International Journal of Bioorganic Chemistry
2022; 7(1): 11-16
http://www.sciencepublishinggroup.com/j/ijbc
doi: 10.116 !/j.ijbc.20220701.12
"##$: 2%7!-&'! ((rint); "##$: 2%7!-&'&2 ()nline)

Effect of Balanced Fertilizers and Lime Rate on Maize (*Zea mays* L) Yield in Omo Nada District, Southwestern Oromia, Ethiopia

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To cite this article:

+lem*6ehu +bdet*- 3*rom* 4irdis*- 3ede5* #ori. 055ect o5 .*l*nced 4ertili7ers *nd 8ime ,*te on 9*i7e (*Zea mays* 8) :ield in)mo $*d* ;istrict- #outhwestern)romi*- 0thiopi*. *International Journal of Bioorganic Chemistry.* <ol. 7- $o. 1- 2022- pp. 11-16. doi: 10.116 !/j.ijbc.20220701.12

Received: 9*rch '1- 2022; **Accepted**: 9*6 7- 2022; **Published**: 9*6 12- 2022

Abstract: ;eclining o5 soil nutrients is *mong the 5*ctors th*t le*d to low crop 6ields in #ub-#*h*r*n +5ric* including 0thiopi*. =he e>periment w*s conducted to ?eri56 *nd demonstr*te the bene5ici*l e55ect o5 lime *nd b*l*nced 5ertili7er *pplic*tion r*te in impro?ing the 6ield o5 9*i7e on *cid soils o5)mo $*d* district. =he e>periment comprised se?en tre*tments n*mel6; /ontrol- $(#- $(#.- $(#. with 100@ recommended r*te o5 8ime- $(#. with 7%@ recommended r*te o5 8ime- $(#. with %0@ recommended r*te o5 8ime *nd $(#. with 2%@ recommended r*te o5 lime were l*id out in ,*ndomi7ed /omplete .locA ;esign (,/.;) replic*ted *cross ten 5*rmersB 5ields. ;*t* *n*l6sis w*s conducted on gr*in 6ield d*t* to detect ?*ri*tion *mong tre*tments. (*rti*l budget *n*l6sis w*s *lso done to determine the economic 5e*sibilit6 o5 tre*tments. =he results re?e*led th*t there were highl6 signi5ic*nt di55erences ((C 0.01) *mong tre*tments in their e55ect on gr*in 6ield o5 m*i7e. +ccordingl6- $(#. with 5ull recommended lime g*?e signi5ic*ntl6 superior 6ield o5 m*i7e (in sites. =his tre*tment incre*sed the me*n gr*in 6ield o?er the control b6 27.26 Dt/h* 6ields *d?*nt*ges. +pplic*tion o5 lime *lone did not incre*se the 6ield o5 9*i7e in *ll sites suggesting th*t the soil were se?erel6 depleted o5 essenti*l nutrients. =he result o5 p*rti*l budget *n*l6sis d*t* *lso showed th*t the highest net bene5it *nd m*rgin*l r*te o5 return (66@) w*s obt*ined 5rom $(#. with 5ull recommended lime. 4in*ll6- the highest biologic*l *nd economic*l 6ield o5 9*i7e w*s obt*ined 5rom $(#. tre*tment *pplied *t 100 Ag/h* *nd 5ull recommended r*tes o5 lime. ,esults suggest th*t nutrient depletion c*n be mitig*ted in the *re* through using o5 lime; hence longer-term producti?it6 o5 sm*llholders c*n be sust*ined.

Keywords: #oil +cidit6- .*l*nced 4ertili7er- 9*i7e (roduction- 8ime

1. Introduction

9*i7e (*Zea mays* 8.) is one o5 the most import*nt cere*l crops in the world. "t r*nAs third *mong other cere*ls *5ter whe*t *nd rice E1F. 9*i7e is the most widel6 grown *mong cere*l crops in +5ric* *nd * st*ple 5or *round h*l5 the inh*bit*nts in the continent. "t is grown *cross di?erse *gro-ecologic*l 7ones where o?er 200 million people depend on the crop 5or 5ood securit6 E2F. 9*i7e *ccounts 5or *lmost h*l5 o5 the c*lories *nd protein consumed in 0*stern *nd #outhern +5ric*- *nd one-5i5th in Gest +5ric* E'F.

Howe?er- the 6ield is o5ten limited due to * combin*tion o5 se?er*l 5*ctors th*t include continuous mono cropping *nd in*deDu*te 5ertili7er use- which in turn c*used soil 5ertilit6 degr*d*tion. #e?er*l studies re?e*led th*t optimum $ *nd (r*tes di55ered 5or di55erent m*i7e growing loc*tions E F *nd with di55erent cropping s6stem- suggesting th*t the old tr*dition o5 using bl*nAet 5ertili7er recommend*tion c*n no more be *n *ppropri*te pr*ctice to 5ollow. =he proper *pplic*tion o5 pl*nt nutrients *re determined b6 Anowing the nutrient reDuirement o5 the crop *nd the nutrient suppl6ing power o5 the soil E%F.

,ecentl6 *cDuired soil in?entor6 d*t* 5rom 0thio#"# *lso re?e*led th*t in *ddition to $ *nd (- nutrients such *s #- .-

In *re de5icient in 0thiopi*n soils in gener*l *nd stud6 *re* in p*rticul*r E6F. 9oreo?er- the m*gnitude o5 $- (*nd other micronutrient e55ects on gr*in 6ield o5 m*i7e ?*r6 with sites due to di55erences in soil nutrient suppl6ing c*p*cit6 *nd crop m*n*gement pr*ctices in the stud6 *re* E7F. =he 6ield obt*ined b6 the 5*rmers in the stud6 *re*s is low due in*ppropri*te *gronomic pr*ctice- l*cA o5 st*ble high 6ielder ?*rieties- drought *nd soil erosion *nd poor essenti*l soil nutrient E!F.

;eterior*ting soil 5ertilit6- sh*llow soil depth- high run-o55 *nd low in5iltr*tion c*p*cit6 o5 the soil *re the m*jor restriction 5or support*ble *gricultur*l production in)mo $*d*. #o something is done to rep*ir soil 5ertilit6 5irst to incre*se crop production. =he most common problems in *ll regions where precipit*tion is high enough to le*ch *ppreci*ble *mounts o5 e>ch*nge*ble b*ses 5rom the soil sur5*ce E&F. =here *re di55erent liter*ture th*t showed *t soil pH C %.% *55ects the growth o5 crops due to high concentr*tion o5 *luminum (+l) *nd m*ng*nese (9n)- *nd de5icienc6 o5 (- nitrogen ($)- sul5ur (#) *nd other nutrients E10F.

=he southwestern region o5 0thiopi* co?ers *re*s with highl6 suit*ble 5or m*i7e on inherentl6 5ertile $itisol with humid to sub-humid clim*te 7ones. Jimm* *dministr*ti?e 7one h*?e declining soil 5ertilit6 th*t is one o5 the m*jor constr*ints 5or m*i7e production. =here5ore- to o?ercome soil *cidit6 problem using liming m*teri*l is the prim*r6 options to r*ises soil (h *t which crops ?igorousl6 grow properl6 E11F. =he m*jor recentl6 recommended blended 5ertili7ers 5or)mo $*d* b6 +=+ is $(#. E!F but the optimum r*tes o5 the recommended blended 5ertili7er 5or m*i7e crops is not 6et identi5ied 5or)mo n*d* district.

9oreo?er- liming contributes *ppreci*ble *mount o5 b*sic second*r6 m*cronutrients liAe /*^{2K} *nd 9g^{2K} which *re essenti*l 5or pl*nts E12F. +ccordingl6- 0?*lu*tion o5 8ime *nd blended 4ertili7ers 055ects on gr*in 6ield o5 9*i7e *t)mo $*d* district- Jimm* Ione w*s st*rted b6 .edele ,ese*rch /enter *s joint *cti?it6 with Jimm* Lni?ersit6 /+#/+(0 project during 2017. =he result showed th*t soil pH o5 e>periment*l site w*s 5*lling in ?er6 strongl6 *cidic (.0%-%.0') be5ore sowing *nd ch*nge to moder*tel6 *cidic (.1!-%.67) *5ter h*r?est in cropping se*son o5 2017 E1'F.

+lem*6ehu E1'F reported th*t ch*nge in pH 5rom ?er6 strongl6 *cidic (.0%) to moder*tel6 *cidic %.67 *nd 6ield o5 1.72 Dt/h* w*s recorded 5rom the tre*tment combin*tion o5 100 Ag/h* $(#. with 1. 2 ton/h* lime 5or m*i7e- 5ollowed b6 the ch*nge in pH 5rom .0% to %.'1 *nd 6ield '& Dt/h* w*s obt*ined 5rom the tre*tment combin*tion o5 100 Ag/h* $(#. with 1.06% ton/h* lime. +lthough the soil pH w*s incre*sed due to lime *pplic*tion- it did not re*ch to the desired r*nge needed b6 m*i7e (%.%-7.0). =here5ore- the objecti?es o5 this stud6 w*s to ?eri56 *nd demonstr*te the bene5ici*l e55ect o5 lime *nd b*l*nced 5ertili7er *pplic*tion r*tes in impro?ing the 6ield o5 9*i7e on *cid soils in)mo $*d* district- #outhwestern)romi*- 0thiopi*.

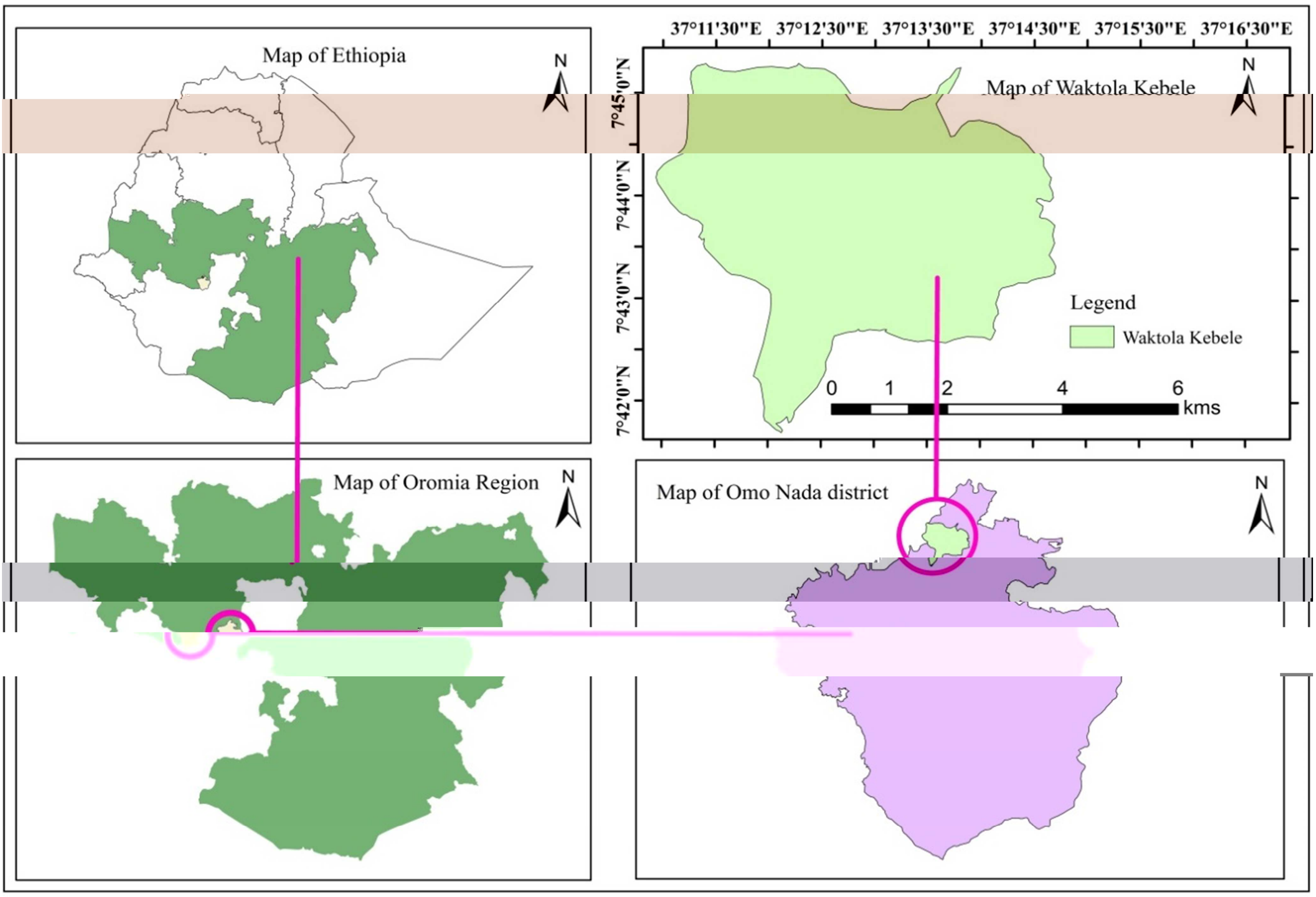

Figure 1. *Map of the Study area.*

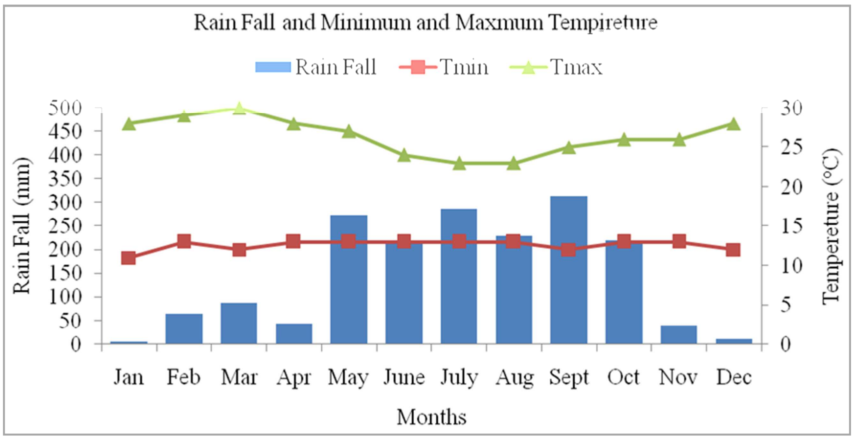

Figure 2. *The annual rainfall, maximum and minimum temperature of the study area.*

2. Materials and Methods

2.1. Description of Study Area

=he stud6 w*s conducted on 5*rmersB 5ield *t w*Atol* Meble-)mo $*d* district- Jimm* Ione o5 southwestern)romi*. 3eogr*phic*ll6- the *re* is loc*ted *t 07N 2 %.7P to 07N ' !.7P l*titude ($) *nd 0'7N12%&.1P to 0'7N1' 1P longitude (0). =he *ltitude r*nges 5rom 1617 to 1!&' m.*.s.l 5*lling in * tepid moist to cool highl*nds *gro ecologic*l 7one. =he l*nd5orms o5 the *re* *re ch*r*cteri7ed b6 undul*ting to rolling pl*te*us- sc*ttered moder*te hills- *nd dissected side slope s*nd ri?er gorges E1 F.

"t is situ*ted in cool to sub-humid highl*nds o5 southwestern 0thiopi*. =he m*in r*in6 se*son in the stud6 *re* stretches 5rom 9*rch to #eptember with bimod*l distribution. =he thirt6 6e*rs *?er*ge me*n *nnu*l r*in5*ll recorded w*s 11&! mm *nd the minimum *nd m*>imum temper*ture w*s *bout 11.!N/ *nd 27.2N/- respecti?el6. $itisol *re the domin*nt re5erence soil groups in the upper slopes in the low l6ing pl*in *re*s E1%F. +ccording to the h*rmoni7ed soil m*p o5 +5ric* E16F- the m*jor re5erence soil groups o5 the southwestern highl*nd pl*te*us *re $itisol- <ertisol- 8eptosol- ,egosol- /*mbisol *nd +crisols. $itisol *re the domin*nt re5erence soil groups in co55ee-growing *re*s o5 southwest 0thiopi* *nd in the stud6 *re*- which h*?e * depth o5 more th*n 1.% m- cl*6e6 *nd red in color. =hese soils *re well dr*ined with good ph6sic*l properties such *s high w*ter holding c*p*cit6- * deep rooting depth *nd st*ble soil *ggreg*te structure.

2.2. Lime Requirement Determination

4or lime recommend*tion- soil s*mple 5rom sites were collected be5ore lime *pplic*tion *nd subjected to *n*l6ses o5 *cidit6 *ttribute. Ghen soil pH is below %.%- liming is * common method to incre*se the soil pH *nd reduce *cidit6. .ut the *mount o5 lime reDuired to bring cert*in pH to optimum r*nge 5or crop growth depends on some 5*ctor *s org*nic m*tter- cl*6 content *nd soil pH. 8ime ,eDuirement (8,) o5 sites *nd crops were determined b*sed on e>ch*nge*ble *cidit6 (0>. +c) E17F. 8, (ton/h*) Q0>ch*nge*ble +cidit611.%110. Ghere; 8,Q8ime ,eDuirement. =o *?oid o?er liming- *n *d*pt*tion 5*ctor w*s proposed th*t t*Aes the +l sensiti?it6 o5 crops into *ccount. 4*ctor Q C 1 5or +l-toler*nt crops Q 1.0 5or moder*tel6 +l-toler*nt crops Q 1.% 5or +l- sensiti?e crops E1!F. .*sed on soil result recommended r*te o5 lime (2.& ton/h*) w*s uni5orml6 *pplied to the e>periment*l 5ield bec*use soil *cidit6 is * common problem in the district. 8ime (/*/),) w*s e?enl6 bro*d c*sted m*nu*ll6 *nd thoroughl6 mi>ed in the upper 1%cm depth o5 the soil one month be5ore seed sowing.

2.3. Field Layout and Experimental Design

=he e>periment comprised 0ight tre*tments were used (1) /ontrol (2) $(# (') $(#. ( ) $(#. with 100@ recommended r*te o5 8ime (%) $(#. with 7%@ recommended r*te o5 8ime (6) $(#. with %0@ recommended r*te o5 8ime (7) $(#. with 2%@ recommended r*te o5 lime (!) recommended lime *lone were l*id out in r*ndomi7ed complete blocA design (,/.;) replic*ted *cross ten 5*rmersB 5ields in e*ch loc*tion. =he plot si7e 10mR10m (100m^2) w*s used 5or the e>periment. /omposite soil s*mples were t*Aen 5rom eight site r*ndoml6 selected 5*rm 5ields. ,esults o5 the test indic*ted th*t the soil s*mples were within the highl6 *cidic c*tegor6 (soil pH r*nged '.11-%.1') *s per the +cid #oils 9*n*gement *nd 8ime +pplic*tion 3uideline th*t 4eder*l 9inistr6 o5 +griculture published E1&F (=*ble 1). 4ertili7er r*tes o5 100 Ag $(# Ag/h*- 100 Ag/h* $(#. *nd 100 Ag/h* Lre* w*s *pplied *nd h*l5 ure* *pplied *5ter % d*6s.

Table 1. *Treatment Combination.*

Treatment code	Lime rates	Fertilizer kg/ha	Treatment combination
1	0	0	0:00
2	0	100 $(#	0:100 $(#
'	0	100$(#.	0:100$(#.
	100@ ,8	0	100@ ,8: 0
%	100@ ,8	100$(#.	100@ ,8:100 $(#.
6	7%@ ,8	100$(#.	100@ ,8:100 $(#.
7	%0@ ,8	100$(#.	100@ ,8:100 $(#.
!	2%@ ,8	100$(#.	100@ ,8:100 $(#.

,8Q,ecommended 8ime.

h*r?esting d*te *nd mech*nism- stor*ge- tr*nsport- etc. =his w*s done b6 reducing the tot*l 6ield b6 the recommended le?el o5 10@- *nd *rri?ing *t the net 6ield. =hen to determine the gross bene5it b6 multipl6ing net 6ield b6 the 5ield price (m*rAet price *djusted 5or *n6 costs rel*ted to stor*ge- tr*nsport*tion- etc.). =hen *ll costs *nd bene5it o5 e*ch tre*tment were c*lcul*ted sep*r*tel6 to *rri?e *t the net bene5it o5 e*ch tre*tment. =his w*s helped rese*rchers identi56 tre*tments with highest bene5it 5or *pplic*tion o5 lime. $et bene5its *nd costs th*t ?*r6 between tre*tments were used to c*lcul*te m*rgin*l r*te o5 return to in?estment c*pit*l *s to mo?e 5rom * less e>pensi?e to * more e>pensi?e tre*tment. 0conomic *n*l6sis w*s c*rried considering onl6 the purch*sing cost o5 inputs *s 5*rmers norm*ll6 use 5*mil6 l*bor to process- tr*nsport *nd *ppl6 lime *nd 5ertili7ers to crop 5ields. 9oreo?er- sensiti?it6 *n*l6sis w*s m*de to see the sensiti?it6 o5 the recommended r*te when subjected to input *nd output price ch*nges.

Table 4. *Partial Budget of in-depth trail.*

Partial budget	Treatment							
	RL+ NPSB	0.75 RL+NPSB	0.5 RL+NPSB	0.25 RL+NPSB	Only RL	Only NPS	Only NPSB	Control
3 : (Dt h*$^{-1}$)	% .'	%0.&	7.2	'.6	''.7	'&.!	0.	27.1
+ : (Dt h*$^{-1}$)	!.!7	%.!1	2. !	'&.''	'0.''	'%.!2	'6.'6	2 .'&
34 . (. irrh*$^{-1}$)	202!.2	'&'&6.6	'6%'2.!	''!2'.!	260!'.!	'0!0%.2	'126&.6	20&7%.
Lre* (. irr/100 Ag)	1260.6&	1260.6&	1260.6&	1260.6&	0	1260.6&	1260.6&	0
$ (# (. irr/100 Ag)	0	0	0	0	0	1271	0	0
$ (# . (. irr/100 Ag)	0	0	0	0	0	0	12!1.7!	
8 + (100 birr /d*6)	00	'00	200	100	00	0	0	0
= < / (. irr/h*)	1660.6&	1%60.6&	1 60.6&	1'60.6&	00	1271	12!1.7!	0
$et bene5it	0'67.%	'7!'%.&1	'%072.11	'2 6'.11	2%6!'.!	2&%' .2	2&&!7.!2	20&7%.
9 , ,	2.							

$ote: - , 8Qrecommended lime- 3 : Q3r*in 6ield- + : Q+djusted : ield- 34 . Q3rowth 4ield . ene5it- 8+Q8ime +pplic*tion- = < / Q=ot*l ?*ri*ble / ost *nd 9 , , Q9*rgin*l , *tes o5 return.

=he results o5 p*rti*l budget *n*l6sis d*t* *re shown in (=*ble) +ccordingl6- the highest net bene5it (0'67.% 0= .) w*s obt*ined 5rom $ (# . with 5ull , ecommended lime tre*tment 5ollowed $ (# . with 7%@ o5 5ull recommended lime tre*tment '7!'%.&10 . . =he highest m*rgin*l r*te o5 return (2 '@) w*s obt*ined 5rom $ (# . with 5ull recommended lime tre*tments. "n this e>periment- it w*s 5ound th*t blended 4ertili7er *pplic*tion *lone did not incre*se the m*i7e 6ield on 5*rmersB 5ield due to *cidit6 problem.

4. Conclusion and Recommendations

"n this e>periment- it w*s 5ound th*t b*l*nced *pplic*tion o5 5ertili7er *lone did not incre*se the m*i7e 6ield but gre*ter due to *cidit6 problem. =his *greement with report o5 E1 F th*t showed 4ertili7er *pplic*tion *lone did not signi5ic*ntl6 incre*se the 6ield o5 crops in these unless it is *pplied *long with lime or inorg*nic 5ertili7ers due to se?ere nutrient depletions pre?*iling in these *re*s. "n such * c*se- *pplic*tion o5 lime r*ises the pH *nd m*Aes the nutrients *?*il*ble to crops. =he current e>periment con5irmed th*t lime is essenti*l but must be complimented with b*l*nced pl*nt nutrients in order to get *deDu*te 9*i7e 6ield in the stud6 *re*s. Hence it is economic*ll6 5e*sible to impro?e m*i7e 6ield *nd 6ield components on *cidic soils o5 the stud6 *re* b6 combined use o5 lime *nd $ (# . 5ertili7er. =here5ore- soil test b*sed lime *nd $ (# . *pplic*tion c*n be used 5or the sust*in*ble production o5 m*i7e on *cidic soils in 0thiopi*. +ccordingl6- 100@- 7%@*nd %0@ recommended lime r*tes h*d st*tistic*ll6 signi5ic*nt e55ect on 6ield *nd 100@ recommend lime with 100Ag/h* $ (# . blended is best on the stud6 *re*.

5. Prospects

055ects o5 . *l*nced 5ertili7er *nd lime r*te on 9*i7e h*?e the best option to t*cAle *cidit6 problem *nd incre*se crop production. Howe?er ?*rious *spects rem*in to be in?estig*ted.

=hus- 5uture rese*rch ende*?or should 5ocus on:

1. / ombined b*l*nced 5ertili7er *nd lime *pplic*tion b*sed on their properties is needed.
2. , ese*rch "nstitution should 5ocus on sol?ing o5 *cidit6 problem *s m*in worA.

Conflict of Interest

=he *ll *uthors decl*re th*t there is no con5lict o5 interest reg*rding the public*tion o5 this *rticle.

Acknowledgements

=he *uthor th*nAs Jimm* / + # / + (0 (roject 5or the 5in*nci*l support pro?ided to conduct the e>periment. +lso " would liAe *cAnowledge . edele +gricultur*l , ese*rch / enter 5or their cooper*tion during 5ield worA *nd soil l*bor*tor6 *n*l6sis.

References

E1F 4ood *nd +griculture) rg*ni7*tion / orpor*te #t*tistic*l ; *t*b*se (4+) #=+=). 2017. #t*tistic*l d*t*b*ses *nd d*t*-sets o5 the 4ood *nd +griculture) rg*ni7*tion o5 the Lnited $*tions.

E2F 9*c*ule6- H. *nd ,*m*djit*- =.- 201%. /ere*l crops: rice- m*i7e- millet- sorghum *nd whe*t. +bdou ;iou5 "ntern*tion*l- ;*A*r #eneg*l.

E'F 9*c*ul*6- H.- 201%. /ere*l crops: rice- m*i7e- millet- sorghum- *nd whe*t: b*cAground p*per. /on5erence on T4eeding +5ric*B ;*A*r- #eneg*l- 21U2')ctober 201%.

E F #hi5er*w .oAe- 9uluget* H*bte- +tin*5u + *nd +b*6 +6*lew. 201!. 9*cro *nd 9icronutrients 5or optimi7ing m*i7e production *t H*w*ss* Iuri* ;istrict- #outhern 0thiopi*. Journ*l o5 .iolog6- +griculture *nd He*lthc*re- !: 222 -'20!.

E%F ;*gne /himdess*. 2016. .lended 4ertili7er 055ects on 9*i7e :ield *nd :ield components o5 Gestern)romi*- 0thiopi*. +griculture- 4orestr6 *nd 4isheries- % (%): 1%1-162.

E6F 0thiopi*n #oil "n5orm*tion #6stem (0thio#"#) (2016). #oil *n*l6sis report. +gricultur*l =r*ns5orm*tion +genc6 (Lnpublished).

E7F =es5*6e .*lemi- 9es5in Mebede- 3eber #el*ssie H*ilu- J*iros ,urind*- J*mes 9utegi- =olch* =u5*- =oler* +ber* *nd =es5*6e #hi5er*w #id*. 201&. :ield ,esponse *nd $utrient Lse 055icienciesunder ;i55erent 4ertili7er +pplic*tions in 9*i7e (*Zea mays* 8.) in /ontr*sting +gro0cos6stem. "ntern*tion*l Journ*l o5 (l*nt *nd #oil #cience. 2& (')- pp. 1-1&.

E!F +=+ (+gricultur*l =r*ns5orm*tion +genc6)- 201 . #oil 4ertilit6 #t*tus *nd 4ertili7er ,ecommend*tion +tl*s 5or =igr*6 ,egion*l #t*te- 0thiopi*. 0thiopi*n +gricultur*l =r*ns5orm*tion+genc6 (+=+)- +. +.- 0thiopi*.

E&F +ch*lu /himdi- Helu5 3ebreAid*n- MibebewMibret *nd +bi =*desse- 2012- #t*tus o5 selected ph6sicochemic*l properties o5 soils under di55erent l*nd use s6stems o5 Gestern)romi*- 0thiopi*. Journ*l o5 .iodi?ersit6 *nd 0n?ironment*l #ciences, 2 ('): %7-71.

E10F +breh* Mid*nem*ri*m- Helu5 3ebreAid*n- =eA*lign 9*mo *nd Mindie =es5*6e. 201'. Ghe*t crop response to liming m*teri*ls *nd $ *nd (5ertili7ers in *cidic soils o5 =segede highl*nds- northern 0thiopi* +griculture- Journ*l o5 4orestr6 *nd 4isheries 2 ('): 126-1'%.

E11F 9*rcelo /uritib* 0spindul*- <*lterle6#o*res ,och*- 9o*cil+l?es de #ou7*- 9*rcel* /*mp*nh*ro- *nd 3uilherme de #ous* (*ul*. 201'. ,*tes o5 ure* with or without ure*se inhibitor 5or topdressing whe*t. /hile*n journ*l o5 *gricultur*l rese*rch 7' (2).

E12F 4*geri* $. M- .*lig*r <. /- Jones /. + (2010). 3rowth *nd miner*l nutrition o5 5ield crops '[rd] 0dition. /, / (ress.

E1'F +lem*6ehu +bdet*. 055ect o5 .lended 4ertili7er *nd 8ime +pplic*tion ,*tes on 3r*in :ield *nd :ield /omponent o5 9*i7e (*Zea mays* 8.) in)mo $*d* ;istrict- Jimm* Ione #outh-western- 0thiopi*. +meric*n Journ*l o5 .ioscience *nd .ioengineering. <ol. &- $o. - 2021- pp. &!-10'. doi: 10.116 !/j.bio.20210&0 .11.

E1 F G*ssie- H*ile- #hi5er*w .oAe. 200&. 9itig*tion o5 soil *cidit6 *nd 5ertilit6 decline ch*llenges 5or sust*in*ble li?elihood impro?ement: rese*rch 5indings 5rom southern region o5 0thiopi* *nd its polic6 implic*tions.

E1%F Hillette H*ilu- =eA*lign 9*mo- ,iiAA*MesAinen- 0riA M*rltun- Helu5 3ebreAid*n V =*6e .eAele. 201%. #oil 5ertilit6 st*tus *nd whe*t nutrient content in <ertisol cropping s6stems o5 centr*l highl*nds o5 0thiopi*.

E16F ;*wid- 201!. <*lid*tion o5 .lended 4ertili7er 5or 9*i7e (roduction Lnder 8imed /ondition o5 +cid #oil Journ*l o5 $*tur*l #ciences ,ese*rch ! (2'): %2-%!.

E17F =eA*lign 9*mo- MesAinen- ,.- M*rltun- 0.- 3ebreAid*n- H.- V .eAele- =. 201%. #oil 5ertilit6 st*tus *nd whe*t nutrient content in <ertisols cropping s6stems o5 centr*l highl*nds o5 0thiopi*. +griculture V 4ood #ecurit6- 1-10.

E1!F .uni + 201 . 055ects o5 8iming +cidic #oils on "mpro?ing #oil (roperties *nd :ield o5 H*ricot .e*n. J 0n?iron +n*l =o>icol 1(1) e9 -.5 9 B(7)(-17 6 17 9 .17 B))-6 -2 9 .7 6 2 B (9)) 2 6 B (6) .9 2 7 5 1 3 0 i 4 4 2