

# %LRGHJUDGDWLRQ RI .HUDWLQ IURP &KLFNHQ RI 6XVWDLQDEOH 'HYHORSPHQW

-DL \*RGKHM6KHNKDU 6.

'HSDUWPHQW RI %LRWHFKQRORJ\ %DEDVDKHE %KLPUDR \$PEHGNDU 8QLYHUVLW\ /XFNQRZ ,QGLD  
&RUUHVSRLD \*RGKHM6KHNKDU 'HSDUWPHQW RI %LRWHFKQRORJ\ %DEDVDKHE %KLPUDR \$PEHGNDU 8QLYHUVLW\  
MDLJRGKHMD#UHGLIIPDLO FRP

5HF GDWH 6HSSFF GDWH -XQH 3XE GDWH -XQ

&RS\ULJKW ( \*RGKHM6KHNKDU - HW DO 7KLV LV DQ RSHQ DFFHVV DUWLFOH GLVWULEXWHG XQGHU WKH WHU  
XVH GLVWULEXWLRQ DQG UHSURGXFWLRQ LQ DQ\ PHGLXP SURYLGHG WKH RULJLQDO DXWKRU DQG VRXU

## \$EVWUDFW

.HUDWLQ IURP &KLFNHQ RI 6XVWDLQDEOH 'HYHORSPHQW JHUDW LPSRUWDQFH LQ IHDWKHU ZDVW GHJUDGDWLRQ  
RI OLYHVWRFN IHG DQG SURGXFWLRQ RI SURWHLQ K\GURO\VDWHV \$QQXDOO\ V  
GLVFKDUJHG LQWR WKH VXUURXQGLQJ HQYLURQPHQW DV D E\ SURGXFW RI FRPP  
FRXOG PLQLPL]H UHJODWRU\ SUREOHPV RI XQFRQWUROOHG DFFXPXODWLRQ RI Z  
NHUDWLQ ZKLFK LV QRW HDVLO\ GHJUDGDEOH E\ FRPPRQ SURWHRO\WLF HQJ\PHV

7KH SUHVHQW VWXG\ GHDOV ZLWK LGHQWLILFDWLRQ RI IXQJL WGDW SOD\ D VLJQ  
DQG NHUDWLQ GHJUDGDWLRQ DELOLW\ RI WKH LVRODWHG IXQJL )HDWKHU RI EU  
IDUP 0DQGLU +DQXG 5DLSXU )XQJL ZHUH LVRODWHG E\ IHDWKHU EDLWLQJ W  
6RERXUDXG 'H[WURVH \$JDU 6'\$ PHGLXP DQG WKHLU SXUH FXOWXUH ZDV SUHSDU  
SKHQRO FRWRQ EOXH VWDKRGGLRPHQWV DQXG DFFHVV SHUJLOOXV  
)ODYXV 7KH SXUH FXOWXUH ZHUH JURZQ LQ PLQHDO PHGLD ZLWK PJ RI IHDW  
&DUERQ DQG LQFXEDWHG IRU WKH SHULRG RI GD\ \$W GD\ LQWHUYDOV W  
ELRGHJUDGDWLRQ ZDV HYDOXDWHG E\ DQDO\]LQJ WKH FXOWXUH ILOWUDWH 7KH  
PHWKLRLQLH FRPSRQHQWV GXULQJ WKH SURFHVV RI ELRGHJUDGDWLRQ ZDV VWXG  
NHUDWLQ 7KHUH ZDV DOVR D FKDQJH LQ S+XFRW\SHGLXPWRZD\W\W ONDOLQL  
PRVW SRZHUIXO ELR UHPHGLDO IXQJXV LQ WKH FXUHQW VWXG\ :LWK DQ LQFUHDY  
LV SRVVLEOH WR XVH WKHVH VL[ IXQJXV IRU WKH GHJUDGDWLRQ RI HQRUPRXV TXD  
WR UHF\FOH WKH ZDVWHV DQG WXXV PDLQWDLQLQJ WKH HQYLURQPHQWDO TXDQWL

.H\ZRUG)XQJX\LRUHPHGLDWLRQ 3RXOWU\ SURFHVV LQJ .HUDWLQ  
)HDWKHU EDLWLQJ /DFWR SKHQRO FRWRQ EOXH VWDLQLQJ

,QWURGXFWRQ

ZRUOG KDYH EHHQ VXUYH\HG IRU WKH SUHVHQFH RI NHUDWLQRSKLOLF IXQJL > @  
ORVW RI WKHVH IXQJL EHORQJ WR IDPLOLHV \$UWKURGHUPDWDFHDH DQG  
2Q\JHQDFHDH RUGHU 2Q\JHQDOHV LQ \$VFRP\FHWHV > @

0HWKRGRORJ\

0HWKRG RI VDPSON FROOHFWLRQ DQG LVRODWLRQ RI SRWHQWLDO IXQJDO  
FRORQLHV

)HDWKHUV RI EURLOHU FKLFNHQ ZHUH FROOHFWHG IURP -DJJL SRXOWU\ IDUP  
ODQGLU +DVDXG 5DLSXU )XQJL ZHUH LVRODWHG E\ IHDWKHU EDLWLQJ  
WHFKQLTXH )HDWKHUV RI KHQV ZHUH FXW DQG ILQHO\ SRZGHUHG DQG  
VWHULOLVHG E\ XVLQJ VRGLXP K\SRFKORULWH VROXWLRQ IRU PLQXWHV



)LJXUH 6\FHSKDODVWUXP



&XUUHQW DQG IXWXUH XVH

1DP \*: /HH ': /HH +6 f1DWLYH IHDWK

:DVWDJH RI SURWHLQ ULFK UHVHUYH LV )HUYLGREDFWHULXPLVODQGLFXP \$: D Q
PHDO XVLQJ NHUDWLQRO\WLF IXQJL > @ 7KH DGGLWLRQ RI PLFURELDO
GLJHVWHG IHDWKHU PHDO WR WKH DQLPDO IHG LPSURYHV GLJHVWLELQW\ DQ
EROVWHUHG JURZWK RI SRXOWU\ 1XWULWLRQDO HQKDFHPPHQW FDQ DOVR EH
DFKLHYHG E\ K\GURO\VLV RI UDZ IHDWKHUV XVLQJ WKHVH NHUDWLQRO\WLF IXQJL
OLFURELDO GLJHVWHG IHDWKHU PHDO LV DOVR XVHG DV VORZ QLWURJHQ UHOHDV
IHUWLQJHU .HUDWLQRSKLOLF IXQJL DUH XVHG IRU WKH SURGXFWLRQ RI
ELRGHJUDGDEOH ILOPV FRDWLQJV DQG JOXH IURP NHUDWLQRXV ZDVWH
.HUDWLQDQVHV RI WKHVH IXQJL DUH XWLOLJHG LQ HQJ\PH EDVHG GHWHUJHQWV
ZKLFK DUH XVHG LQ WKH UHPRYDO RI NHUDWLQRXV VRLOV FRPPRQ LQ WKH
ODXQGU\ RQ FROODUV RI VKLUWV HWF 7KHVH HQJ\PHV DUH DOVR XVHG IRU
FOHDQLQJ XS RI GUDLQV FORJJHG ZLWK NHUDWLQ ZDVWH 7KHVH NHUDWLQDQVHV
DOVR HPSOR\HG LQ WKH OHDWKHU LQGXVWU\ LQ KDLU VDYLQJ GHKDLULQJ LQ SO
RI FKHPLFDO EDVHG GHKDLULQJ 5HFHQWO\ WKHVH NHUDWLQDQVHV KDYH EHHQ
IRXQG WR GHJUDGH SULRQ SURWHLQ OHDGLQJ WR WKH SUHYHQWLRQ FXUH RI PD
FRZ GLVHDVH > @ )XUWKHU NHUDWLQDQVHV DUH DSSOLHG LQ WKH PRGLLFDWLRQ
RI VLON DQG ZRRO ILEHUV IRU DFQH RU SVRULDVLV IRU PDNLQJ YDFFLQHV RI
GHUPDWRSK\WRVLV DQG KDV DGGLFWLYHV LQ VNLQ OLJKWHQLQJ DJHQWV ,Q
DGGLWLRQ WR WKH NHUDWLQDQVHV WKHVH IXQJL KDYH WKH SRWHQWLDO WR JHQ
QDWXUDO JDV IRU IXHO IURP SRXOWU\ ZDVWH GHJUDGDWLRQ

:DVWH PDWHULDO KHQ IHDWKHU D ELR VRUEHQW ZDV VXFFHVVIXOO\ XWLOLJH
LQ UHPRYLQJ D ZDWHU VROXEHO KDJDUGRXV WULSKHQ\O PHWKDQH G\H
%ULOOLDQW %OXH )&) IURP ZDVWHZDWHU &KLFNHQ IHDWKHUV FRXOG KHOS VDYH
WUHHV E\ WDNLQJ WKH SODFH RI ZRRG SXOS LQ DLU ILOWHUV SDSHU SURGXFW
DQG RWKHU XVHV DFFRUGLQJ WR FKHPLVW :DOWHU 6FKPLGW RI WKH 8 6
\$JULFXOWXUDO 5HVHDFK 6HUYLFH 5HSODFLQJ KDOI WKH ZRRG SXOS FRQWHQW
RI FRPSRVLWH SDSHU ZLWK FKLFNHQ IHDWKHUV PHDQV RQO\ KDOI DV PDQ\
WUHHV &KLFNHQ IHDWKHUV FDQ DOVR WR EH XVH IRU WKH SURGXFWLRQ RI IXHO

5HIHUUHQFHV

0DEURX(N f)HDWKHU GHJUDGDWLRQ E\ D QHZ NHUDWLQRO\WLF
6WUHSWRP\FHV VS 06 g :RUOG -RXUQDO RI OLFURELRORJ\ DQG
%LRWHFKQRORJ\
+DQ 0 /XR : \*X 4 <X ; f,VRODWLRQ DQG FKDUDFWHULJDWLRQ RI D
NHUDWLQRO\WLF SURWHDVH IURP D IHDWKHU GHJUDGLQJ EDFWHULXP 3VHXGRPRQDV
DHUXJLQRVD & g \$IULFDQ -RXUQDO RI OLFURELRORJ\ 5HVHDFK
\$FGD01 f:DVWH FKLFNHQ IHDWKHU DV UHLQIRUFHPPHQW LQ FHPHQW
ERQGHG FRPSRVLWHV g 3KLOLSSLQH -RXUQDO RI 6FLHQFH
/LQ ; /HH &\* &DVDOH (6 6KLL -&+ f3XULILFDWLRQ DQG
FKDUDFWHULJDWLRQ RI D NHUDWLQDQVH IURP D IHDWKHU GHJUDGLQJ %DFLOOXV
OLFKHQLIRUPLV VWUDLQ g \$SSOLHG DQG (QYLURQPHQWDO OLFURELRORJ\
'HLVDVLJPDSSD .0 f,QGXVWULDO DSSOLFDWLRQ RI
NHUDWLQDQVH DQG VROXEHO SURWHLQV IURP IHDWKHU NHUDWLQV g -RXUQDO RI
(QYLURQPHQWDO %LRORJ\
0XNKRS DGG\ &KDQGD \$/ f3URWHDVH RI D
NHUDWLQRO\WLFVWUHSWRP\FHWH WR XQKDLU JRDW VNLQ g ,QGLDQ -RXUQDO RI
([SHULPHQWDO %LRORJ\