDUHFK \$FFHSWHG GDUHFK 03XEOLVKHG GDUHFK
&RSULJKW 2NSDOD 1( HW DO 7KLV LV DQ RSHQ DFFHV DULFOH GLVWULEXWHG XQGHU WKH WHUPV RI
XVH GLVWULEXWLRQ DQG UHSURGXFWRQ LQ DQ\ PHGLXP SURYLGHG WKH RULJLQDO DXWKRU DQG VRXU

\$EVWUDFW
7KH FRRNLQJ DQG HDWLQJ TXDOLWLHV RI ULFH DUH VRPH RI WKH SUREOHPV I
DURXQG WKH ZRUOG ,Q WKLV VWXG\ ZH LQYHVWLJDWHG WKH FRRNLQJ DQG HDWL
%RWK DUH ULFH FXOWLYDUV ZLWK GLIIHUHQW SKHQRW\SLF WUDLWV
7KH UHVXOWV VKRZ WKDW %DVPDWL LQFUHDVHG E\ DQ DYHUDJH RI DIW
LQFUHDVHG E\ DQ DYHUDJH RI DIWHU FRRNLQJ %DVPDWL KDG D SDVWLQJ
;LDQ KDG D SDVWLQJ WHPSHUDWXUH RI f& +RZHYHU +XD -LQJ ;LDQ KDG D
%DVPDWL KDG D ILQDO YLFRVLW\ RI F3 7KH DP\ORVH FRQWHQWV RI WKH
-LQJ ;LDQ KDG DQ DP\ORVH FRQWHQW RI ZKLOH WKDW RI %DVPDWL ZDV
VWDFK JUDQXOH PRUSKRORJ\ RI WKH WZR FXOWLYDUV ZHUH UHPDUNDEO\ GLIIHU
7KH ORZHU SDVWLQJ WHPSHUDWXUH RI %DVPDWL SRVLWLYHO\ FRUUHODWHG Z
+XD -LQJ ;LDQ DSSHUV WR KDYH UHODWLYHO\ EHWWHU HDWLQJ TXDOLWLHV G
FRQWHQW ,W ZRXOG EH SHUWLQHQW WR GR PRUH UHVHDFK DERXW K\EULG OLQH
%DVPDWL WR VHH LI WKH\ SRVVHV WKH JRRG FRRNLQJ TXDOLWLHV RI %DVPDW
-LQJ ;LDQ

.H\ZRUOG &RRNLQJ TXDOLWLHV (DWLQJ TXDOLWLHV) W\ D RPDWLFH TXDOLWLHV LQFOXGH
;LDQ HDWLQJ TXDOLW\ DQG QXWULWLRQDO TXDOLWLHV
&RRNHG ULFH HORQJDWLRQ ZDWHU DEV
\$EEUHYLDWLRQ %DVPDWL F3 &HQWL SRVLWLY\ WHPSHUDWXUH DUH VRPH RULJLQ
;LDQ UHSUHVHQW WKH FRRNLQJ DQG HDWLQJ
VWXG\ ZDV L QLRGLHO\ FRRNLQJ DQG HDV
EHWZHHQ +XD -LQJ ;LDQ DQG %DVPDW
LQFOXGLQJ FRRNHG ULFH HORQJDWLRQ O
5LFH JUDQXOH PRUSKRORJ\ ZDQJ DP\ORVH FRQW
DQG LV D VWDSOH IRRG IRU RYHU KDQJUDQXOH PRUSKRORJ\ SDVWLQJ WHPSHUDWX
FRPPHUFDO ULFH FXOWLYDUV VSRIHULWKHU
DQG WKHVH VXEVSRIHULWKHU WHPSHUDWXUH
DQG SK\VLRRJLFDQ WUDLWV > @ ,Q FRXOWULHV ZLWK KLJK KXPDO SRSXODWLRQ
OLNH &KLQD DQG ,QLD ULFH LV FRQVXPHG GDLO\ LQ D YDULHW\ RI ZD\ 5LFH
LV WKH PRVW ZLGHO\ FXOWLYDWHG FURS LQ &KLQD 5LFH SURGXFWLRQ LQ ,QLD
KDV LQFUHDVHG UHPDUNDEO\ LQ WKH 5LFH HDV DQG QRZ UHSUHVHQW
DSSUR[LPDWHO\ RQH WKLUG RI WKH JOREDO ULFH SURGXFWLRQ > @ 5LFH LV DOV
VWDSOH IRRG LQ \$IULFD ZKHUH LW LV FXOWLYDWHG ZLGHO\ ZLWK D VWXG\
LQFUHDVH LQ FRQVXPSWLRQ VDPH FRQGLWLRQHLWHSUWDLHWHLV DUH %
\$V KRXXVKRQG LQFRPHV LQFUHDVHV ULFH; FRQVXPDW\ DUH KLJK RPDQGLDULFMLH
ZLWK EHWWHU FRRNLQJ DQG HDWLQJ TXDOLWLHV 5LFH JUDQXOH PRUSKRORJ\
LPSRUWDQW FRQFHUQ IRU ULFH EUHHGHUVH SURGXFWLW\ DQG FRQVXPSWLRQ
WKH ZRUOG > @ ,PSURYHPHQW RI JUDQXOH PRUSKRORJ\ LV DQ DLP RU PRVW ULFH
EUHHGHUVH FRPPHUFDO YDOXH RI ULFH > @ ,QFUHDVHG
SURGXFWLWLRQ ULFH LV QHHGHG DOO\ RYHU WKH ZRUOG QRW MXVW
EHFDXVH RI WKH LQHYLWDEOH HSDQVLRQ RI WKH KXPDO SRSXODWLRQ EXW DOV
EHFDXVH RI WKH SURMHFWHG HGHPDUNDEO\ WUDLQDEOH SURSDUWULHV RI +XD -LQJ ;LDQ

6LQFH SDUW RI WKLW V WXIGR VZDW DUF KXVHSQXO HW KHV H[SHULPHQW \$V DOO VROY  
PRUSKRORJ\ RQ WKH SDVWLQJ WHPSHZBWXZHRO \$MBVHLQYHGLDQ ULQDQGH WKHU  
%DVPDWL ZH GHFLGHG WR DG VWRW HLJKW YDULHWLHV WR VWXG\ WKH  
RI VWDFK JUDQXOH PRUSKRORJ\ RQ WKLW SDY SLRSHUPLHV

'HKXVNLQJ PLOOLQJ DQG SXOYHULL 3DVWLQJ SURSHU\ DQDO\VLV ZDV FDU  
7HF0\$67(5 LQVWUXPHQW P/ RI GLVWLOO

:KROH DQG PDWXUH JUDLQV RI WHQ YDURSHUHLFDZHVWHGHG&XVNHU GVRVDQGLQQJ J  
\$R /LDQJ <RQJ 4L &DL &KDQJ -/\*- GH WKXVNFIDRPLQVWQMPH \$QVHSJUDGON ZDV SODFH  
WKDW JRW EURNHQ GXULQJ WKH SURFHVV ZHUH GLVFDUGHG DV ZHUH LPPDWXUH  
JUDLQV :KROH DQG PDWXUH GHKXVNHU G V D Q L Q J L Q H F A H U R Q P P O U R V F R V K 6(0  
7DL}KRX -LQJ \$R /7-0 PLQDMLFVDFKLRJHPLOOLQJ

ZDV WR UHPRYH ULFH EUDQ ZKLFK FRQVLPVWRPQWKY ZDV GRRH ZLWK BHLWDFK  
WLVVXHV 5LFH JUDLQV ZHUH DOO PLOOHG 5LFH JUDLQV ZHUH FHWG ZLWK WKU PDDQGHDFDV  
VROXWLRQ DQG ZHUH VSXWWHU FRDWHG  
0LOOHG ULFH JUDLQV ZHUH SXOYHULL 5LFH JUDLQV ZHUH FHWG ZLWK WKU PDDQGHDFDV  
H IUHTXHQF\ ZDV VHW DW VHF DQG WKH JUDLQV ZHUH PLOOHG IRU  
VHF 1RWH WKDW WKH 5LFH JUDLQV ZHUH PLOOHG IRU JUDQXOH PRUSKRORJ\ RI HDFK  
WKH VDPSOHV DWVHXDQYHGLRQ

&RRNHG ULFH HORQJDWLRQ

&RRNHG ULFH HORQJDWLRQ ZDV KHUHFHWXSWWHQHG DV FVKKHLRQ  
EHWZHHQ WKH OHQJWK RI JUDLQV PLOOHG EHIRUH DQG  
GHWDLOHG FRRNLQJ SURWRFRQ EHORZ &RRNHG ULFH HORQJDWLRQ  
SUHFLVLRQ LV YHU\ FUXFLDO WKHUH RUHD OLFURWHN 6FDQDQHU L VFDQQUH  
ZDV XVHG WR PDNH DOO RI WKH OHQJWK PHDVXUHV PLOOHG IRU DQYDU > @ DQG %DVP  
LQGHQWLYDU > @ 6WXGLHV KDYH VXJJHV

5DZ ULFH DQG FRRNHG ULFH PHDVXUH 5LFH ZHUH PHDVXUHGDVUDU EOH ULFH YD

)RU HDFK OLQH JUDLQV RI PLOOHG 5LFH ZHUH PHDVXUHGDVUDU EOH ULFH YD  
ZHUH PHDVXUHGDVUDU EOH ULFH YD  
WUDQVIHUHG WR D 3&5 SODWH FRQW  
JUDLQV ZHUH DOORZHGDVUDU EOH ULFH YD  
ULFH JUDLQV ZDV WKHQ SODFHG LQ D 3  
ZHUH LQGLYLGXDOO\ FRRNHG IRU PLC  
r & H FRRNHG ULFH JUDLQV ZHUH WKHQ  
DQG SODFHGDVUDU EOH ULFH YD  
WHPSHUDWXUH WKH\ ZHUH WUDQVIHU  
ZLWK WKH VFDQQUH \$V ZLWK WKH UDZ  
PHDVXUH VLPXOWDQHRXVO\ WKLW KHO  
FRQWHQW WKDW FRXOG KDYH UHVXOWH  
PHDVXUH FHWG ZLWK WKU PDDQGHDFDV  
RI WKH WKUHH UHSOLFDFWHV

(ORQJDWLRQ RI FRRNHG ULFH

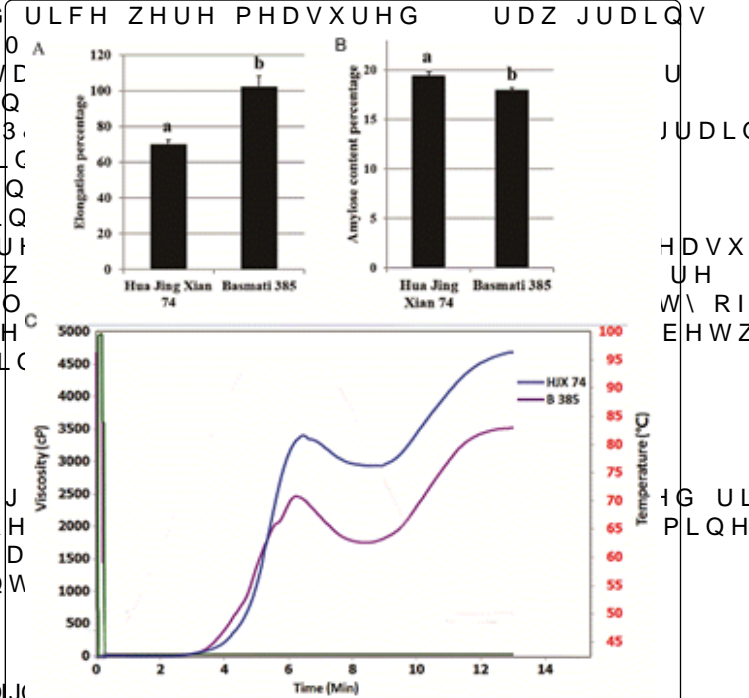
,Q RWKHU WR GHWHUPLQH WKH HORQJ  
IRU HDFK FROWLYDU WKH PHDQ YDOXH  
EHIRUH DORNLQJ JIROORZLQJ IRUPXD  
GHWHUPLQH WKH HORQJDWLRQ SHUFHQW

Elongation (%E) =  $\frac{ACML-BCML}{BCML} \times 100$

:KHU ( LV HORQJDWLRQ SHUFHQW RNDJ  
PHDQ OHQJWK DQG %&0/ LV WKH EHIRUH

7RWDO VDFK DQG DP\ORVH FRQWHQW \$V DVPDWL DQDO\VLV \$P\ORVH FRQWHQW SHU  
DQG %DVPDWL & WKH SURKHUADRILQ

LVH[SHULPHQW ZDV SHUIRUPHG VWULFDQ\ LQ FRSVORLQEH ZLWK WKH  
LQVWUXFWLRQV VWLSXODWHG E\ OHJD\PH LQ WKH LQVWUXFWLRQ PDQXDO IRU  
WKHLU \$P\ORVH \$P\ORSHFWLQ \$VVD\ NLW KRZHYHU 6RGLXP DJLGH ZDV QRW



3DJH RI

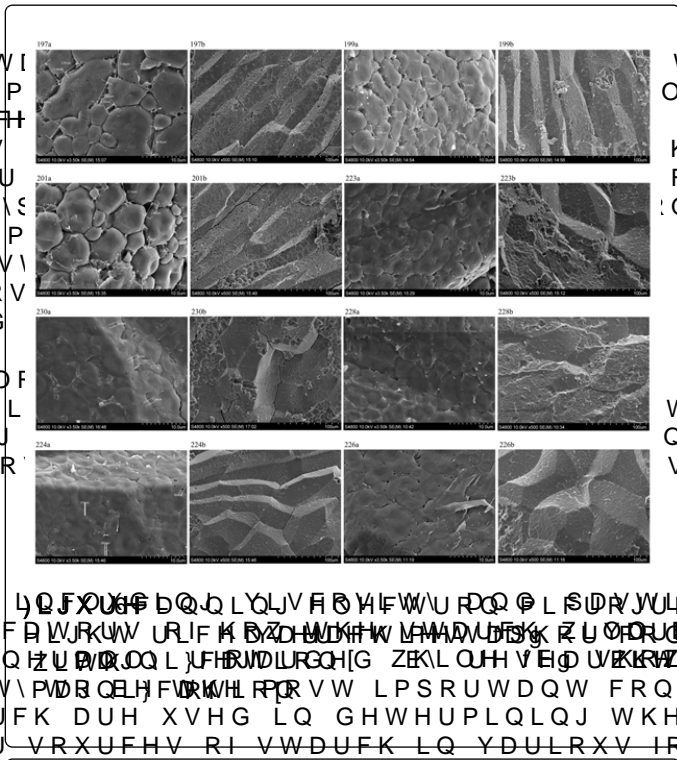
,Q WKLV VWXG\ WKH OHQJWK RI %DVWUDWFK JUDQXOHV PRUSKRORJ\ RI  
ZKLOH +XD -LQJ ;LDQ LQFUHDVHG E\ DQ DYHUDJH RI DV DQG K  
VKRZQ LQ )LJXUH \$ QVLYH HORQJDWLRQ RI %DVWUDWFK JUDQXOHV FRP  
GHVLUDEOH WUDLW PRUH SURQRXQFHG VWUDWFK JUDQXOHV FRP

\$P\ORVH FRQWHQW

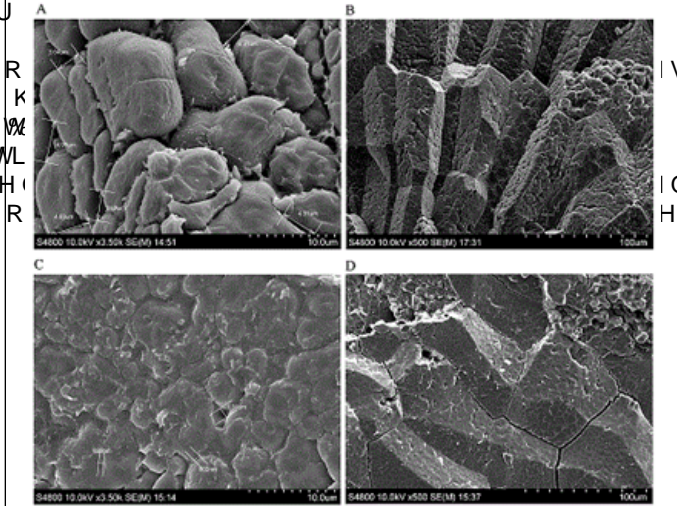
\$P\ORVH FRQWHQW LV DQRWKHU YLWI  
HDWLQJ TXDOLW\ RI FRRNHG ULFH \$P  
UHSRUWHGWR TXDOLW\ RI FRRNHG WLYH  
DP\ORVH FRQWHQW FGDUDFWHULVWLFV  
SRVWXODWHG WR EH UHVSRVLEOH IRU  
WR WUDQVOXFHQW NHUQHOV ZKLFK W  
> @ 5LFH VWUDWFK JUDQXOHV  
ORZ VWUDWFK DP\ORVH ORZ V  
LQWHUPHGLDWH VWUDWFK DP\ORV  
DP\ORVH > @ +XD -LQJ ;LDQ DQG  
VWUDWFK FRQWHQW FDWHJRU\ ZLWK  
UHVSHFWLYHO\ 1RWH WKDW WKH DP\ORV  
KLJKHU WKDQ WKDW RI %DVPDWL )L  
IRU VRPH ULFH FXOWLYDUV ZLWK ORQJ  
6WXGLHV KDYH UHSRUWHG WKDW DP\ORV  
UDQJHG IURP WR > @

3DVWLQJ SURSHUWLHV

3DVWLQJ SURSHUWLHV RI VWUDWFK  
WHPSHUDWXUH DUH LPSRUWDQW LQGLF  
GXULQJ SURFHVVQJ 6WUDWFK LV JHQ  
FRQFHUQHG ZLWK WKH HDWLQJ TXDOLW\  
RI ULFHSDVWLQJ SURSHUWLHV RI VWUDWFK  
VXLWDELOLW\ RI XVH IRU SDUWLFXODU  
RWKHU DOOLHG SURGXFW DSSOLFDWLRQV  
KDV D QDQDORVFRVLW\ RI F3 KLJKHU  
r& FRPSDUHG WR %DVPDWLWLVZLWK  
SDVWLQJ WHPSHUDWXUH RI r& 'XH WR  
IURP +XD -LQJ ;LDQ ZLOO OLNHO\ K  
FRPSDUHG WR IRRG SURFHVVHV SURPLW  
EDVHG RQ > @ ZKR UHSRUWHG WKDW  
FRUHOHWG ZLWK WKH TXDOLW\ RI H  
H[FHOHQW LQGLFDWLRQ RI WKH YLFR  
PL[LQJ FRRNHU



WKH  
O\  
KDV E  
FRPSD  
:QWHQV  
  
LV  
WHG  
QWHQV  
VWUDWFK



IVVHG  
IQVV D  
HUHG E

7HVW 9DULHW\	3DVWLQJ 7HPS f&

)LJXUH FDQQQLQJ HOHFWRQ PLFURJUDSK  
PRUSKRORJ\ RI +XD -LQJ ;LDQ DQG %DV  
ZLW JQL}FBWLRQ[ % %DVPDWQL}FBZLVRQ  
[ & +XD -LQJ PLDJQL}FZLWLQR' +XD -LQ  
;LDQ FZLWLQR}FBWLRQ[

7DEOH SDVWLQJ WHPSHUDWXUH RI HLJKW ULFH FXOWLYDUV



&LWDW2RISDOD 1( 'XDQ / 6KHQ \* =KDQJ \* 4L ; &RPSDULVRQV R,IQ&RIFLHQ &XQV6YDULVQ  
5HV GRL

3DJH RI

3DWLQGRO - \*RQ]DOH] % :DQJ <- }CF&OXQUV\$H \$- 06WDLUFK0 )LW]JHUDOG 0\$ &  
VWUXFWXUH DQG SK\VLFRFKHPLFDO SURSHUWIDHGVHQVSWDULFCWFRPISRHWUWURFDQQGQVWUX  
&HUHDO 6FL &HUHDO &KHP  
3XFKRQJNDYDULQ + 9DUDYLQLW 6 %HUJWKD&QJKU 1 6LQ&RPSDD&WLYH6R&KIG\16 \*LOO  
RI SLOR VFDOH ULFH VWDUFK SURGXFWLRQW&HURDQD&D&G&L&K&H&R&O&R&G&L&F&O&B&Q&H&R&S&H&O&W&I&H&V&D  
SURFHVV 6WDUFK 6WDUNH VRXUFHV )RRG &KHP  
5DJDDH 6 \$EGHO \$DO (60 3DVWLQJ SURSHUWLHV RI VWDUFK DQG SURWHLQ  
LQ VHOHFWHG FHUHDOV DQG TXDOLW\ RI WKHLU IRRG SURGXFWV )RRG &KHP