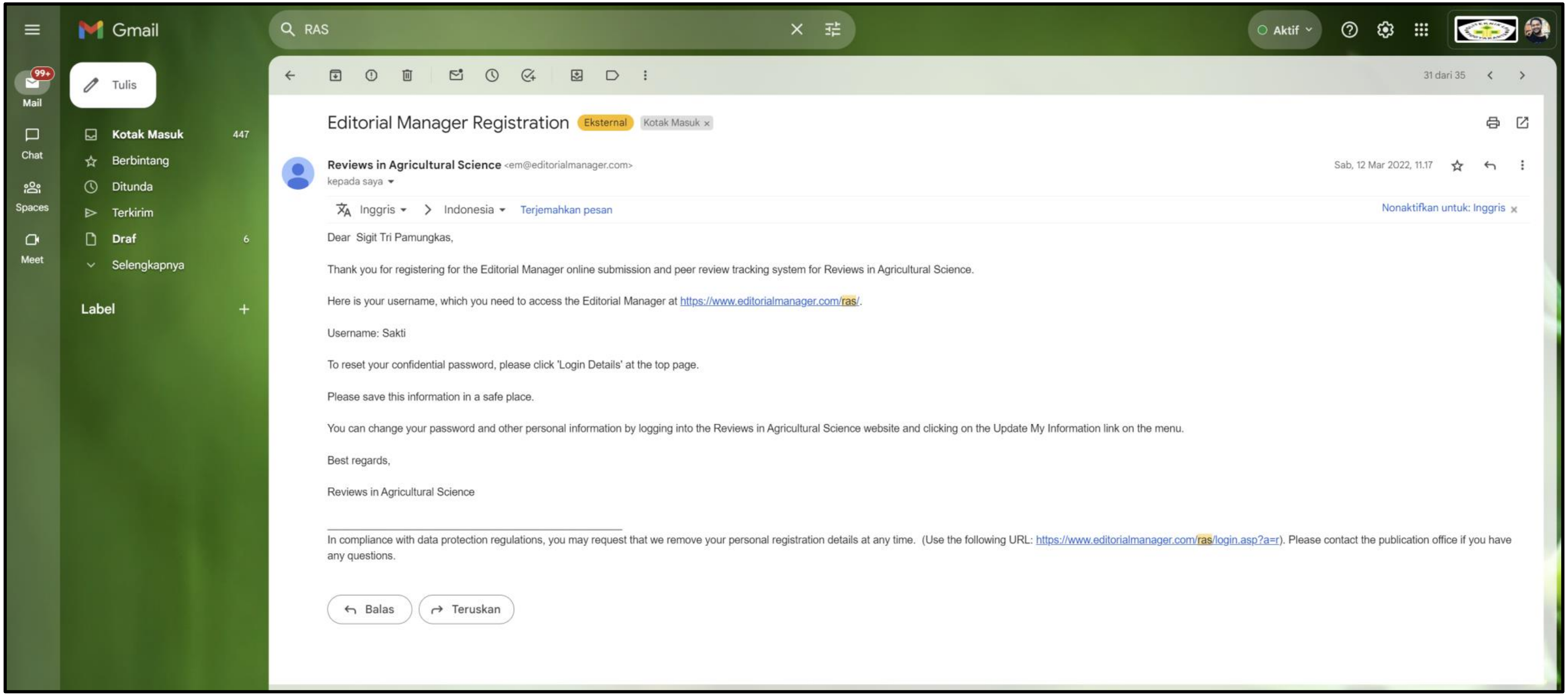
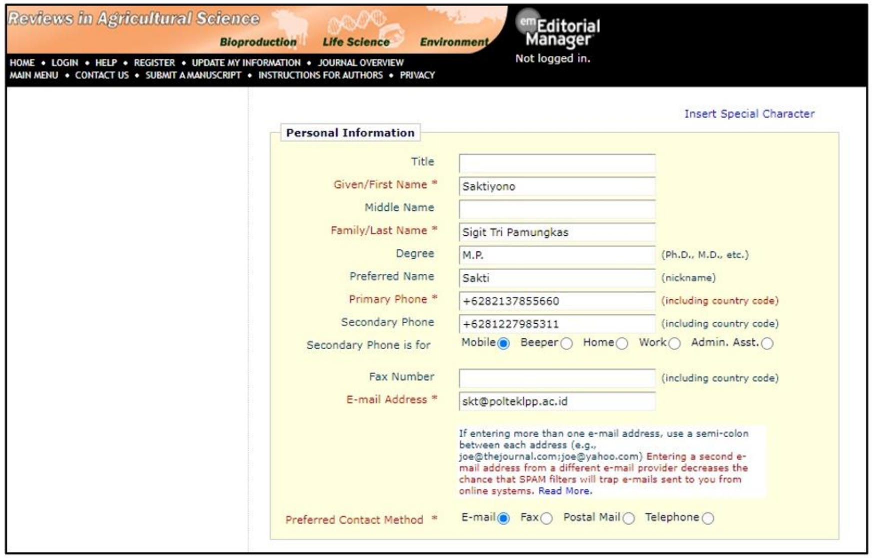
BUKTI KORESPONDENSI JURNAL

Nama	: Saktiyono Sigit Tri Pamungkas
Nama PT	: Politeknik LPP
Alamat PT	: Jl. LPP Nomor 1 A Balapan, Kota Yogyakarta
Satuan Kerja	: Program Studi Budidaya Tanaman Perkebunan
Nama Jurnal	: Reviews in Agricultural Science (RAS)
Alamat URL	: https://www.jstage.jst.go.jp/article/ras/10/0/10_168/_article
DOI	: https://doi.org/10.7831/ras.10.0_168
Edisi Terbit	: 2022 volume 10 (168-185)

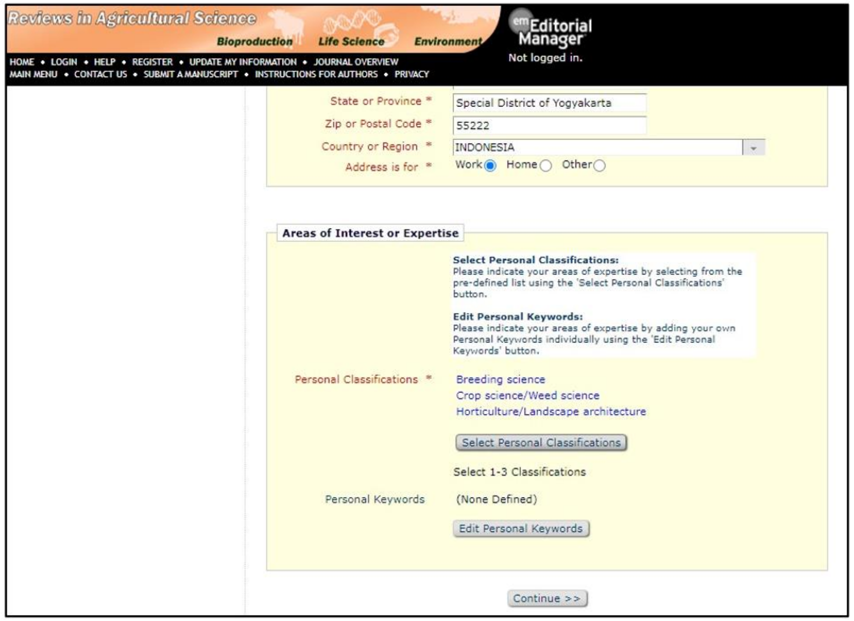
1. Proses register untuk *editorial manager online submission* (12 Maret 2022)

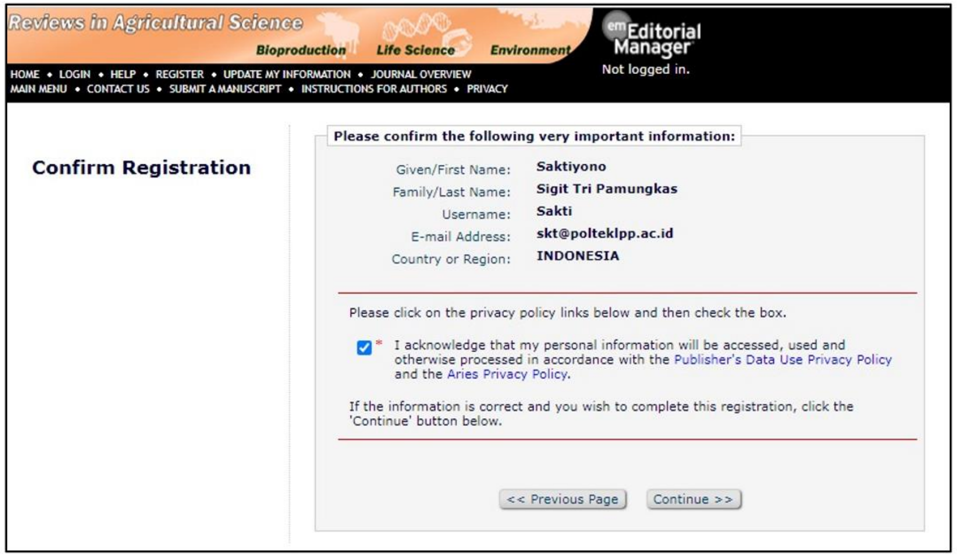


Berikut merupakan proses register untuk *editorial manager online submission:*

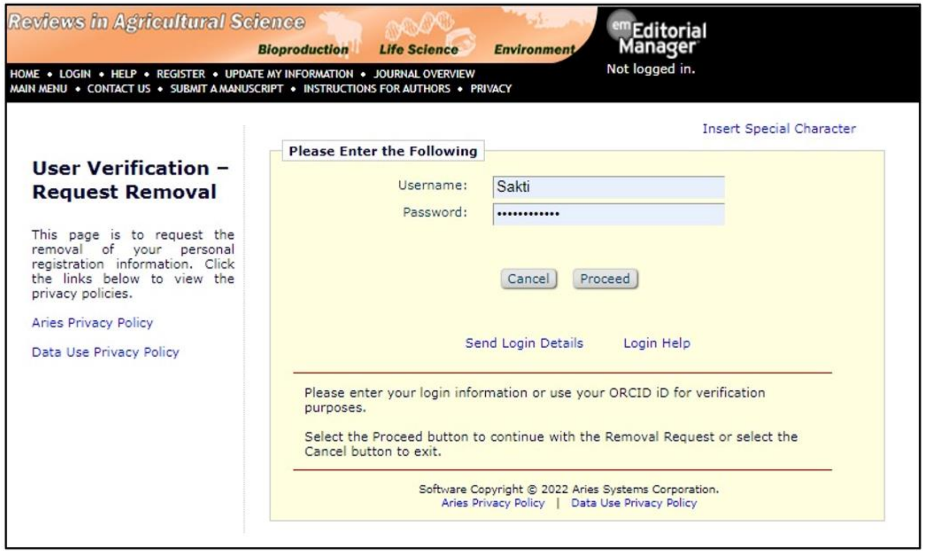


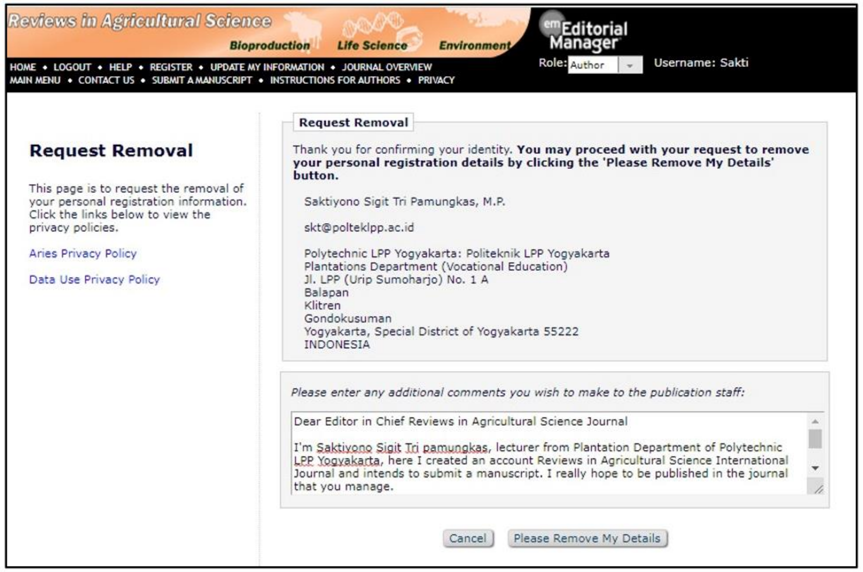

Reviews in Agricultural Science
Bioproduction
Life Science
Environment
em Editorial Manager
Not logged in.
HOME • LOGIN • HELP • REGISTER • UPDATE MY INFORMATION • JOURNAL OVERVIEW
MAIN MENU • CONTACT US • SUBMIT A MANUSCRIPT • INSTRUCTIONS FOR AUTHORS • PRIVACY
Insert Special Character
Institution Related Information
Position
Institution *
Polytechnic LPP Yogyakarta: Politek
Start typing to display potentially matching institutions.
Department *
Plantations Department (Vocational
Street Address *
Jl. LPP (Urip Sumoharjo) No. 1 A
Balapan
Klitren
Gondokusuman
City *
Yogyakarta
State or Province *
Special District of Yogyakarta
Zip or Postal Code *
55222
Country or Region *
INDONESIA
Address is for *
Work Home Other


Reviews in Agricultural Science
Bioproduction
Life Science
Environment
em Editorial Manager
Not logged in.
HOME • LOGIN • HELP • REGISTER • UPDATE MY INFORMATION • JOURNAL OVERVIEW
MAIN MENU • CONTACT US • SUBMIT A MANUSCRIPT • INSTRUCTIONS FOR AUTHORS • PRIVACY
State or Province *
Special District of Yogyakarta
Zip or Postal Code *
55222
Country or Region *
INDONESIA
Address is for *
Work Home Other
Areas of Interest or Expertise
Select Personal Classifications:
Please indicate your areas of expertise by selecting from the pre-defined list using the 'Select Personal Classifications' button.
Edit Personal Keywords:
Please indicate your areas of expertise by adding your own Personal Keywords individually using the 'Edit Personal Keywords' button.
Personal Classifications *
Breeding science
Crop science/Weed science
Horticulture/Landscape architecture
Select Personal Classifications
Select 1-3 Classifications
Personal Keywords
(None Defined)
Edit Personal Keywords
Continue >>

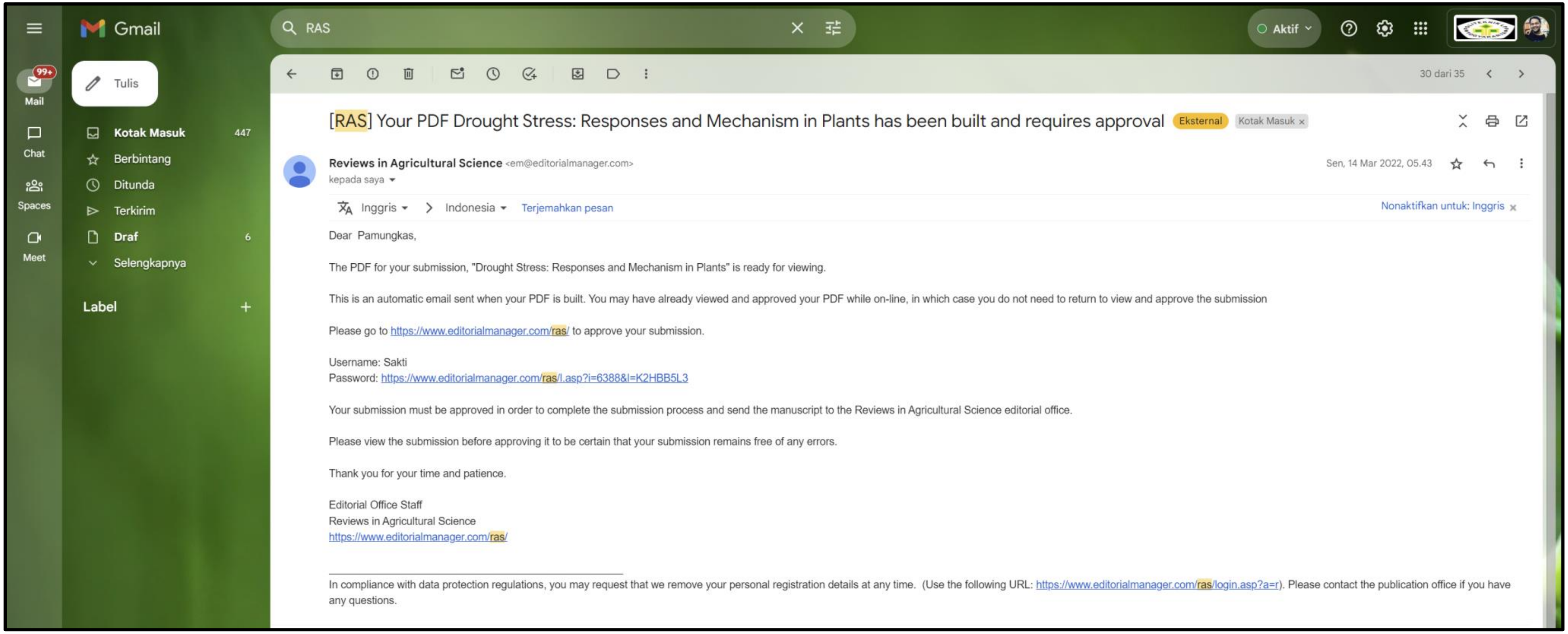

Reviews in Agricultural Science
Bioproduction
Life Science
Environment
em Editorial Manager
Not logged in.
HOME • LOGIN • HELP • REGISTER • UPDATE MY INFORMATION • JOURNAL OVERVIEW
MAIN MENU • CONTACT US • SUBMIT A MANUSCRIPT • INSTRUCTIONS FOR AUTHORS • PRIVACY
Confirm Registration
Please confirm the following very important information:
Given/First Name: Saktiyono
Family/Last Name: Sigit Tri Pamungkas
Username: Sakti
E-mail Address: skt@polteklpp.ac.id
Country or Region: INDONESIA
Please click on the privacy policy links below and then check the box.
I acknowledge that my personal information will be accessed, used and otherwise processed in accordance with the Publisher's Data Use Privacy Policy and the Aries Privacy Policy.
If the information is correct and you wish to complete this registration, click the 'Continue' button below.
<< Previous Page
Continue >>


Reviews in Agricultural Science
Bioproduction
Life Science
Environment
em Editorial Manager
Not logged in.
HOME • LOGIN • HELP • REGISTER • UPDATE MY INFORMATION • JOURNAL OVERVIEW
MAIN MENU • CONTACT US • SUBMIT A MANUSCRIPT • INSTRUCTIONS FOR AUTHORS • PRIVACY
Registration Complete
Check your email for a message to confirm your registration. Note that Editorial Manager may have assigned a different Username if the one you selected is already in use.
Go to Login Page





2. Proses *submission* (14 Maret 2022)



[RAS] Your PDF Drought Stress: Responses and Mechanism in Plants has been built and requires approval

Reviews in Agricultural Science <em@editorialmanager.com>

kepada saya

Sen, 14 Mar 2022, 05.43

Dear Pamungkas,

The PDF for your submission, "Drought Stress: Responses and Mechanism in Plants" is ready for viewing.

This is an automatic email sent when your PDF is built. You may have already viewed and approved your PDF while on-line, in which case you do not need to return to view and approve the submission

Please go to https://www.editorialmanager.com/ras/ to approve your submission.

Username: Sakti
Password: https://www.editorialmanager.com/ras/l.asp?i=6388&l=K2HBB5L3

Your submission must be approved in order to complete the submission process and send the manuscript to the Reviews in Agricultural Science editorial office.

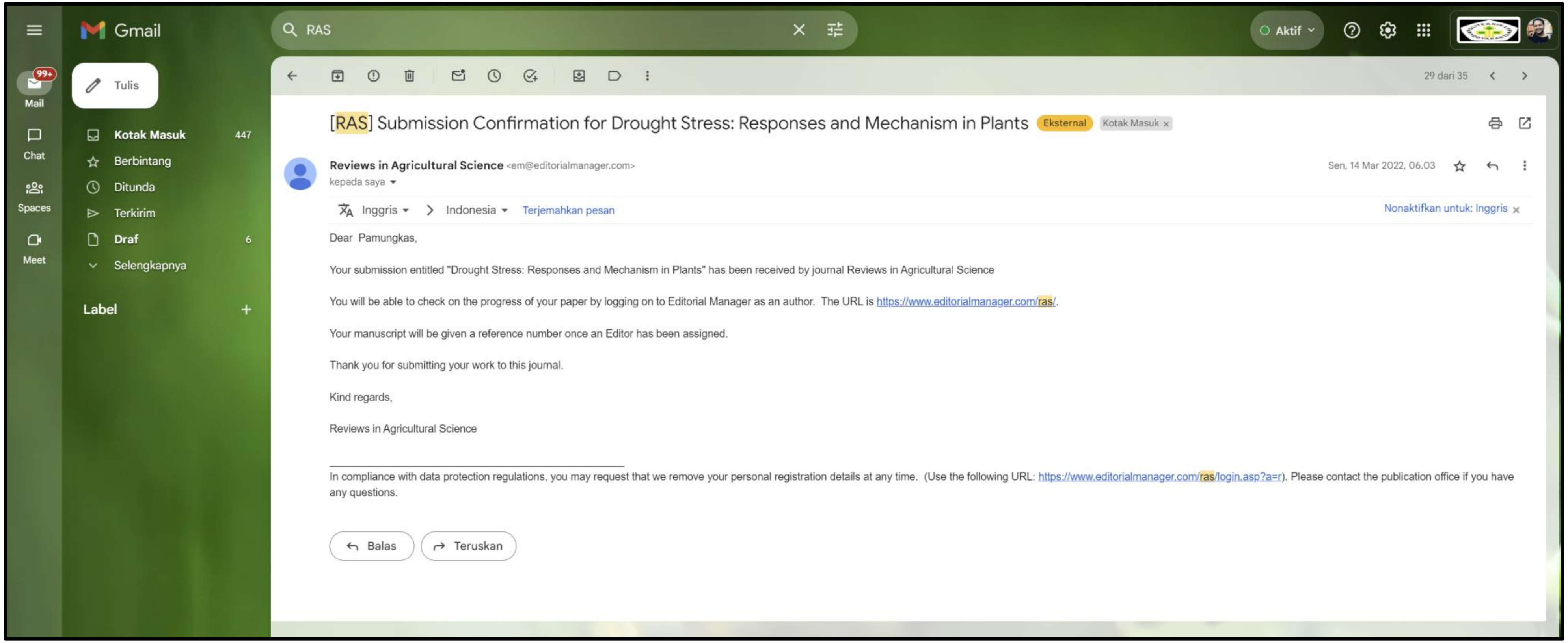
Please view the submission before approving it to be certain that your submission remains free of any errors.

Thank you for your time and patience.

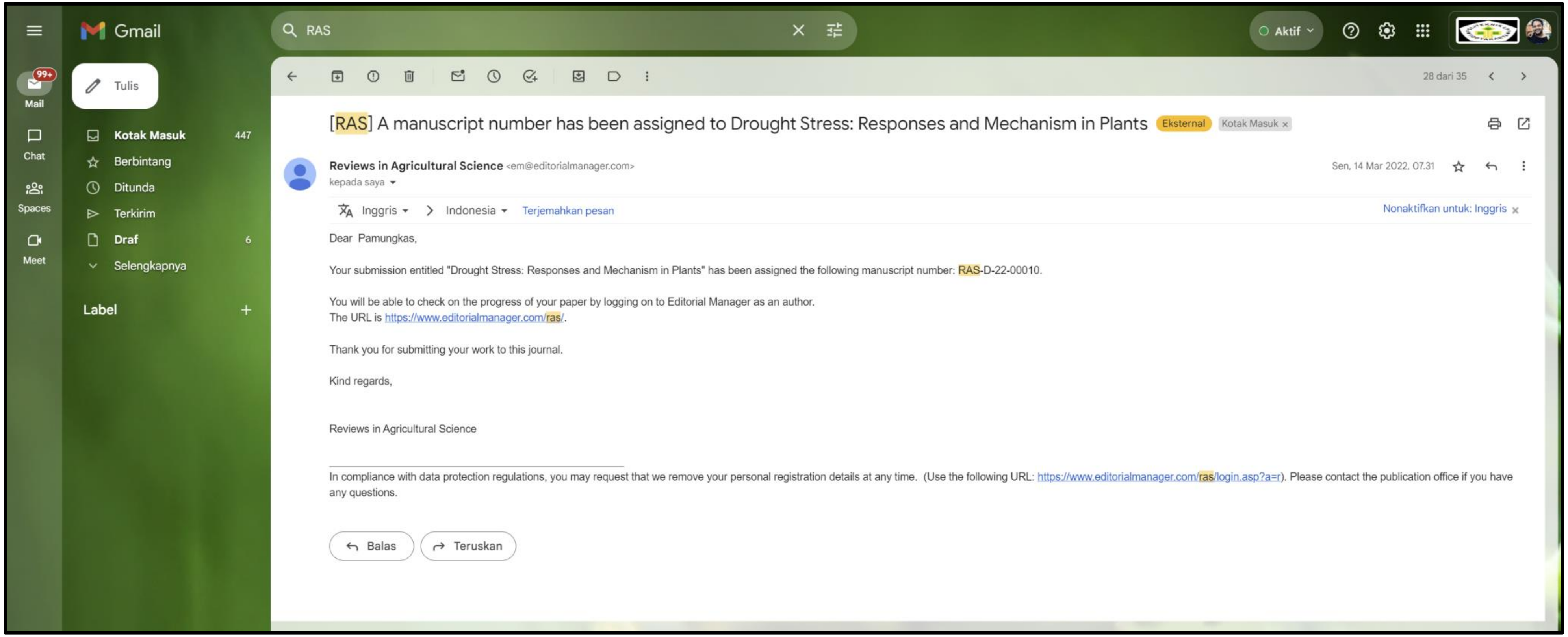
Editorial Office Staff
Reviews in Agricultural Science
https://www.editorialmanager.com/ras/

In compliance with data protection regulations, you may request that we remove your personal registration details at any time. (Use the following URL: https://www.editorialmanager.com/ras/login.asp?a=r). Please contact the publication office if you have any questions.

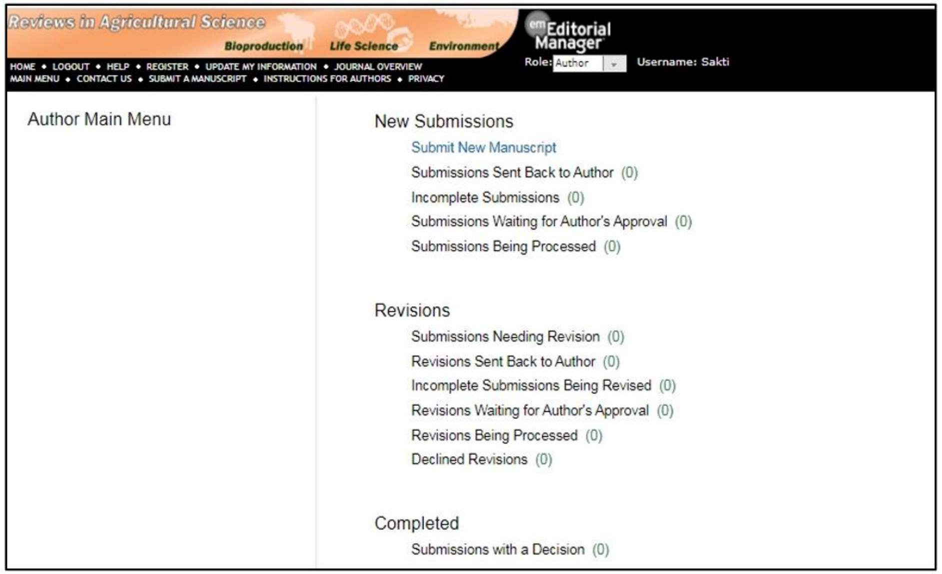
3. Proses konfirmasi *submission* (14 Maret 2023)

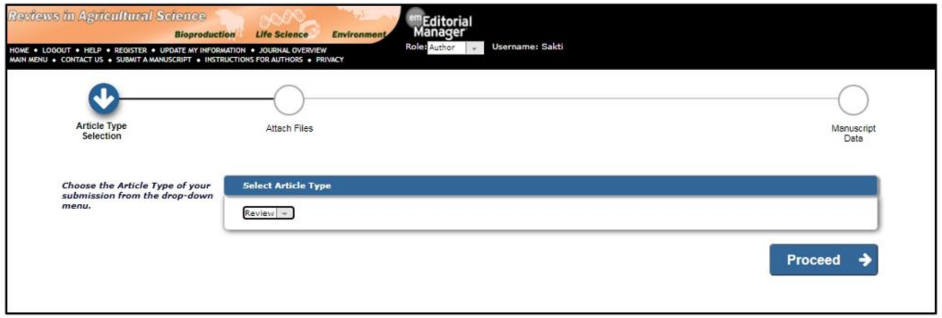


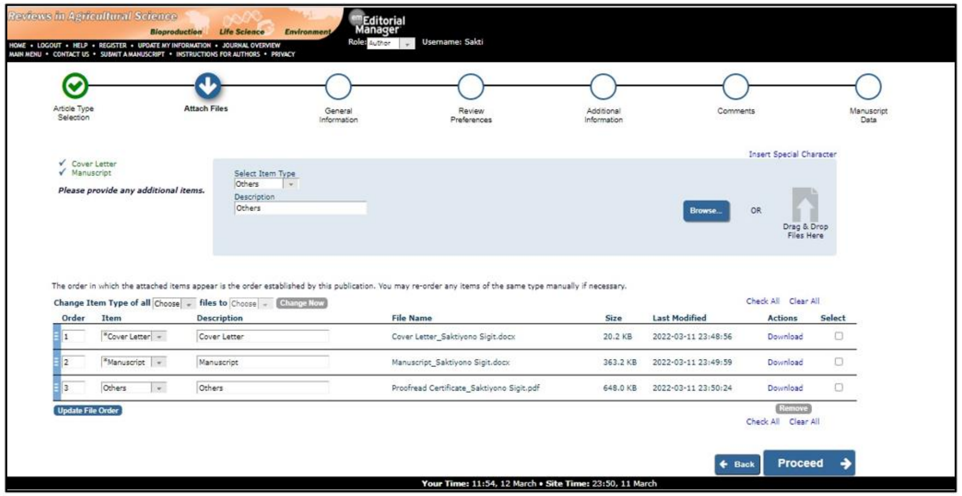
4. Proses *assigned a manuscript* (14 Maret 2022)

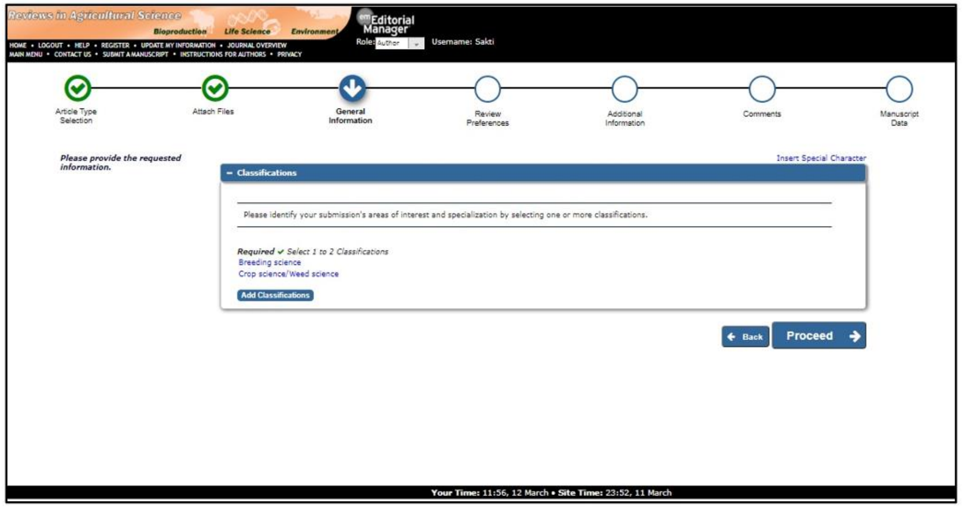


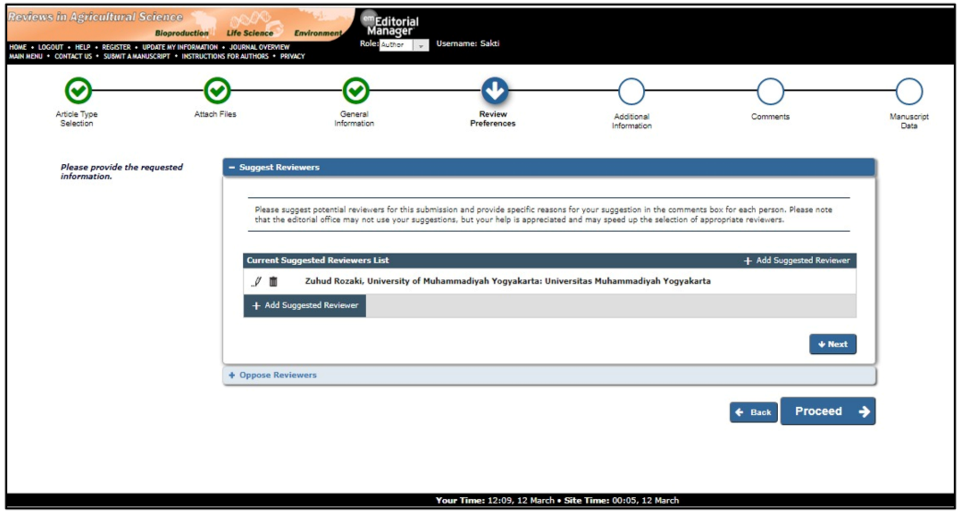
Berikut merupakan proses *submission a manuscript :*

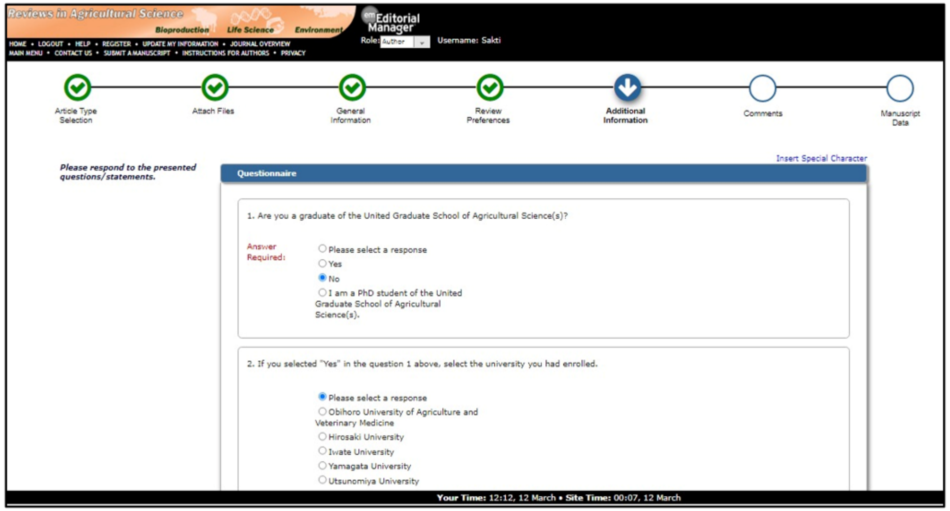


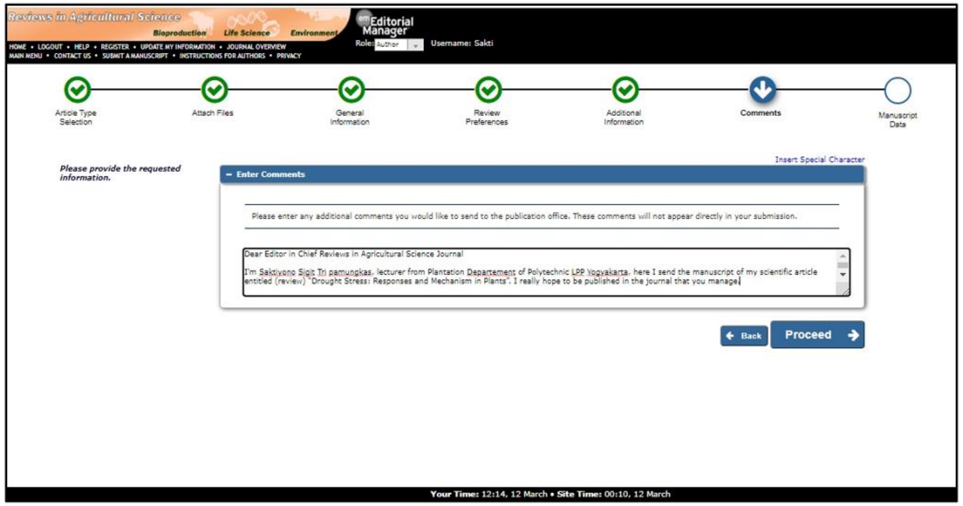


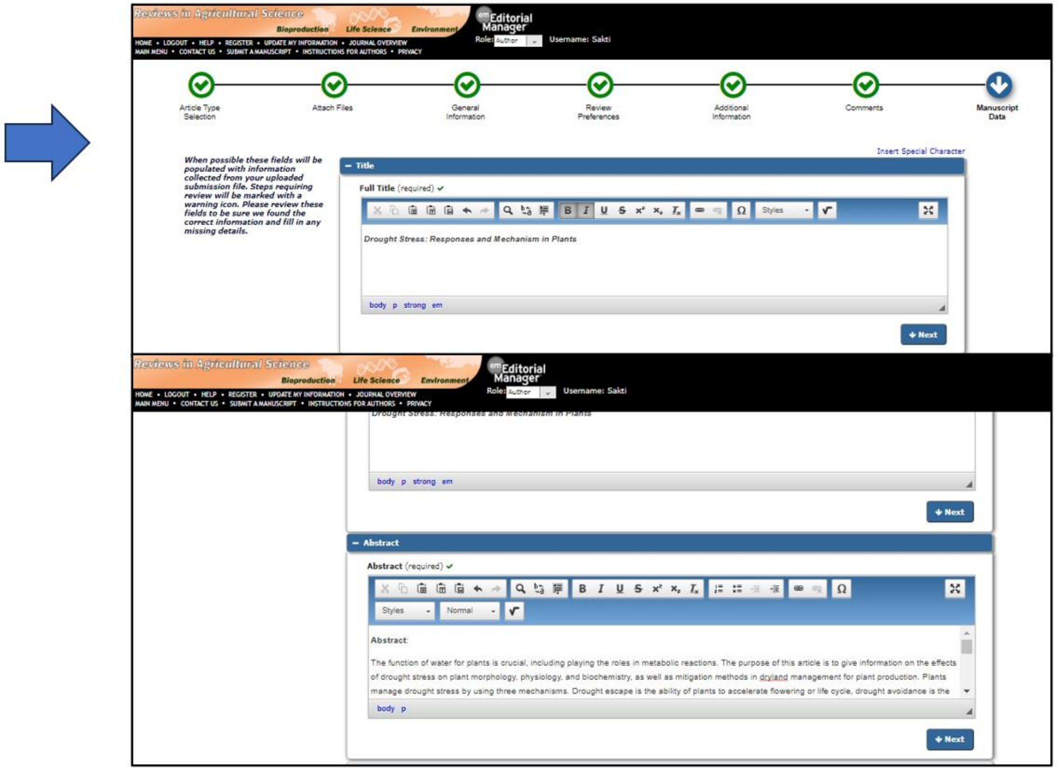

Reviews in Agricultural Science
Editorial Manager
Username: Sakti
Article Type Selection
Attach Files
General Information
Review Preferences
Additional Information
Comments
Manuscript Data
Cover Letter
Manuscript
Please provide any additional items.
Select Item Type
Description
Browse...
OR
Drag & Drop Files Here
Insert Special Character
Change Item Type of all
Order
Item
Description
File Name
Size
Last Modified
Actions
Select
Cover Letter_Saktiyono Sigit.docx
Manuscript_Saktiyono Sigit.docx
Proofread Certificate_Saktiyono Sigit.pdf
Update File Order
Back
Proceed
Your Time: 11:54, 12 March • Site Time: 23:50, 11 March


Reviews in Agricultural Science
Editorial Manager
Username: Sakti
Article Type Selection
Attach Files
General Information
Review Preferences
Additional Information
Comments
Manuscript Data
Please provide the requested information.
Insert Special Character
Classifications
Please identify your submission's areas of interest and specialization by selecting one or more classifications.
Required ✓ Select 1 to 2 Classifications
Breeding science
Crop science/Weed science
Add Classifications
Back
Proceed
Your Time: 11:56, 12 March • Site Time: 23:52, 11 March

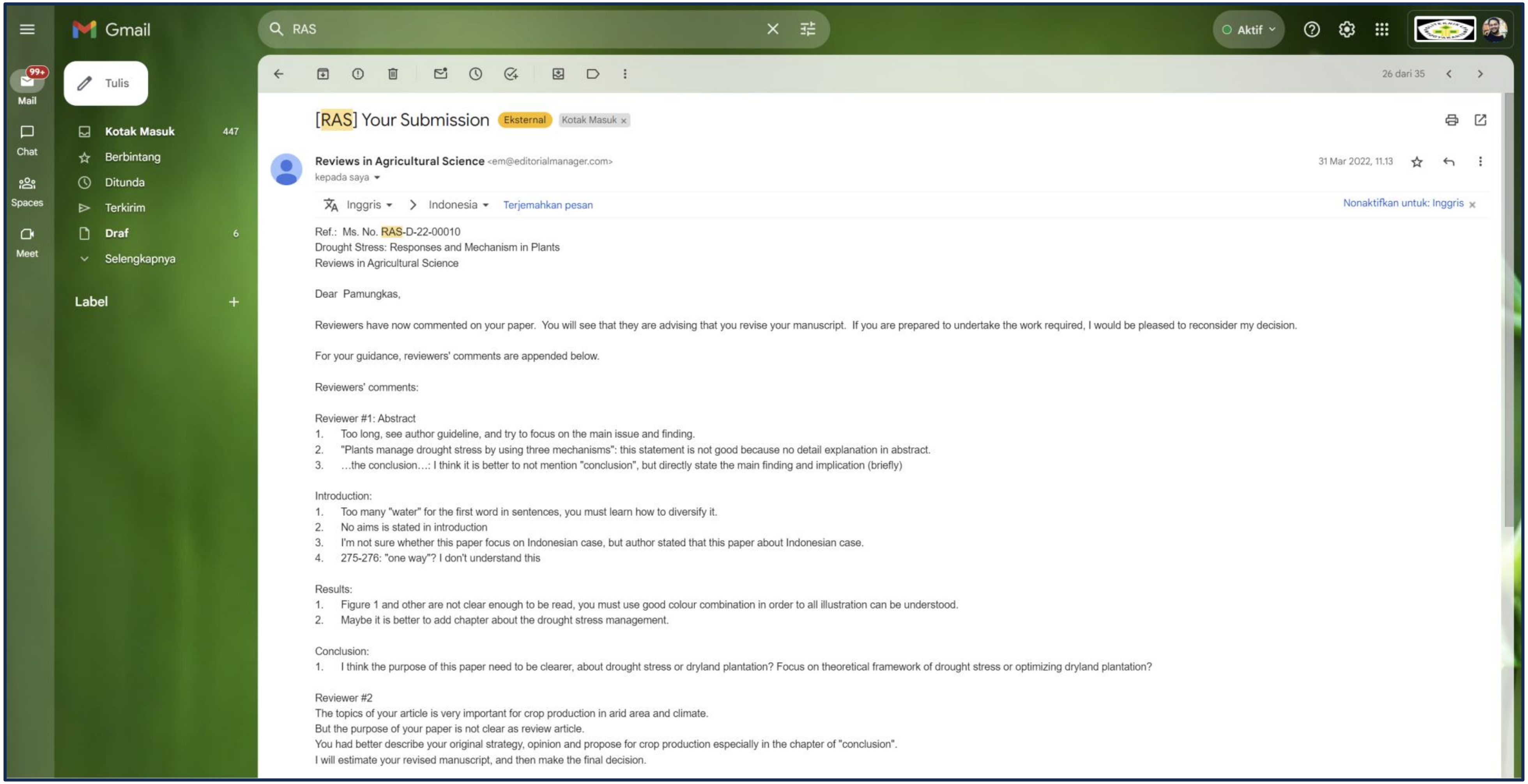

Reviews in Agricultural Science
Editorial Manager
Username: Sakti
Article Type Selection
Attach Files
General Information
Review Preferences
Additional Information
Comments
Manuscript Data
Please provide the requested information.
Suggest Reviewers
Please suggest potential reviewers for this submission and provide specific reasons for your suggestion in the comments box for each person. Please note that the editorial office may not use your suggestions, but your help is appreciated and may speed up the selection of appropriate reviewers.
Current Suggested Reviewers List
Add Suggested Reviewer
Zuhud Rozaki, University of Muhammadiyah Yogyakarta: Universitas Muhammadiyah Yogyakarta
Next
Oppose Reviewers
Back
Proceed
Your Time: 12:09, 12 March • Site Time: 00:05, 12 March


Reviews in Agricultural Science
Editorial Manager
Username: Sakti
Article Type Selection
Attach Files
General Information
Review Preferences
Additional Information
Comments
Manuscript Data
Please respond to the presented questions/statements.
Insert Special Character
Questionnaire
1. Are you a graduate of the United Graduate School of Agricultural Science(s)?
Answer Required:
Please select a response
Yes
No
I am a PhD student of the United Graduate School of Agricultural Science(s).
2. If you selected "Yes" in the question 1 above, select the university you had enrolled.
Please select a response
Obihoro University of Agriculture and Veterinary Medicine
Hirosaki University
Iwate University
Yamagata University
Utsunomiya University
Your Time: 12:12, 12 March • Site Time: 00:07, 12 March





5. Proses *correction/reviewers comments* (31 Maret 2022)



Ref.: Ms. No. RAS-D-22-00010
Drought Stress: Responses and Mechanism in Plants
Reviews in Agricultural Science

Dear Pamungkas,

Reviewers have now commented on your paper. You will see that they are advising that you revise your manuscript. If you are prepared to undertake the work required, I would be pleased to reconsider my decision.

For your guidance, reviewers' comments are appended below.

Reviewers' comments:

Reviewer #1: Abstract
1. Too long, see author guideline, and try to focus on the main issue and finding.
2. "Plants manage drought stress by using three mechanisms": this statement is not good because no detail explanation in abstract.
3. …the conclusion…: I think it is better to not mention "conclusion", but directly state the main finding and implication (briefly)

Introduction:
1. Too many "water" for the first word in sentences, you must learn how to diversify it.
2. No aims is stated in introduction
3. I'm not sure whether this paper focus on Indonesian case, but author stated that this paper about Indonesian case.
4. 275-276: "one way"? I don't understand this

Results:
1. Figure 1 and other are not clear enough to be read, you must use good colour combination in order to all illustration can be understood.
2. Maybe it is better to add chapter about the drought stress management.

Conclusion:
1. I think the purpose of this paper need to be clearer, about drought stress or dryland plantation? Focus on theoretical framework of drought stress or optimizing dryland plantation?

Reviewer #2
The topics of your article is very important for crop production in arid area and climate.
But the purpose of your paper is not clear as review article.
You had better describe your original strategy, opinion and propose for crop production especially in the chapter of "conclusion".
I will estimate your revised manuscript, and then make the final decision.

Berikut merupakan proses *correction for reviewers comments batch 1:*

Dear
Editor in Chief Reviews in Agricultural Science,

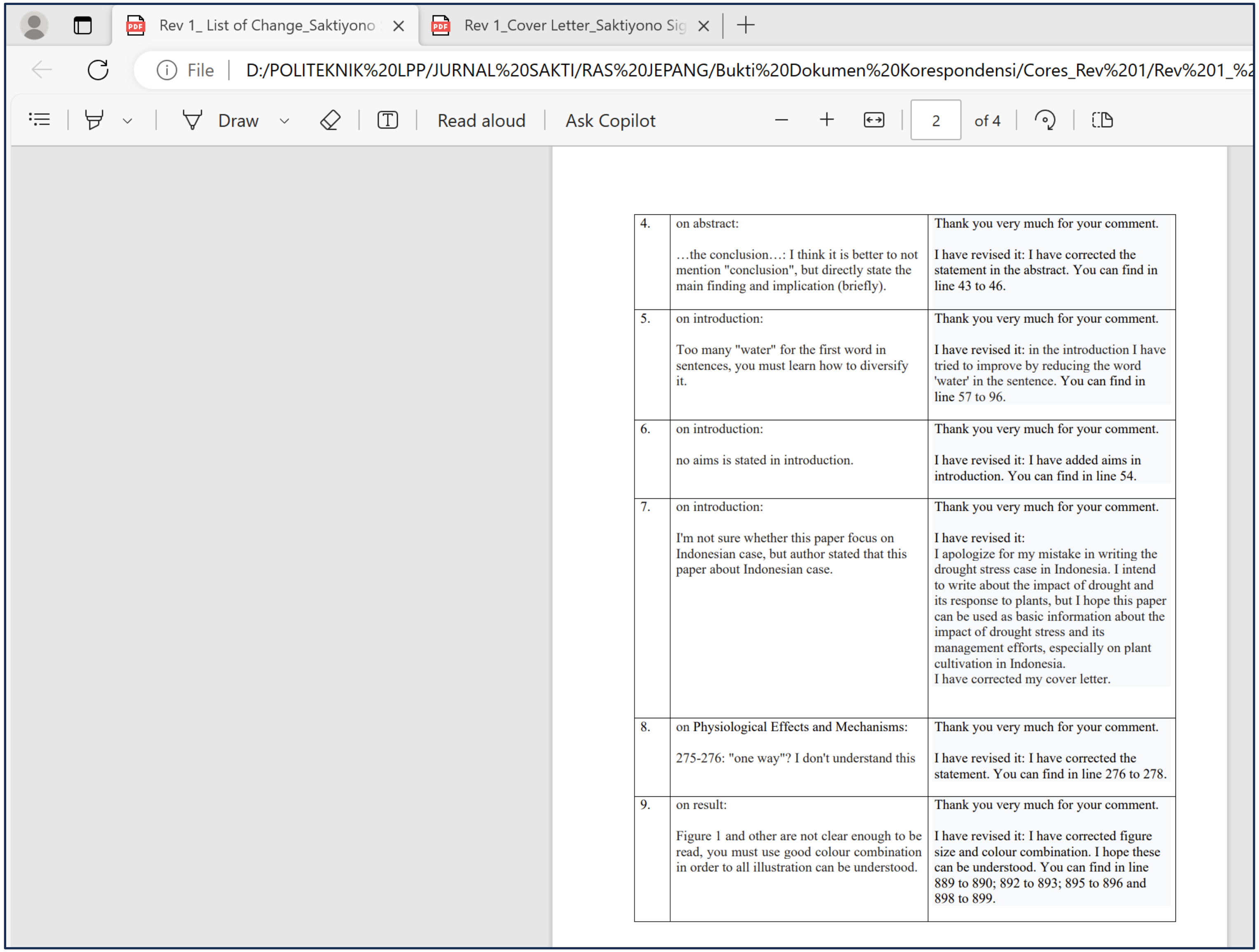
I am Saktiyono Sigit Tri Pamungkas, representing on behalf of the manuscript (Suwarto, Suprayogi and Noor Farid). I wish to submit a revision of my paper according to the reviewers comment.

LIST OF CHANGE

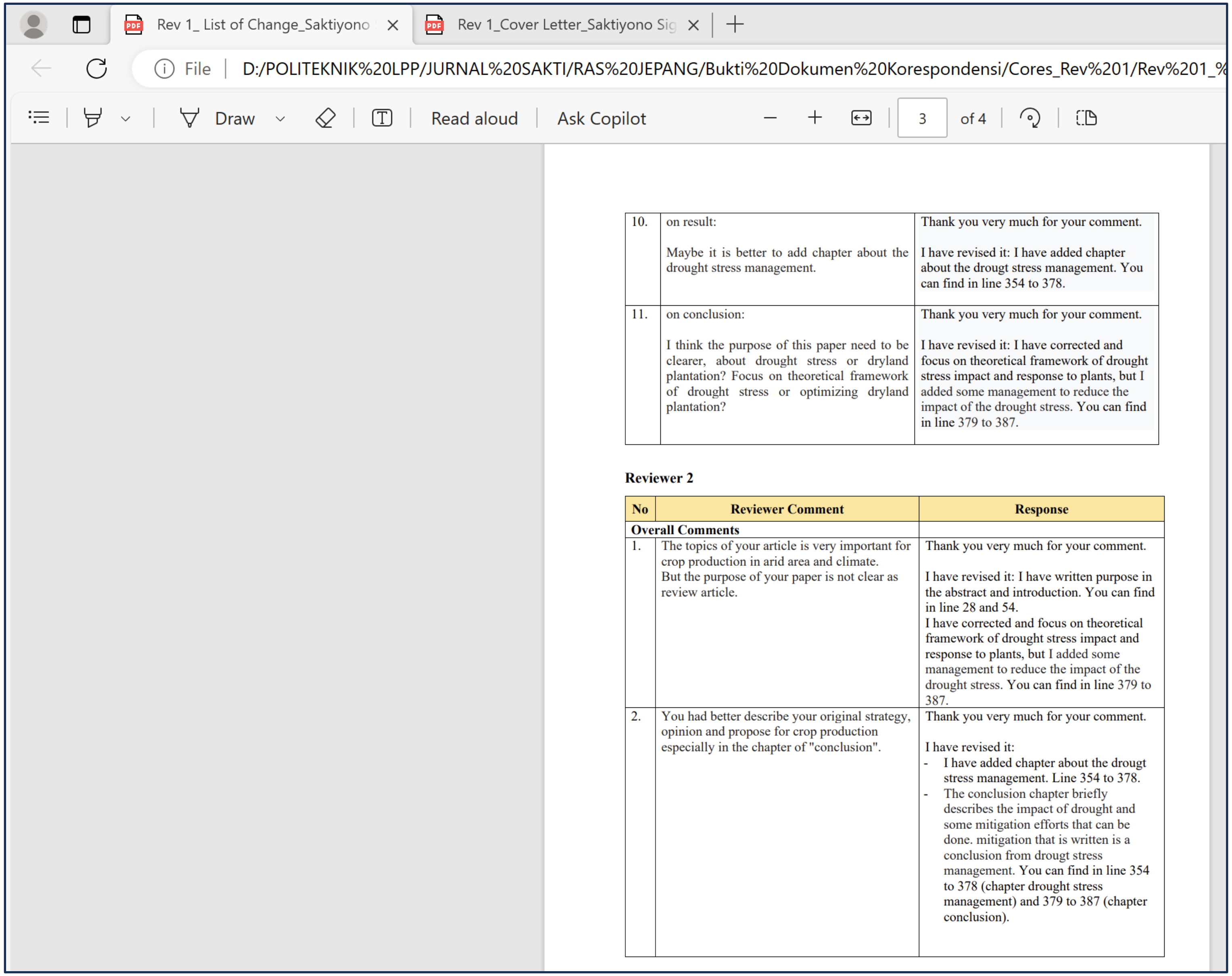
Title: Drought Stress: Responses and Mechanism in Plants
Author: Saktiyono S.T. Pamungkas[1)*], Suwarto[2)], Suprayogi[2)], Noor Farid[2)]

Reviewer 1

No	Reviewer Comment	Response
1.	on abstract: Too long, see author guideline.	Thank you very much for your comment. I have revised it: I have corrected the abstract no more than 300 words according to the guidelines. In the abstract there are 273 word. You can find in line 26 to 46.
2.	on abstract: Try to focus on the main issue and finding.	Thank you very much for your comment. I have revised it: - I have corrected in the abstract. I have written the purpose of writing this review. You can find in line 28. - I have corrected in the abstract. I have focused on the topic of plant responses and mechanisms to drought stress. You can find in line 30 to 43.
3.	on abstract: "Plants manage drought stress by using three mechanisms": this statement is not good because no detail explanation in abstract.	Thank you very much for your comment. I have revised it: I have corrected the statement in the abstract. You can find in line 30.



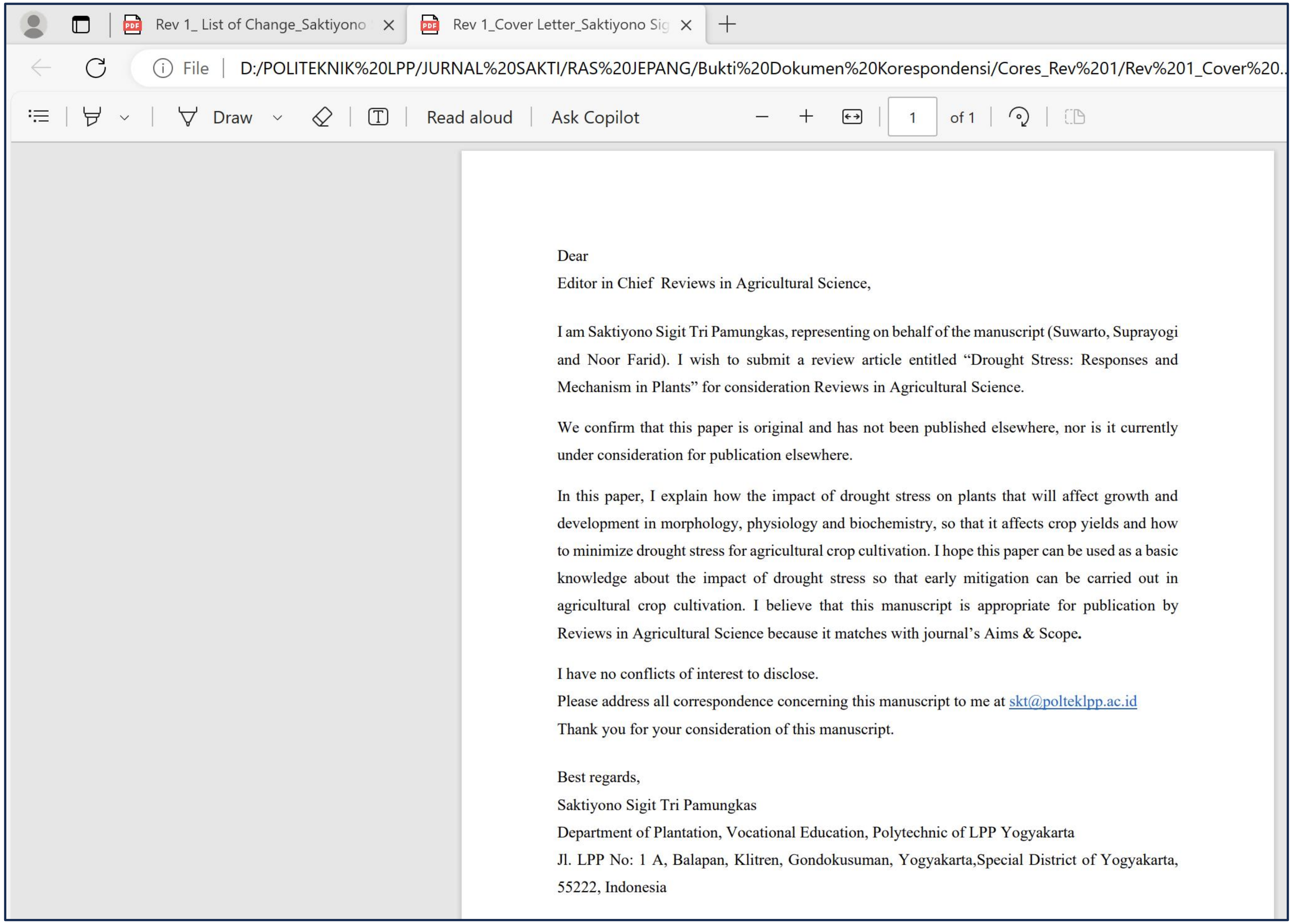
4.	on abstract: …the conclusion…: I think it is better to not mention "conclusion", but directly state the main finding and implication (briefly).	Thank you very much for your comment. I have revised it: I have corrected the statement in the abstract. You can find in line 43 to 46.
5.	on introduction: Too many "water" for the first word in sentences, you must learn how to diversify it.	Thank you very much for your comment. I have revised it: in the introduction I have tried to improve by reducing the word 'water' in the sentence. You can find in line 57 to 96.
6.	on introduction: no aims is stated in introduction.	Thank you very much for your comment. I have revised it: I have added aims in introduction. You can find in line 54.
7.	on introduction: I'm not sure whether this paper focus on Indonesian case, but author stated that this paper about Indonesian case.	Thank you very much for your comment. I have revised it: I apologize for my mistake in writing the drought stress case in Indonesia. I intend to write about the impact of drought and its response to plants, but I hope this paper can be used as basic information about the impact of drought stress and its management efforts, especially on plant cultivation in Indonesia. I have corrected my cover letter.
8.	on Physiological Effects and Mechanisms: 275-276: "one way"? I don't understand this	Thank you very much for your comment. I have revised it: I have corrected the statement. You can find in line 276 to 278.
9.	on result: Figure 1 and other are not clear enough to be read, you must use good colour combination in order to all illustration can be understood.	Thank you very much for your comment. I have revised it: I have corrected figure size and colour combination. I hope these can be understood. You can find in line 889 to 890; 892 to 893; 895 to 896 and 898 to 899.



10.	on result: Maybe it is better to add chapter about the drought stress management.	Thank you very much for your comment. I have revised it: I have added chapter about the drougt stress management. You can find in line 354 to 378.
11.	on conclusion: I think the purpose of this paper need to be clearer, about drought stress or dryland plantation? Focus on theoretical framework of drought stress or optimizing dryland plantation?	Thank you very much for your comment. I have revised it: I have corrected and focus on theoretical framework of drought stress impact and response to plants, but I added some management to reduce the impact of the drought stress. You can find in line 379 to 387.

Reviewer 2

No	Reviewer Comment	Response
Overall Comments		
1.	The topics of your article is very important for crop production in arid area and climate. But the purpose of your paper is not clear as review article.	Thank you very much for your comment. I have revised it: I have written purpose in the abstract and introduction. You can find in line 28 and 54. I have corrected and focus on theoretical framework of drought stress impact and response to plants, but I added some management to reduce the impact of the drought stress. You can find in line 379 to 387.
2.	You had better describe your original strategy, opinion and propose for crop production especially in the chapter of "conclusion".	Thank you very much for your comment. I have revised it: - I have added chapter about the drougt stress management. Line 354 to 378. - The conclusion chapter briefly describes the impact of drought and some mitigation efforts that can be done. mitigation that is written is a conclusion from drougt stress management. You can find in line 354 to 378 (chapter drought stress management) and 379 to 387 (chapter conclusion).



Dear
Editor in Chief Reviews in Agricultural Science,

I am Saktiyono Sigit Tri Pamungkas, representing on behalf of the manuscript (Suwarto, Suprayogi and Noor Farid). I wish to submit a review article entitled "Drought Stress: Responses and Mechanism in Plants" for consideration Reviews in Agricultural Science.

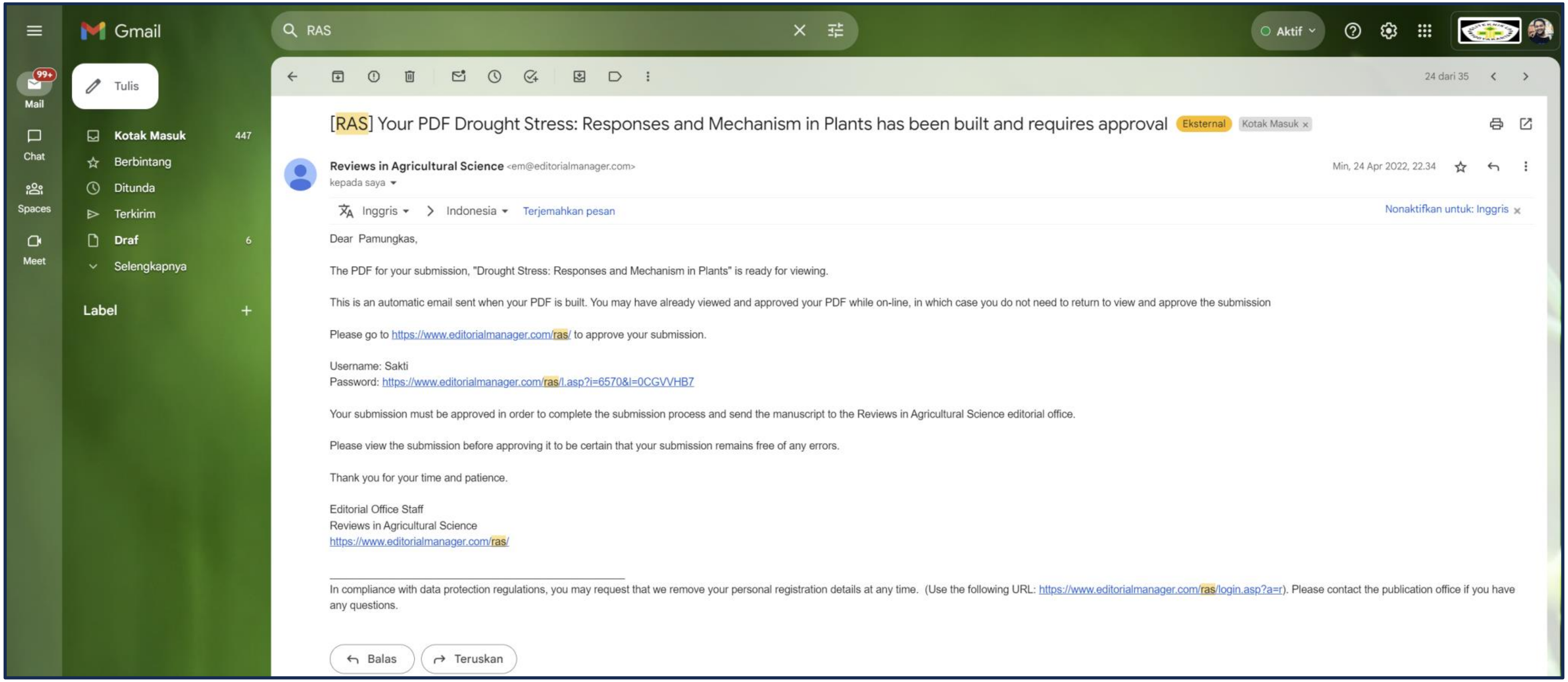
We confirm that this paper is original and has not been published elsewhere, nor is it currently under consideration for publication elsewhere.

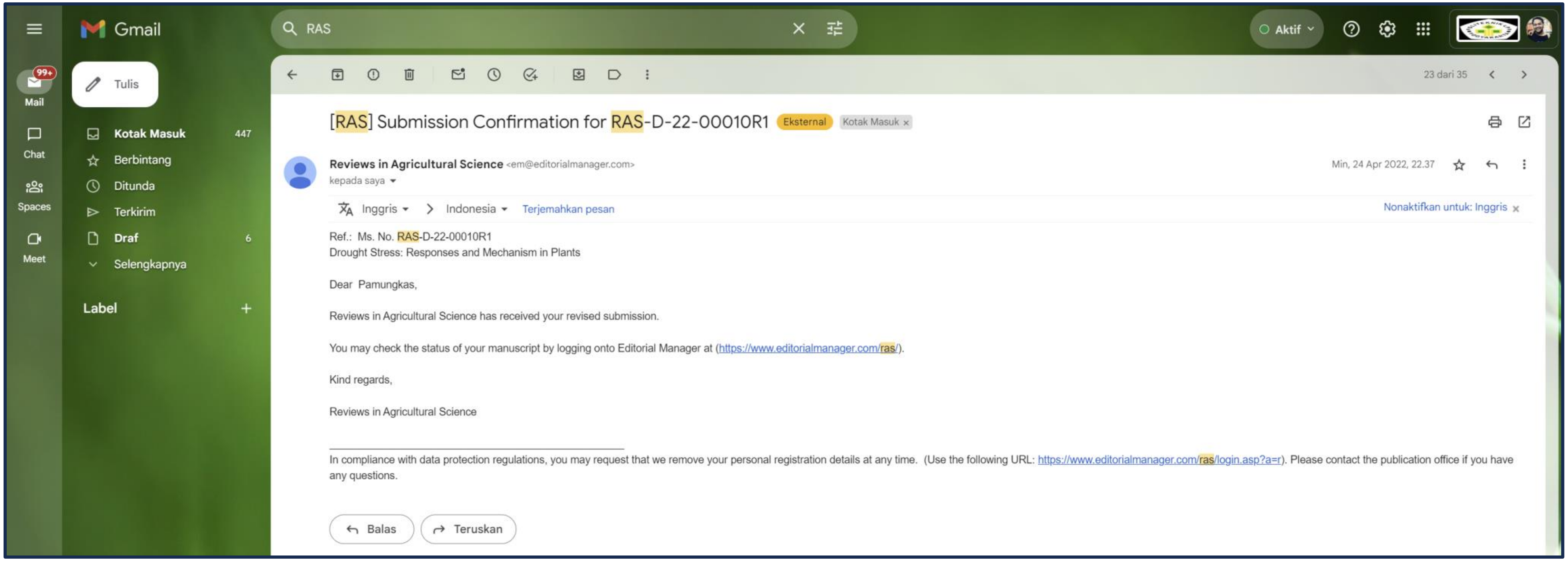
In this paper, I explain how the impact of drought stress on plants that will affect growth and development in morphology, physiology and biochemistry, so that it affects crop yields and how to minimize drought stress for agricultural crop cultivation. I hope this paper can be used as a basic knowledge about the impact of drought stress so that early mitigation can be carried out in agricultural crop cultivation. I believe that this manuscript is appropriate for publication by Reviews in Agricultural Science because it matches with journal's Aims & Scope.

I have no conflicts of interest to disclose.
Please address all correspondence concerning this manuscript to me at skt@polteklpp.ac.id
Thank you for your consideration of this manuscript.

Best regards,
Saktiyono Sigit Tri Pamungkas
Department of Plantation, Vocational Education, Polytechnic of LPP Yogyakarta
Jl. LPP No: 1 A, Balapan, Klitren, Gondokusuman, Yogyakarta,Special District of Yogyakarta, 55222, Indonesia

6. Proses *submission corrected manuscript* (24 April 2022)




[RAS] Submission Confirmation for RAS-D-22-00010R1 Eksternal Kotak Masuk

Reviews in Agricultural Science <em@editorialmanager.com>
kepada saya

Min, 24 Apr 2022, 22.37

Ref.: Ms. No. RAS-D-22-00010R1
Drought Stress: Responses and Mechanism in Plants

Dear Pamungkas,

Reviews in Agricultural Science has received your revised submission.

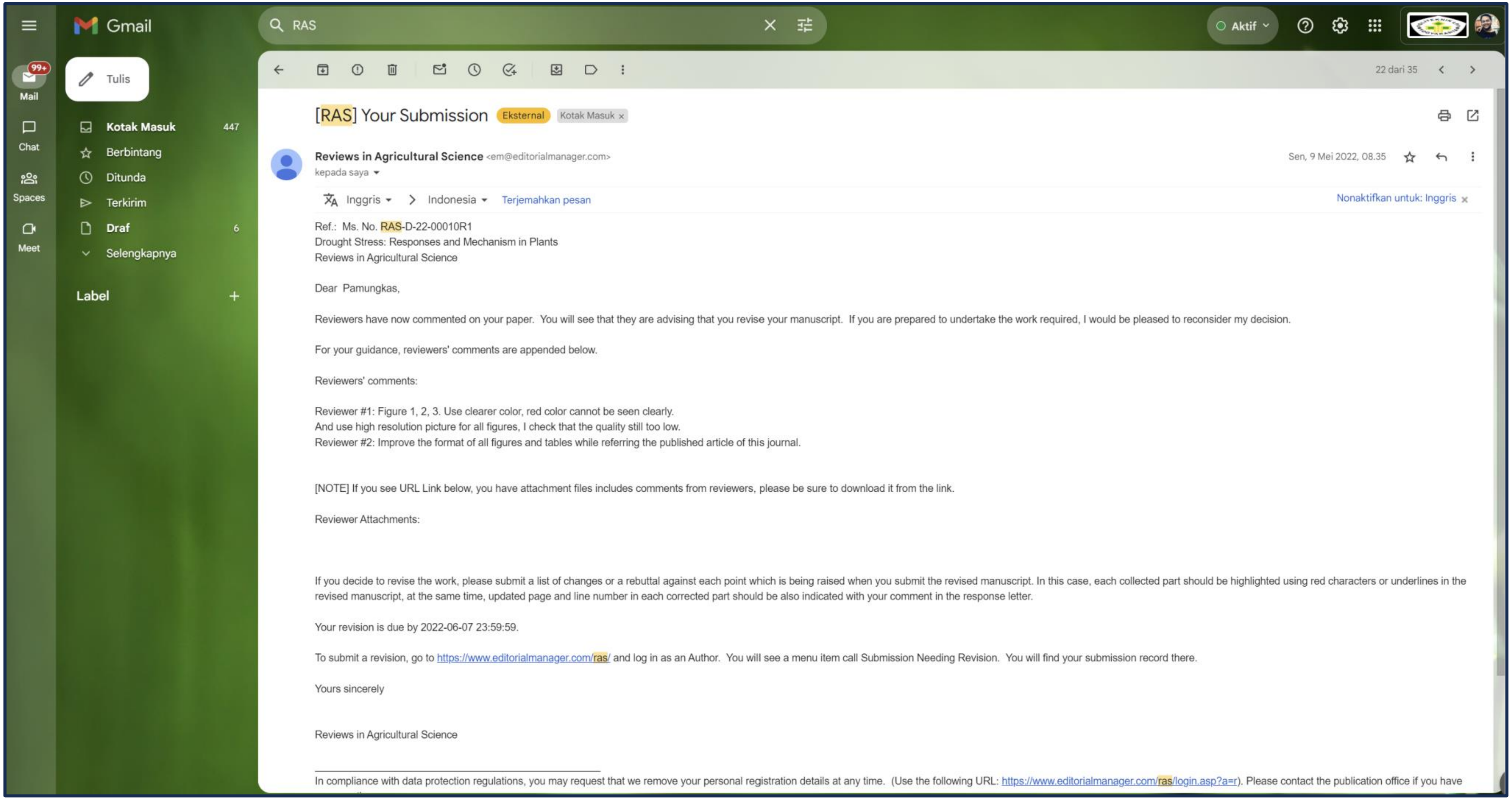
You may check the status of your manuscript by logging onto Editorial Manager at (https://www.editorialmanager.com/ras/).

Kind regards,

Reviews in Agricultural Science

In compliance with data protection regulations, you may request that we remove your personal registration details at any time. (Use the following URL: https://www.editorialmanager.com/ras/login.asp?a=r). Please contact the publication office if you have any questions.

7. Proses *correction/reviewers comments* (9 Mei 2022)



[RAS] Your Submission

Reviews in Agricultural Science <em@editorialmanager.com>
kepada saya

Sen, 9 Mei 2022, 08.35

Ref.: Ms. No. RAS-D-22-00010R1
Drought Stress: Responses and Mechanism in Plants
Reviews in Agricultural Science

Dear Pamungkas,

Reviewers have now commented on your paper. You will see that they are advising that you revise your manuscript. If you are prepared to undertake the work required, I would be pleased to reconsider my decision.

For your guidance, reviewers' comments are appended below.

Reviewers' comments:

Reviewer #1: Figure 1, 2, 3. Use clearer color, red color cannot be seen clearly.
And use high resolution picture for all figures, I check that the quality still too low.
Reviewer #2: Improve the format of all figures and tables while referring the published article of this journal.

[NOTE] If you see URL Link below, you have attachment files includes comments from reviewers, please be sure to download it from the link.

Reviewer Attachments:

If you decide to revise the work, please submit a list of changes or a rebuttal against each point which is being raised when you submit the revised manuscript. In this case, each collected part should be highlighted using red characters or underlines in the revised manuscript, at the same time, updated page and line number in each corrected part should be also indicated with your comment in the response letter.

Your revision is due by 2022-06-07 23:59:59.

To submit a revision, go to https://www.editorialmanager.com/ras/ and log in as an Author. You will see a menu item call Submission Needing Revision. You will find your submission record there.

Yours sincerely

Reviews in Agricultural Science

In compliance with data protection regulations, you may request that we remove your personal registration details at any time. (Use the following URL: https://www.editorialmanager.com/ras/login.asp?a=r). Please contact the publication office if you have

Berikut merupakan proses *correction for reviewers comments batch 2:*

Dear,

Editor in Chief Reviews in Agricultural Science,

I am Saktiyono Sigit Tri Pamungkas, representing on behalf of the manuscript (Suwarto, Suprayogi and Noor Farid). I wish to submit a second revision of my paper according to the reviewers comment.

LIST OF CHANGE

Title: Drought Stress: Responses and Mechanism in Plants
Author: Saktiyono S.T. Pamungkas[1)*], Suwarto[2)], Suprayogi[2)], Noor Farid[2)]

Reviewer 1 and 2

No.	Reviewer Comment	Response
Overall Comments		
1.	Reviewer 1 Figure 1, 2, 3. Use clearer color, red color cannot be seen clearly. And use high resolution picture for all figures, I check that the quality still too low.	Thank you very much for your comment. I have revised it: - I have changed all the red color of the figures (1,2 and 3), I hope this is clearer. You can find in line 889, 892 and 895. - I have corrected and have changed all the resolutions of the figures (1,2,3 and 4) to use the dimensions of 10240 x 5760 pixels and a resolutions of 768 dpi. You can find in line 889, 892, 895 and 898.
2.	Reviewer 2 Improve the format of all figures and tables while referring the published article of this journal.	Thank you very much for your comment. I have revised it: - I have have changed all the resolutions of the figures (1,2,3 and 4) to use the dimensions of 10240 x 5760 pixels and a resolutions of 768 dpi. You can find in line 889, 892, 895 and 898. - I have improve the all of tables (1,2 and 3) by increasing the font size, I hope all the tables can be read clearly. You can find in line 879, 882 and 885.

Rev 1_ List of Change_Saktiyono | Rev 2_ List of Change_Saktiyono | Rev 2_Manuscript_Saktiyono Sig

File | D:/POLITEKNIK%20LPP/JURNAL%20SAKTI/RAS%20JEPANG/Bukti%20Dokumen%20Korespondensi/Cores_Rev%202/Rev%202_Manus

Draw | Read aloud | Ask Copilot | 29 of 31

Table 1. Water status relationship between water potential and soil water volume

Water Status	Water Potential Status		Soil Water Status			Availability to Plant
	pF	Mpa	Sand	Clay	Loam	
Saturation	0	0	39%	50%	54%	Unavailable
Field Capacity	(-) 1-2,5	(-) 0,33	8-10%	20-35%	36-49%	Available
Wilting Point	(-) 4,2	(-) 1,5	4%	9%	29%	Unavailable

Source: [23,32] - modified

Table 2. Plants responses to drought stress

	Response		
	Morphology	Physiology	Biochemical
Drought Stress	Strengthens the roots system (roots elongated)	Stomatal closure	ABA synthesis
	Reduce leaf surface area	Reduce CO_2 fixation	Decreased activity of rubisco
	Rolling the leaves	Decreasing photosynthesis	Accumulation of solute compounds (proline, glycine-betaine, sugar)
	Dropping leaves	Increased ROS compounds	Increased antioxidant compounds
	Early flowering		Drought tolerant gene expression

Source: [52] - modified

Table 3. Relationship between drought stress and the sensitivity of plant metabolic processes

Affected process	Sensitivity															
	Very susceptible						Susceptible				Unsusceptible					
(-) decreased	Pressure (Bar) (-)															
(+) increased	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Cell growth (-)																
Cell wall synthesis (-)*																
Protein synthesis (-)*																
Proto-chlorophyll formation (-)**																
Nitrate reductase (-)																
ABA Synthesis (+)																
Stomatal conductivity (-)																
Fixation of CO_2 (-)																
Respiration																
Xylem conductivity (-)***																
Proline synthesis (+)																
Sugar synthesis (+)																

Note: *= fast growing tissue; **= etiolated leaves; ***= xylem dimension factor

Source: [36] - modified

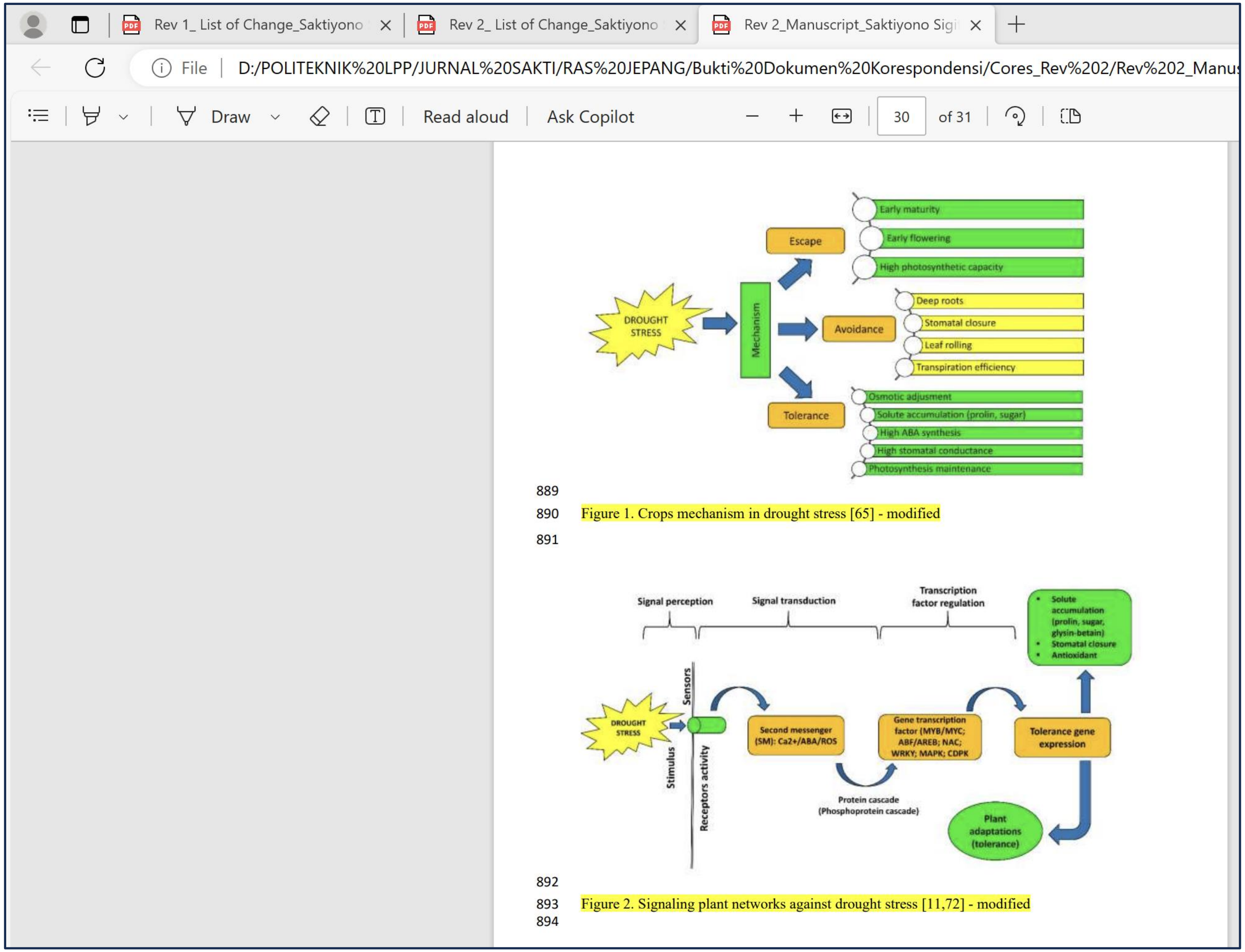


Figure 1. Crops mechanism in drought stress [65] - modified

Figure 2. Signaling plant networks against drought stress [11,72] - modified

Rev 1_ List of Change_Saktiyono | Rev 2_ List of Change_Saktiyono | Rev 2_Manuscript_Saktiyono Sigi

File | D:/POLITEKNIK%20LPP/JURNAL%20SAKTI/RAS%20JEPANG/Bukti%20Dokumen%20Korespondensi/Cores_Rev%202/Rev%202_Manu

Draw | Read aloud | Ask Copilot | 31 | of 31

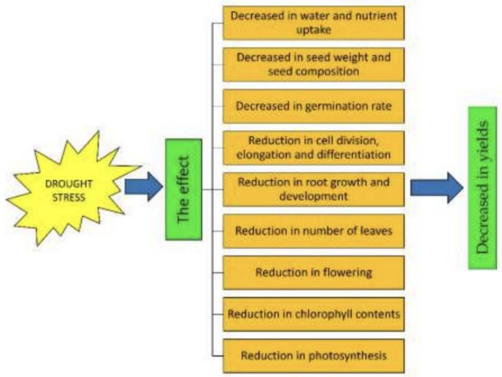


Figure 3. The impact of drought stress on crops [137] - modified

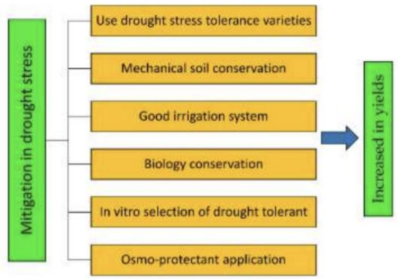
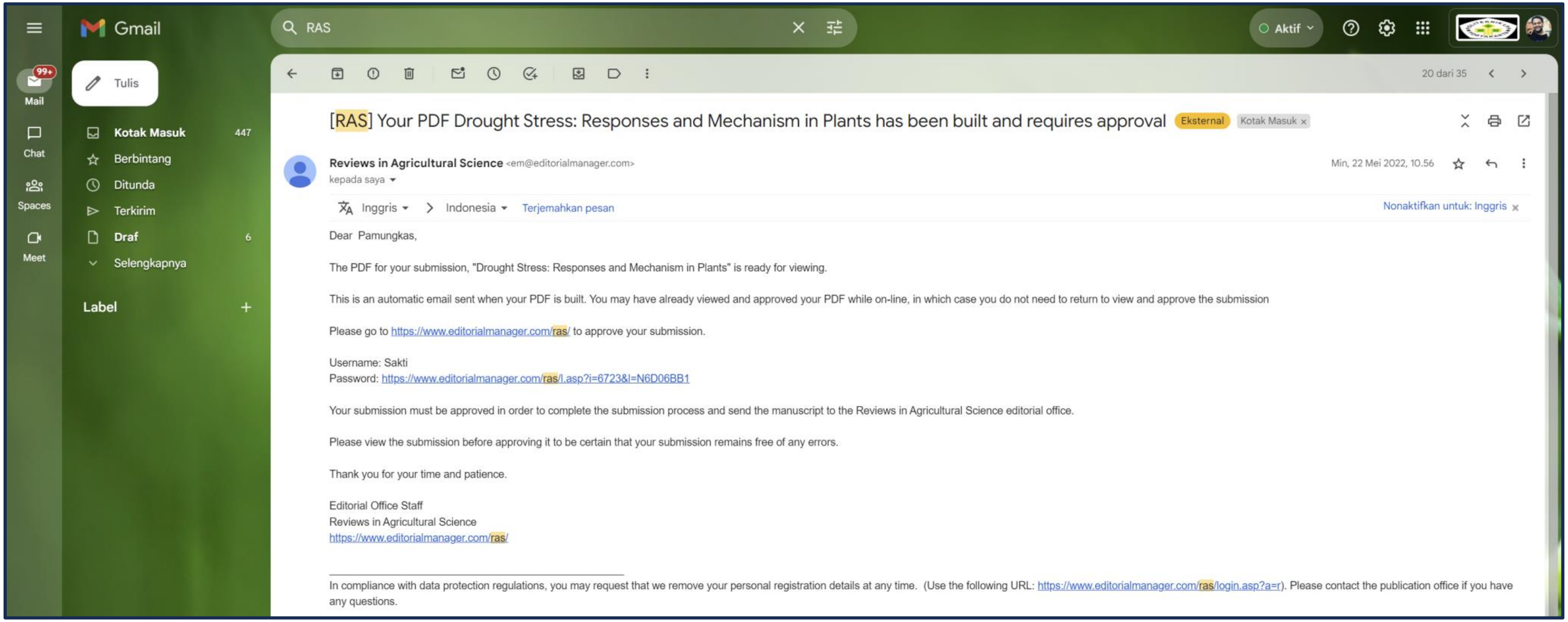


Figure 4. Mitigation in drought stress

8. Proses *approved the submission and submission confirmation for* RAS (22 Mei 2022)



[RAS] Your PDF Drought Stress: Responses and Mechanism in Plants has been built and requires approval

Reviews in Agricultural Science <em@editorialmanager.com>

kepada saya

Min, 22 Mei 2022, 10.56

Dear Pamungkas,

The PDF for your submission, "Drought Stress: Responses and Mechanism in Plants" is ready for viewing.

This is an automatic email sent when your PDF is built. You may have already viewed and approved your PDF while on-line, in which case you do not need to return to view and approve the submission

Please go to https://www.editorialmanager.com/ras/ to approve your submission.

Username: Sakti
Password: https://www.editorialmanager.com/ras/l.asp?i=6723&l=N6D06BB1

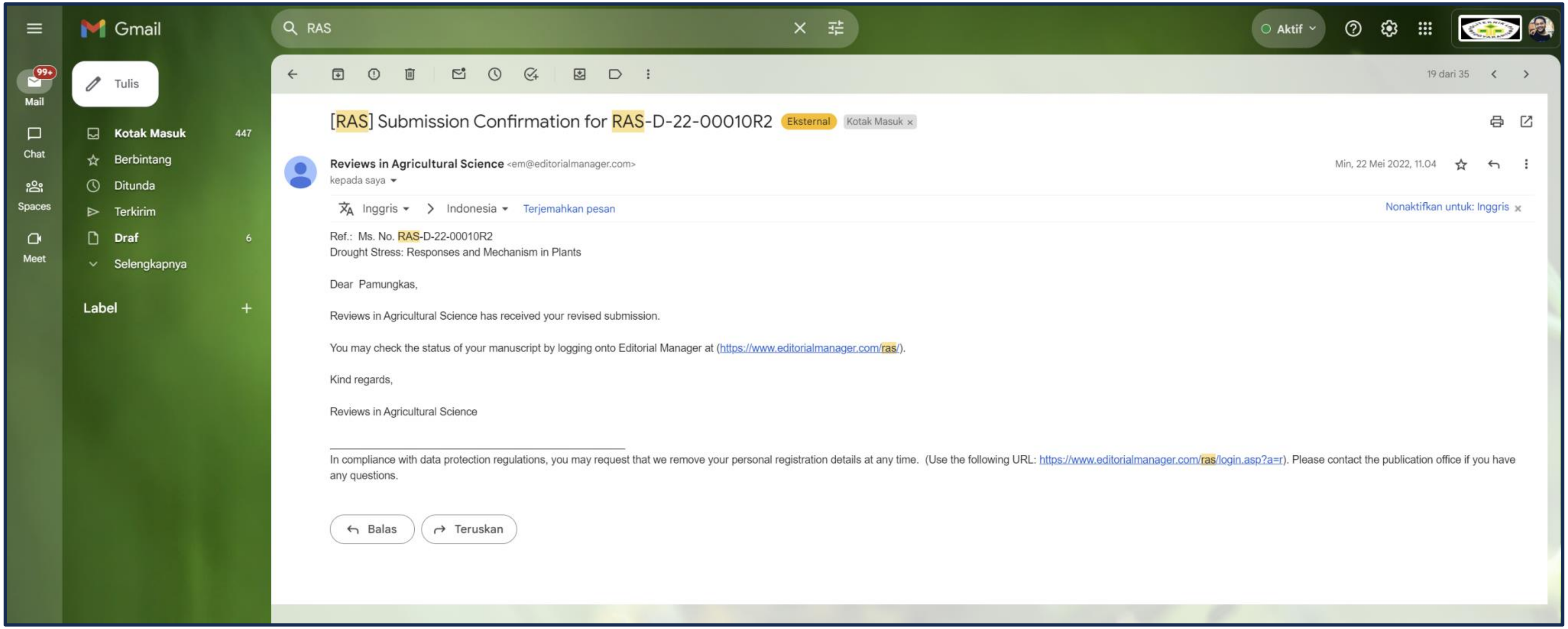
Your submission must be approved in order to complete the submission process and send the manuscript to the Reviews in Agricultural Science editorial office.

Please view the submission before approving it to be certain that your submission remains free of any errors.

Thank you for your time and patience.

Editorial Office Staff
Reviews in Agricultural Science
https://www.editorialmanager.com/ras/

In compliance with data protection regulations, you may request that we remove your personal registration details at any time. (Use the following URL: https://www.editorialmanager.com/ras/login.asp?a=r). Please contact the publication office if you have any questions.


[RAS] Submission Confirmation for RAS-D-22-00010R2 Eksternal Kotak Masuk

Reviews in Agricultural Science <em@editorialmanager.com>
kepada saya
Min, 22 Mei 2022, 11.04

Ref.: Ms. No. RAS-D-22-00010R2
Drought Stress: Responses and Mechanism in Plants

Dear Pamungkas,

Reviews in Agricultural Science has received your revised submission.

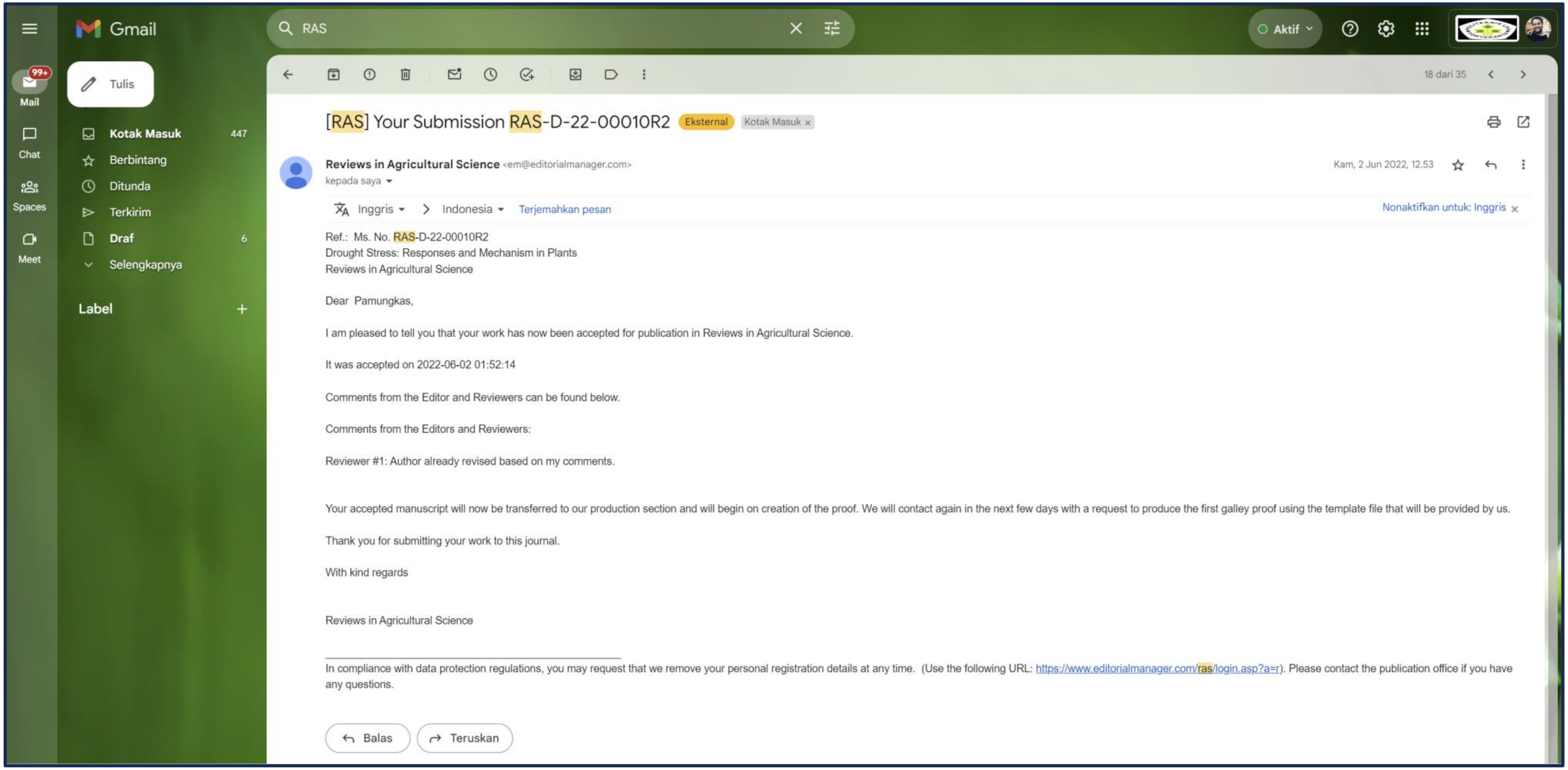
You may check the status of your manuscript by logging onto Editorial Manager at (https://www.editorialmanager.com/ras/).

Kind regards,

Reviews in Agricultural Science

In compliance with data protection regulations, you may request that we remove your personal registration details at any time. (Use the following URL: https://www.editorialmanager.com/ras/login.asp?a=r). Please contact the publication office if you have any questions.

9. Proses *the manuscript was accepted to publish* (2 Juni 2022)



[RAS] Your Submission RAS-D-22-00010R2 Eksternal Kotak Masuk

Reviews in Agricultural Science <em@editorialmanager.com>
kepada saya

Kam, 2 Jun 2022, 12.53

Ref.: Ms. No. RAS-D-22-00010R2
Drought Stress: Responses and Mechanism in Plants
Reviews in Agricultural Science

Dear Pamungkas,

I am pleased to tell you that your work has now been accepted for publication in Reviews in Agricultural Science.

It was accepted on 2022-06-02 01:52:14

Comments from the Editor and Reviewers can be found below.

Comments from the Editors and Reviewers:

Reviewer #1: Author already revised based on my comments.

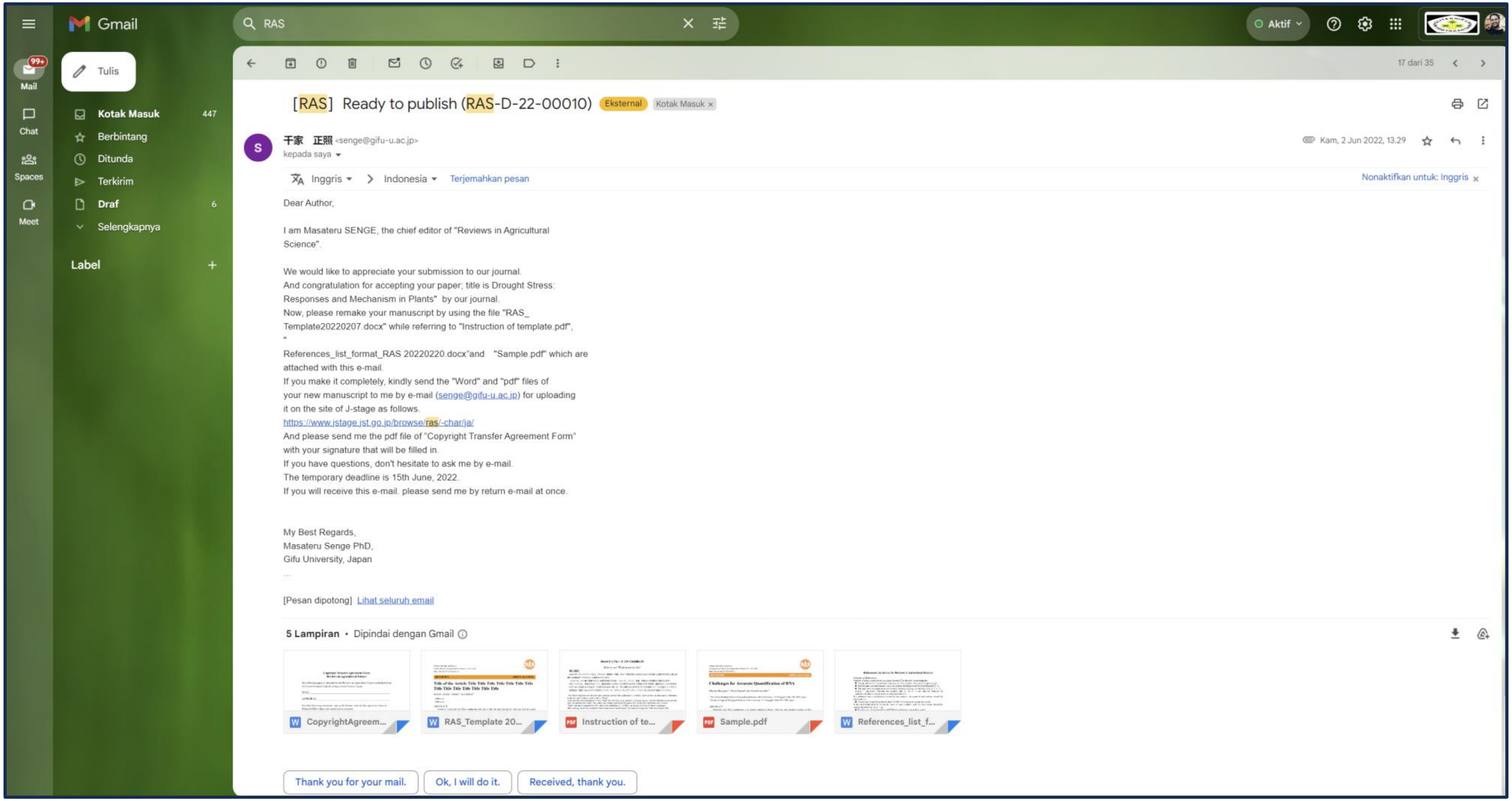
Your accepted manuscript will now be transferred to our production section and will begin on creation of the proof. We will contact again in the next few days with a request to produce the first galley proof using the template file that will be provided by us.

Thank you for submitting your work to this journal.

With kind regards

Reviews in Agricultural Science

In compliance with data protection regulations, you may request that we remove your personal registration details at any time. (Use the following URL: https://www.editorialmanager.com/ras/login.asp?a=r). Please contact the publication office if you have any questions.



[RAS] Ready to publish (RAS-D-22-00010) Eksternal Kotak Masuk

千家 正照 <senge@gifu-u.ac.jp>
kepada saya
Kam, 2 Jun 2022, 13.29

Dear Author,

I am Masateru SENGE, the chief editor of "Reviews in Agricultural Science".

We would like to appreciate your submission to our journal.
And congratulation for accepting your paper; title is Drought Stress: Responses and Mechanism in Plants" by our journal.
Now, please remake your manuscript by using the file "RAS_ Template20220207.docx" while referring to "Instruction of template.pdf", " References_list_format_RAS 20220220.docx"and "Sample.pdf" which are attached with this e-mail.
If you make it completely, kindly send the "Word" and "pdf" files of your new manuscript to me by e-mail (senge@gifu-u.ac.jp) for uploading it on the site of J-stage as follows.
https://www.jstage.jst.go.jp/browse/ras/-char/ja/
And please send me the pdf file of "Copyright Transfer Agreement Form" with your signature that will be filled in.
If you have questions, don't hesitate to ask me by e-mail.
The temporary deadline is 15th June, 2022.
If you will receive this e-mail. please send me by return e-mail at once.

My Best Regards,
Masateru Senge PhD,
Gifu University, Japan

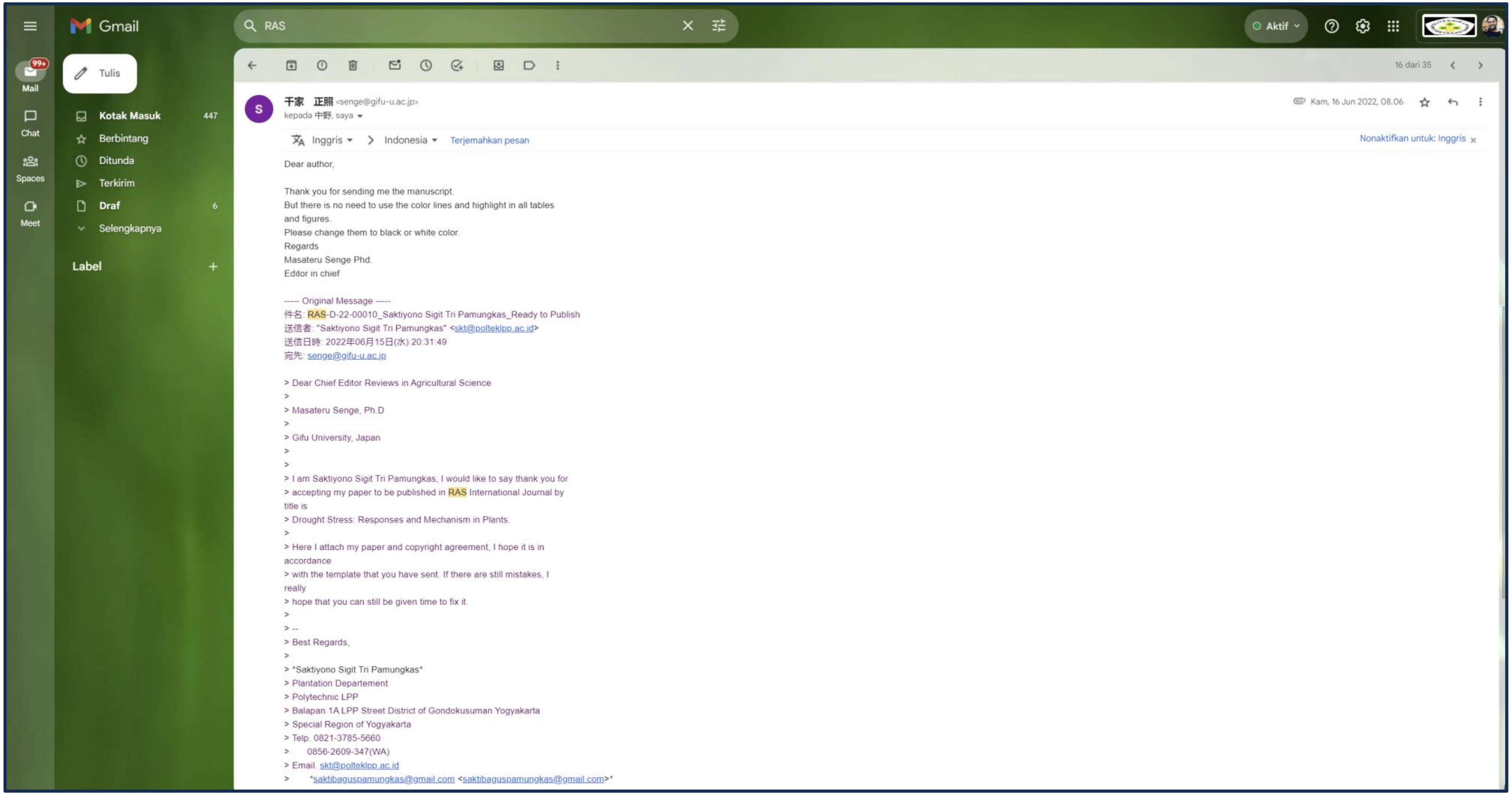
[Pesan dipotong] Lihat seluruh email

5 Lampiran • Dipindai dengan Gmail

CopyrightAgreem... | RAS_Template 20... | Instruction of te... | Sample.pdf | References_list_f...

Thank you for your mail. | Ok, I will do it. | Received, thank you.

10. Proses finalisasi publikasi (2 – 26 Juni 2022)


Gmail
RAS
Aktif
Tulis
Mail
Chat
Spaces
Meet
Kotak Masuk 447
Berbintang
Ditunda
Terkirim
Draf 6
Selengkapnya
Label
16 dari 35

千家 正照 <senge@gifu-u.ac.jp>
kepada 中野, saya
Kam, 16 Jun 2022, 08.06

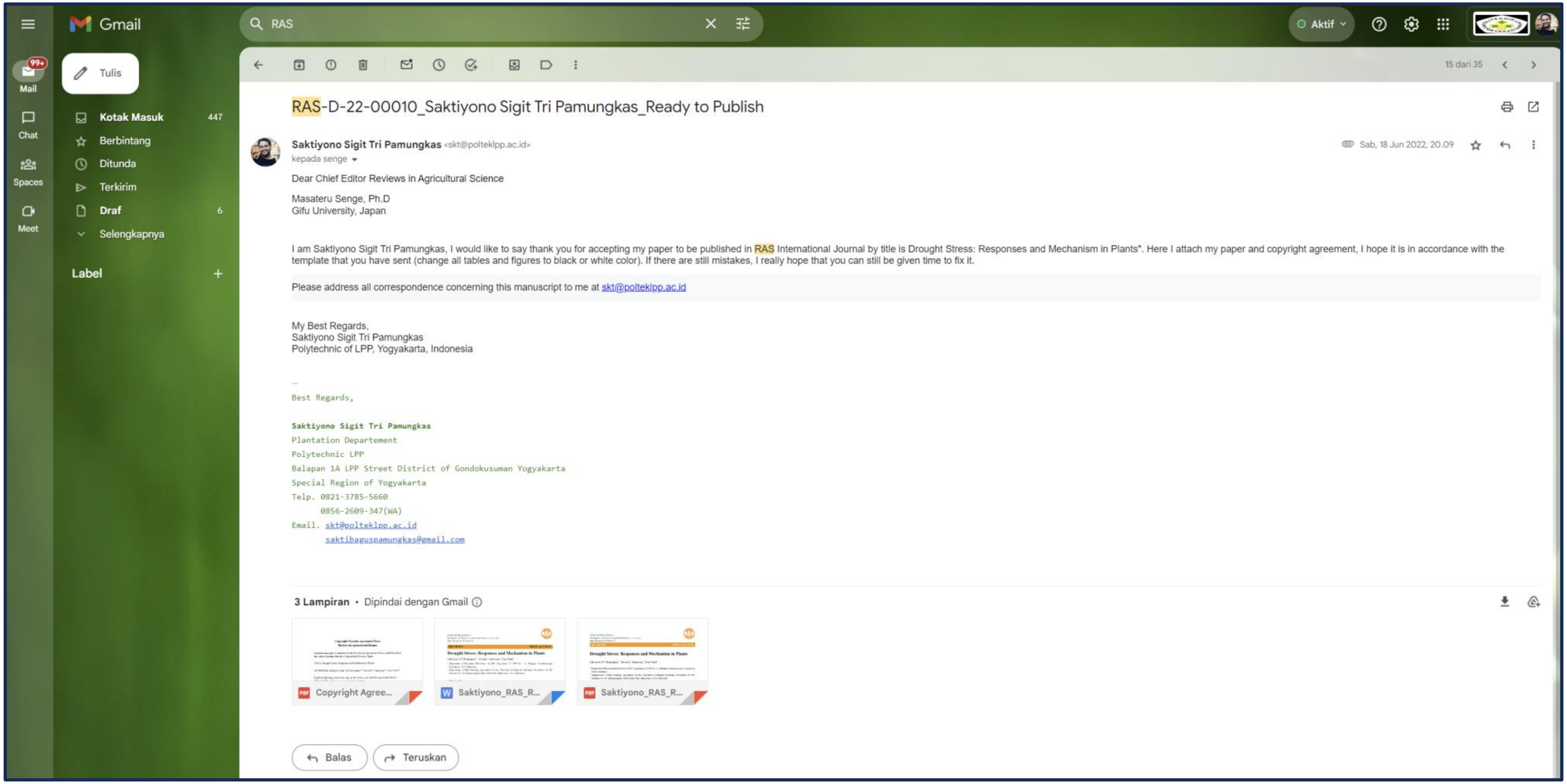
Inggris > Indonesia Terjemahkan pesan
Nonaktifkan untuk: Inggris

Dear author,

Thank you for sending me the manuscript.
But there is no need to use the color lines and highlight in all tables
and figures.
Please change them to black or white color.
Regards
Masateru Senge Phd.
Editor in chief

----- Original Message -----
件名: RAS-D-22-00010_Saktiyono Sigit Tri Pamungkas_Ready to Publish
送信者: "Saktiyono Sigit Tri Pamungkas" <skt@polteklpp.ac.id>
送信日時: 2022年06月15日(水) 20:31:49
宛先: senge@gifu-u.ac.jp

> Dear Chief Editor Reviews in Agricultural Science
>
> Masateru Senge, Ph.D
>
> Gifu University, Japan
>
>
> I am Saktiyono Sigit Tri Pamungkas, I would like to say thank you for
> accepting my paper to be published in RAS International Journal by
title is
> Drought Stress: Responses and Mechanism in Plants.
>
> Here I attach my paper and copyright agreement, I hope it is in
accordance
> with the template that you have sent. If there are still mistakes, I
really
> hope that you can still be given time to fix it.
>
> --
> Best Regards,
>
> *Saktiyono Sigit Tri Pamungkas*
> Plantation Departement
> Polytechnic LPP
> Balapan 1A LPP Street District of Gondokusuman Yogyakarta
> Special Region of Yogyakarta
> Telp. 0821-3785-5660
> 0856-2609-347(WA)
> Email. skt@polteklpp.ac.id
> *saktibaguspamungkas@gmail.com <saktibaguspamungkas@gmail.com>*



RAS-D-22-00010_Saktiyono Sigit Tri Pamungkas_Ready to Publish

Saktiyono Sigit Tri Pamungkas <skt@polteklpp.ac.id>
kepada senge
Sab, 18 Jun 2022, 20.09

Dear Chief Editor Reviews in Agricultural Science

Masateru Senge, Ph.D
Gifu University, Japan

I am Saktiyono Sigit Tri Pamungkas, I would like to say thank you for accepting my paper to be published in RAS International Journal by title is Drought Stress: Responses and Mechanism in Plants". Here I attach my paper and copyright agreement, I hope it is in accordance with the template that you have sent (change all tables and figures to black or white color). If there are still mistakes, I really hope that you can still be given time to fix it.

Please address all correspondence concerning this manuscript to me at skt@polteklpp.ac.id

My Best Regards,
Saktiyono Sigit Tri Pamungkas
Polytechnic of LPP, Yogyakarta, Indonesia

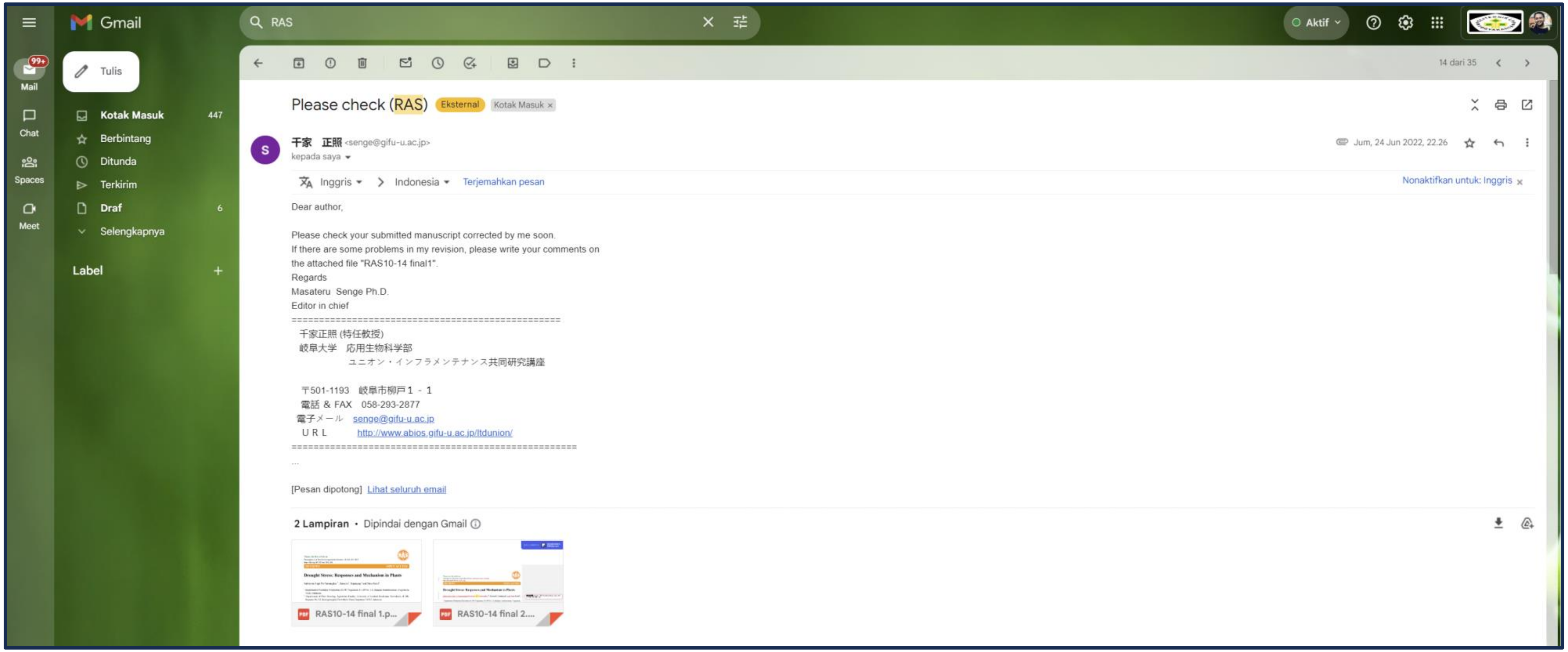
--
Best Regards,

Saktiyono Sigit Tri Pamungkas
Plantation Departement
Polytechnic LPP
Balapan 1A LPP Street District of Gondokusuman Yogyakarta
Special Region of Yogyakarta
Telp. 0821-3785-5660
0856-2609-347(WA)
Email. skt@polteklpp.ac.id
saktibaguspamungkas@gmail.com

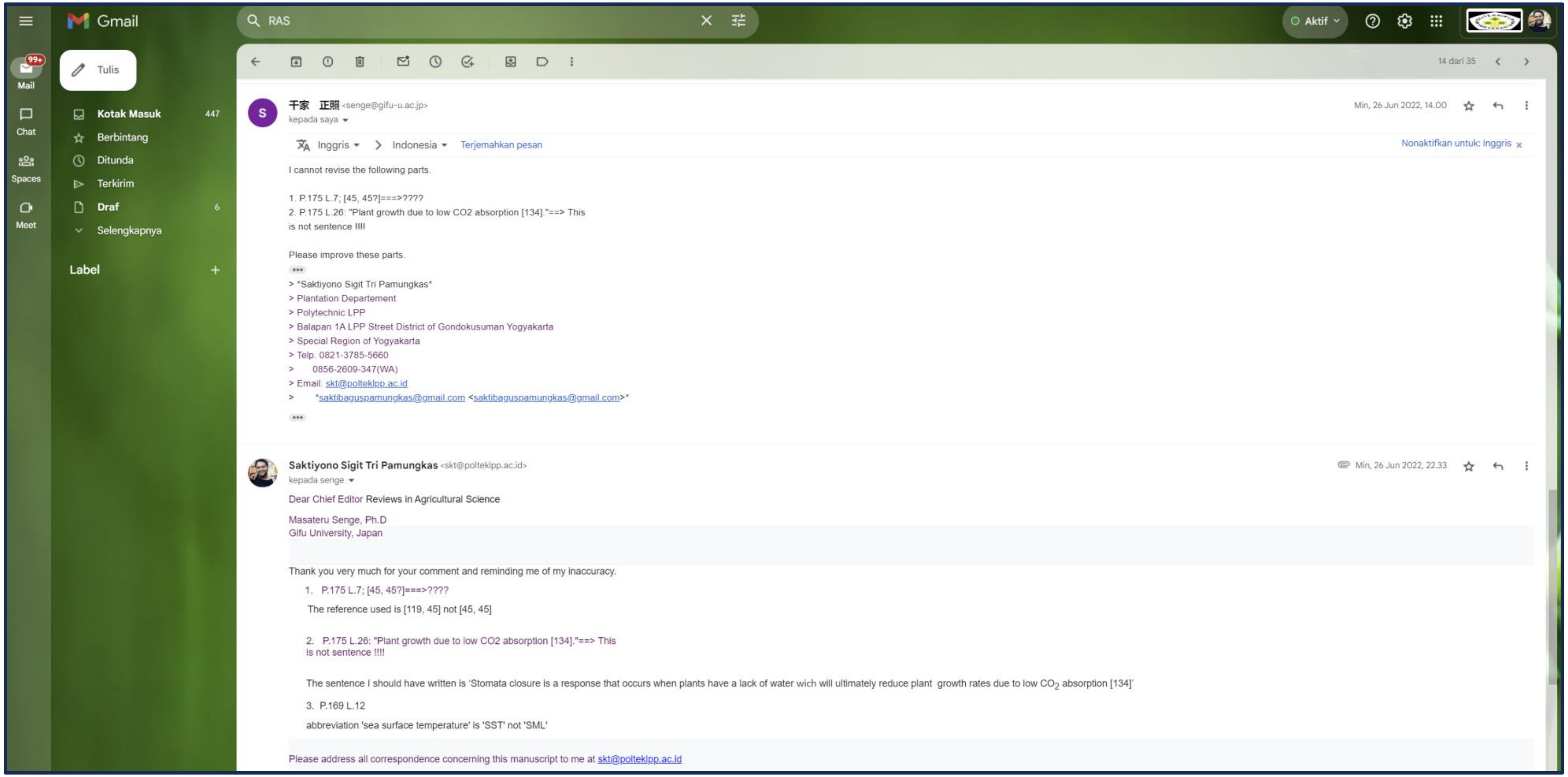
3 Lampiran • Dipindai dengan Gmail

Copyright Agree...
Saktiyono_RAS_R...
Saktiyono_RAS_R...

Balas
Teruskan



Gmail
RAS
Tulis
Mail
Chat
Spaces
Meet
Kotak Masuk 447
Berbintang
Ditunda
Terkirim
Draf 6
Selengkapnya
Label
Aktif
14 dari 35
Please check (RAS) Eksternal Kotak Masuk ×
千家　正照 <senge@gifu-u.ac.jp>
kepada saya
Jum, 24 Jun 2022, 22.26
Inggris > Indonesia Terjemahkan pesan
Nonaktifkan untuk: Inggris ×
Dear author,
Please check your submitted manuscript corrected by me soon.
If there are some problems in my revision, please write your comments on
the attached file "RAS10-14 final1".
Regards
Masateru Senge Ph.D.
Editor in chief
==
千家正照 (特任教授)
岐阜大学　応用生物科学部
ユニオン・インフラメンテナンス共同研究講座
〒501-1193　岐阜市柳戸１－１
電話 & FAX　058-293-2877
電子メール　senge@gifu-u.ac.jp
ＵＲＬ　http://www.abios.gifu-u.ac.jp/ltdunion/
==
[Pesan dipotong] Lihat seluruh email
2 Lampiran • Dipindai dengan Gmail
RAS10-14 final 1.p...
RAS10-14 final 2....



千家 正照 <senge@gifu-u.ac.jp>
kepada saya

Min, 26 Jun 2022, 14.00

I cannot revise the following parts.

1. P.175 L.7; [45, 45?]===>????
2. P.175 L.26: "Plant growth due to low CO2 absorption [134]."==> This is not sentence !!!!

Please improve these parts.

> "Saktiyono Sigit Tri Pamungkas"
> Plantation Departement
> Polytechnic LPP
> Balapan 1A LPP Street District of Gondokusuman Yogyakarta
> Special Region of Yogyakarta
> Telp. 0821-3785-5660
> 0856-2609-347(WA)
> Email. skt@polteklpp.ac.id
> "saktibaguspamungkas@gmail.com <saktibaguspamungkas@gmail.com>"

Saktiyono Sigit Tri Pamungkas <skt@polteklpp.ac.id>
kepada senge

Min, 26 Jun 2022, 22.33

Dear Chief Editor Reviews in Agricultural Science

Masateru Senge, Ph.D
Gifu University, Japan

Thank you very much for your comment and reminding me of my inaccuracy.

1. P.175 L.7; [45, 45?]===>????

The reference used is [119, 45] not [45, 45]

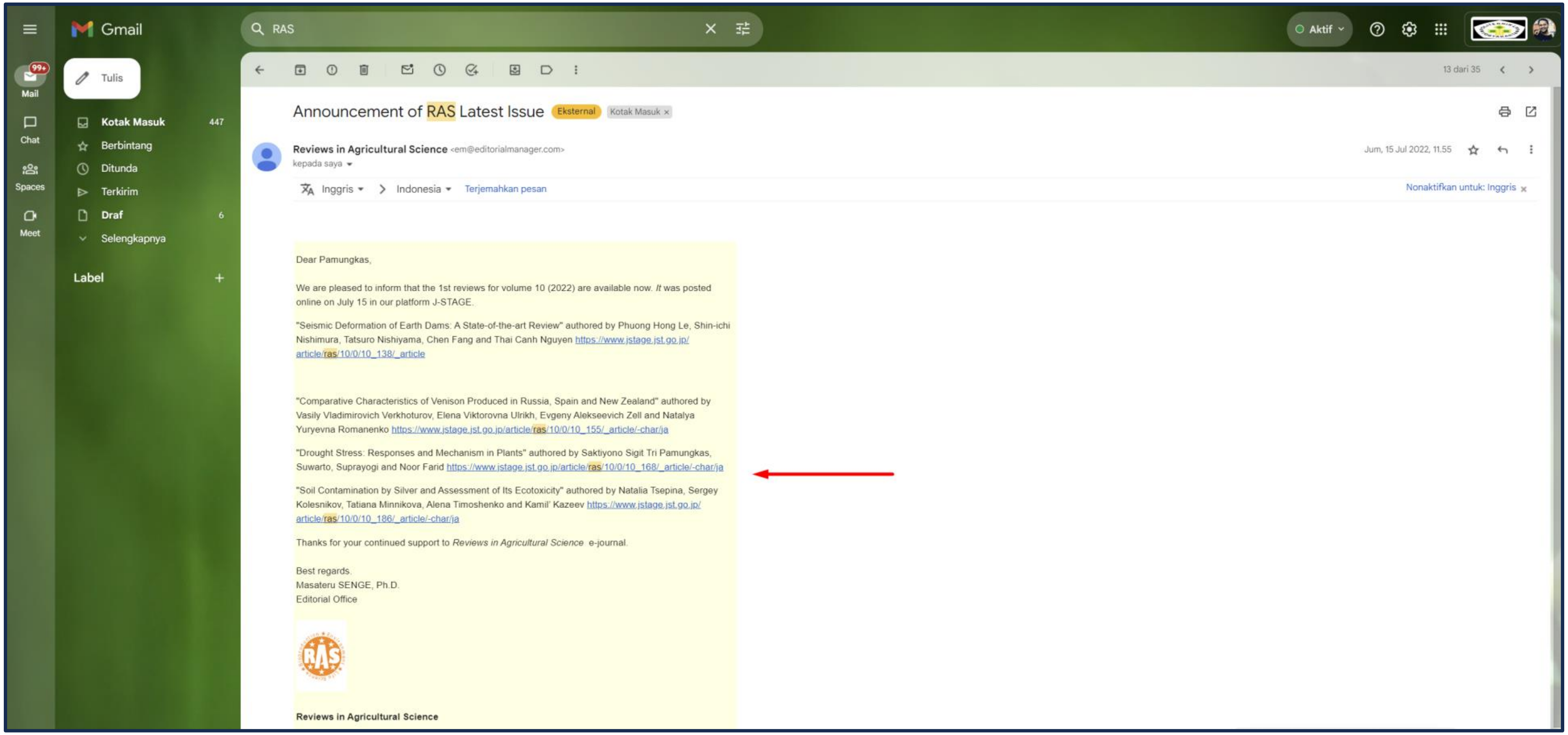
2. P.175 L.26: "Plant growth due to low CO2 absorption [134]."==> This is not sentence !!!!

The sentence I should have written is 'Stomata closure is a response that occurs when plants have a lack of water wich will ultimately reduce plant growth rates due to low CO_2 absorption [134]'

3. P.169 L.12

abbreviation 'sea surface temperature' is 'SST' not 'SML'

Please address all correspondence concerning this manuscript to me at skt@polteklpp.ac.id



Announcement of RAS Latest Issue

Reviews in Agricultural Science <em@editorialmanager.com>
kepada saya

Jum, 15 Jul 2022, 11.55

Dear Pamungkas,

We are pleased to inform that the 1st reviews for volume 10 (2022) are available now. *It* was posted online on July 15 in our platform J-STAGE.

"Seismic Deformation of Earth Dams: A State-of-the-art Review" authored by Phuong Hong Le, Shin-ichi Nishimura, Tatsuro Nishiyama, Chen Fang and Thai Canh Nguyen https://www.jstage.jst.go.jp/article/ras/10/0/10_138/_article

"Comparative Characteristics of Venison Produced in Russia, Spain and New Zealand" authored by Vasily Vladimirovich Verkhoturov, Elena Viktorovna Ulrikh, Evgeny Alekseevich Zell and Natalya Yuryevna Romanenko https://www.jstage.jst.go.jp/article/ras/10/0/10_155/_article/-char/ja

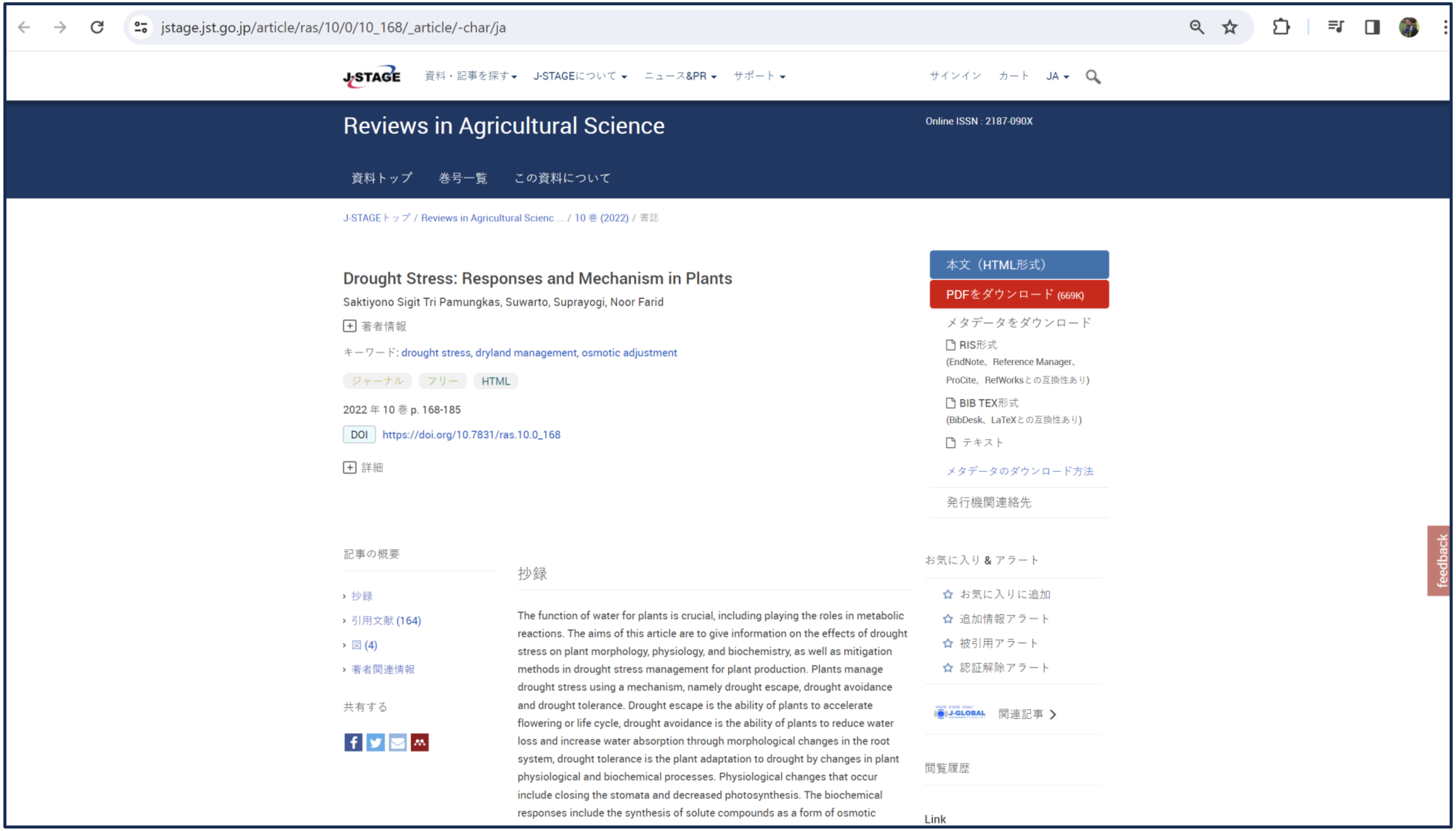
"Drought Stress: Responses and Mechanism in Plants" authored by Saktiyono Sigit Tri Pamungkas, Suwarto, Suprayogi and Noor Farid https://www.jstage.jst.go.jp/article/ras/10/0/10_168/_article/-char/ja

"Soil Contamination by Silver and Assessment of Its Ecotoxicity" authored by Natalia Tsepina, Sergey Kolesnikov, Tatiana Minnikova, Alena Timoshenko and Kamil' Kazeev https://www.jstage.jst.go.jp/article/ras/10/0/10_186/_article/-char/ja

Thanks for your continued support to *Reviews in Agricultural Science* e-journal.

Best regards,
Masateru SENGE, Ph.D.
Editorial Office

Reviews in Agricultural Science



jstage.jst.go.jp/article/ras/10/0/10_168/_article/-char/ja

J-STAGE 資料・記事を探す J-STAGEについて ニュース&PR サポート サインイン カート JA

Reviews in Agricultural Science

Online ISSN : 2187-090X

資料トップ 巻号一覧 この資料について

J-STAGEトップ / Reviews in Agricultural Scienc ... / 10 巻 (2022) / 書誌

Drought Stress: Responses and Mechanism in Plants

Saktiyono Sigit Tri Pamungkas, Suwarto, Suprayogi, Noor Farid

著者情報

キーワード: drought stress, dryland management, osmotic adjustment

ジャーナル フリー HTML

2022 年 10 巻 p. 168-185

DOI https://doi.org/10.7831/ras.10.0_168

詳細

本文（HTML形式）

PDFをダウンロード (669K)

メタデータをダウンロード

RIS形式 (EndNote、Reference Manager、ProCite、RefWorksとの互換性あり)

BIB TEX形式 (BibDesk、LaTeXとの互換性あり)

テキスト

メタデータのダウンロード方法

発行機関連絡先

記事の概要

- 抄録
- 引用文献 (164)
- 図 (4)
- 著者関連情報

共有する

抄録

The function of water for plants is crucial, including playing the roles in metabolic reactions. The aims of this article are to give information on the effects of drought stress on plant morphology, physiology, and biochemistry, as well as mitigation methods in drought stress management for plant production. Plants manage drought stress using a mechanism, namely drought escape, drought avoidance and drought tolerance. Drought escape is the ability of plants to accelerate flowering or life cycle, drought avoidance is the ability of plants to reduce water loss and increase water absorption through morphological changes in the root system, drought tolerance is the plant adaptation to drought by changes in plant physiological and biochemical processes. Physiological changes that occur include closing the stomata and decreased photosynthesis. The biochemical responses include the synthesis of solute compounds as a form of osmotic

お気に入り & アラート

お気に入りに追加

追加情報アラート

被引用アラート

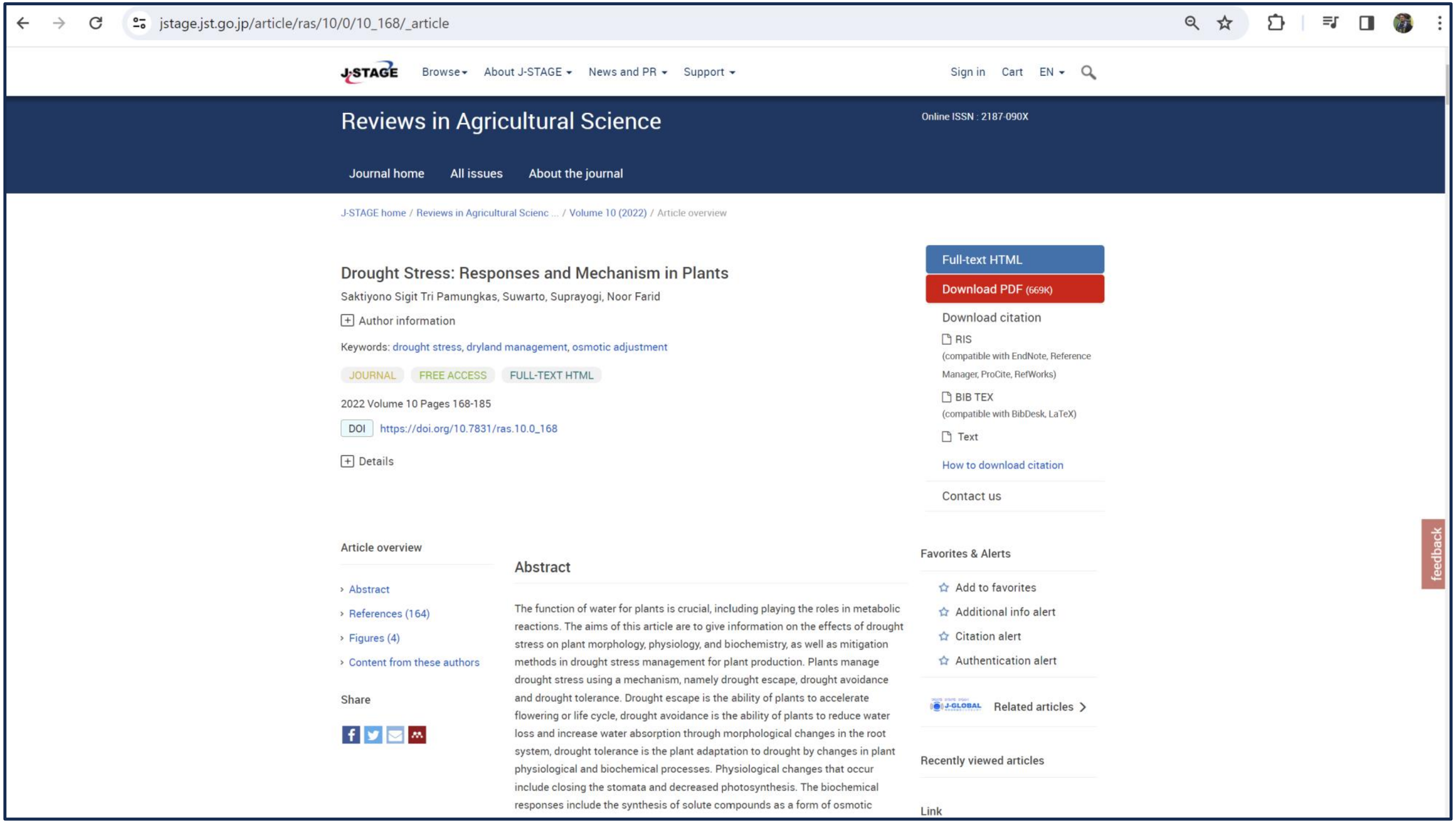
認証解除アラート

J-GLOBAL 関連記事

閲覧履歴

Link

feedback



jstage.jst.go.jp/article/ras/10/0/10_168/_article

J-STAGE Browse About J-STAGE News and PR Support Sign in Cart EN

Reviews in Agricultural Science

Online ISSN : 2187-090X

Journal home All issues About the journal

J-STAGE home / Reviews in Agricultural Scienc ... / Volume 10 (2022) / Article overview

Drought Stress: Responses and Mechanism in Plants

Saktiyono Sigit Tri Pamungkas, Suwarto, Suprayogi, Noor Farid

Author information

Keywords: drought stress, dryland management, osmotic adjustment

JOURNAL FREE ACCESS FULL-TEXT HTML

2022 Volume 10 Pages 168-185

DOI https://doi.org/10.7831/ras.10.0_168

Details

Full-text HTML

Download PDF (669K)

Download citation

RIS (compatible with EndNote, Reference Manager, ProCite, RefWorks)

BIB TEX (compatible with BibDesk, LaTeX)

Text

How to download citation

Contact us

Article overview

- Abstract
- References (164)
- Figures (4)
- Content from these authors

Share

Abstract

The function of water for plants is crucial, including playing the roles in metabolic reactions. The aims of this article are to give information on the effects of drought stress on plant morphology, physiology, and biochemistry, as well as mitigation methods in drought stress management for plant production. Plants manage drought stress using a mechanism, namely drought escape, drought avoidance and drought tolerance. Drought escape is the ability of plants to accelerate flowering or life cycle, drought avoidance is the ability of plants to reduce water loss and increase water absorption through morphological changes in the root system, drought tolerance is the plant adaptation to drought by changes in plant physiological and biochemical processes. Physiological changes that occur include closing the stomata and decreased photosynthesis. The biochemical responses include the synthesis of solute compounds as a form of osmotic

Favorites & Alerts

Add to favorites

Additional info alert

Citation alert

Authentication alert

J-GLOBAL Related articles

Recently viewed articles

Link

feedback

Sakti_Drought Stress_RAS_Q3.pdf

D:/POLITEKNIK%20LPP/JURNAL%20SAKTI/2022/Sakti_Drought%20Stress_RAS_Q3.pdf

Draw | Read aloud | Ask Copilot | 1 of 18

Please cite this article as
Pamungkas *et al*. Reviews in Agricultural Science, 10:168–185, 2022
https://doi.org/10.7831/ras.10.0_168

REVIEWS OPEN ACCESS

Drought Stress: Responses and Mechanism in Plants

Saktiyono Sigit Tri Pamungkas[1*], Suwarto[2], Suprayogi[2] and Noor Farid[2]

[1] Department of Plantation, Polytechnic of LPP, Yogyakarta, Jl. LPP No: 1 A, Balapan, Gondokusuman, Yogyakarta, 55222, Indonesia

[2] Departement of Plant Breeding, Agriculture Faculty, University of Jenderal Soedirman, Purwokerto, Jl. DR. Soeparno No: 63, Karangwangkal, Purwokerto Utara, Banyumas, 53122, Indonesia

ABSTRACT

The function of water for plants is crucial, including playing the roles in metabolic reactions. The aims of this article are to give information on the effects of drought stress on plant morphology, physiology, and biochemistry, as well as mitigation methods in drought stress management for plant production. Plants manage drought stress using a mechanism, namely drought escape, drought avoidance and drought tolerance. Drought escape is the ability of plants to accelerate flowering or life cycle, drought avoidance is the ability of plants to reduce water loss and increase water absorption through morphological changes in the root system, drought tolerance is the plant adaptation to drought by changes in plant physiological and biochemical processes. Physiological changes that occur include closing the stomata and decreased photosynthesis. The biochemical responses include the synthesis of solute compounds as a form of osmotic adjustment in the cell called osmotic adjustment to reduce water loss from the cell. The biochemical indicators are the increased concentrations of abscisic acid (ABA), proline, and sugar (trehalose). ABA acts as a signal to stimulate stomatal closure to reduce the transpiration rate. Proline is an indicator of plants adapting to drought stress, playing a role in the osmotic adjustment of cells to retain in the cell. Trehalose is a compatible sugar acting as an osmoprotectant, it can maintain the integrity of cell membranes (water replacement) and form hydrogen bonds (water entrapment). Plants under drought stress conditions can adapt by making morphological, physiological, and biochemical responses by osmotic adjustment. These conditions need to be managed so that appropriate strategies and technologies are needed as mitigation measures.

Keywords

drought stress, dryland management, osmotic adjustment

1. Introduction

The aims of this article are to give information on the effects of drought stress on plant morphology, physiology, and biochemistry, as well as mitigation methods in drought stress management for plant production. Water is a vital requirement for the survival of plants. Plant tissues are composed mostly of these, which are about 80% to 95%, predominantly found in the cytoplasm and vacuoles [1]. However, some tissues have a content of about 10–15%, one of which is dormant seeds [2]. Water is a major factor in plant growth since it is needed by plants to carry out physiological processes [3]. In plants, these are the main molecule that makes up protoplasm (cytoplasm, nucleus, and organelles) [4]. Besides that, these is a solvent for dissolved substances in cells. If water is used as a solvent for acidic or alkaline components, it will be positively charged (K^+, Ca^{++}, NH_4^+) or negatively charged (NO_3^- SO_3^-, HPO_4^-), respectively. The functions of these as a medium for metabolic and physiological reactions in plants, in

11. Bukti dokumen koreksi (batch 1 dan 2 terlampir)

Lampiran:

1. Correction list (reviewer 1 and 2) batch 1
2. Correction manuscript batch 1
3. Correction list (reviewer 1 and 2) batch 2
4. Correction manuscript batch 2
5. Cover letter submission

Dear

Editor in Chief Reviews in Agricultural Science,

I am Saktiyono Sigit Tri Pamungkas, representing on behalf of the manuscript (Suwarto, Suprayogi and Noor Farid). I wish to submit a revision of my paper according to the reviewers comment.

LIST OF CHANGE

Title: Drought Stress: Responses and Mechanism in Plants
Author: Saktiyono S.T. Pamungkas[1)*], Suwarto[2)], Suprayogi[2)], Noor Farid[2)]

Reviewer 1

No	Reviewer Comment	Response
1.	on abstract: Too long, see author guideline.	Thank you very much for your comment. I have revised it: I have corrected the abstract no more than 300 words according to the guidelines. In the abstract there are 273 word. You can find in line 26 to 46.
2.	on abstract: Try to focus on the main issue and finding.	Thank you very much for your comment. I have revised it: - I have corrected in the abstract. I have written the purpose of writing this review. You can find in line 28. - I have corrected in the abstract. I have focused on the topic of plant responses and mechanisms to drought stress. You can find in line 30 to 43.
3.	on abstract: "Plants manage drought stress by using three mechanisms": this statement is not good because no detail explanation in abstract.	Thank you very much for your comment. I have revised it: I have corrected the statement in the abstract. You can find in line 30.

4.	on abstract: …the conclusion…: I think it is better to not mention "conclusion", but directly state the main finding and implication (briefly).	Thank you very much for your comment. I have revised it: I have corrected the statement in the abstract. You can find in line 43 to 46.
5.	on introduction: Too many "water" for the first word in sentences, you must learn how to diversify it.	Thank you very much for your comment. I have revised it: in the introduction I have tried to improve by reducing the word 'water' in the sentence. You can find in line 57 to 96.
6.	on introduction: no aims is stated in introduction.	Thank you very much for your comment. I have revised it: I have added aims in introduction. You can find in line 54.
7.	on introduction: I'm not sure whether this paper focus on Indonesian case, but author stated that this paper about Indonesian case.	Thank you very much for your comment. I have revised it: I apologize for my mistake in writing the drought stress case in Indonesia. I intend to write about the impact of drought and its response to plants, but I hope this paper can be used as basic information about the impact of drought stress and its management efforts, especially on plant cultivation in Indonesia. I have corrected my cover letter.
8.	on Physiological Effects and Mechanisms: 275-276: "one way"? I don't understand this	Thank you very much for your comment. I have revised it: I have corrected the statement. You can find in line 276 to 278.
9.	on result: Figure 1 and other are not clear enough to be read, you must use good colour combination in order to all illustration can be understood.	Thank you very much for your comment. I have revised it: I have corrected figure size and colour combination. I hope these can be understood. You can find in line 889 to 890; 892 to 893; 895 to 896 and 898 to 899.

10.	on result: Maybe it is better to add chapter about the drought stress management.	Thank you very much for your comment. I have revised it: I have added chapter about the drougt stress management. You can find in line 354 to 378.
11.	on conclusion: I think the purpose of this paper need to be clearer, about drought stress or dryland plantation? Focus on theoretical framework of drought stress or optimizing dryland plantation?	Thank you very much for your comment. I have revised it: I have corrected and focus on theoretical framework of drought stress impact and response to plants, but I added some management to reduce the impact of the drought stress. You can find in line 379 to 387.

Reviewer 2

No	Reviewer Comment	Response
Overall Comments		
1.	The topics of your article is very important for crop production in arid area and climate. But the purpose of your paper is not clear as review article.	Thank you very much for your comment. I have revised it: I have written purpose in the abstract and introduction. You can find in line 28 and 54. I have corrected and focus on theoretical framework of drought stress impact and response to plants, but I added some management to reduce the impact of the drought stress. You can find in line 379 to 387.
2.	You had better describe your original strategy, opinion and propose for crop production especially in the chapter of "conclusion".	Thank you very much for your comment. I have revised it: - I have added chapter about the drougt stress management. Line 354 to 378. - The conclusion chapter briefly describes the impact of drought and some mitigation efforts that can be done. mitigation that is written is a conclusion from drougt stress management. You can find in line 354 to 378 (chapter drought stress management) and 379 to 387 (chapter conclusion).

Best regards,

Saktiyono Sigit Tri Pamungkas

Department of Plantation, Vocational Education, Polytechnic of LPP Yogyakarta

Jl. LPP No: 1 A, Balapan, Klitren, Gondokusuman, Yogyakarta,Special District of Yogyakarta, 55222, Indonesia

Title: Drought Stress: Responses and Mechanism in Plants

Total number of words: 9,898 words

Author: Saktiyono S.T. Pamungkas[1)*], Suwarto[2)], Suprayogi[2)], Noor Farid[2)]
Affiliation[1)]: Department of Plantation, Polytechnic of LPP, Yogyakarta
Address[1)]: Jl. LPP No: 1 A, Balapan, Gondokusuman, Yogyakarta, 55222, Indonesia
[*]Corresponding author: Email: skt@polteklpp.ac.id
Affiliation[2)]: Departement of Plant Breeding, Agriculture Faculty, University of Jenderal Soedirman, Purwokerto
Address[2)]: Jl. DR. Soeparno No: 63, Karangwangkal, Purwokerto Utara, Banyumas, 53122, Indonesia

Abstract:

The function of water for plants is crucial, including playing the roles in metabolic reactions. The aims of this article is to give information on the effects of drought stress on plant morphology, physiology, and biochemistry, as well as mitigation methods in drought stress management for plant production. Plants manage drought stress using a mechanisms, namely drought escape, drought avoidance and drought tolerance. Drought escape is the ability of plants to accelerate flowering or life cycle, drought avoidance is the ability of plants to reduce water loss and increase water absorption through morphological changes in the root system, drought tolerance is the plant adaptation to drought by changes in plant physiological and biochemical processes. Physiological changes that occur include closing the stomata and decreased photosynthesis. The biochemical responses include the synthesis of solute compounds as a form of osmotic adjustment in the cell called osmotic adjustment to reduce water loss from the cell. The biochemical indicators are the increased concentrations of abscisic acid (ABA), proline, and sugar (trehalose). ABA acts as a signal to stimulate stomatal closure to reduce the transpiration rate. Proline is an indicator of plants adapting to drought stress, playing a role in the osmotic adjustment of cells to retain in the cell. Trehalose is a compatible sugar acting as an osmoprotectant, it can maintain the integrity of cell membranes (water replacement) and form hydrogen bonds (water entrapment). Plants under drought stress conditions can adapt by making morphological, physiological, and biochemical responses by osmotic adjustment. These conditions need to be managed so that appropriate strategies and technologies are needed as mitigation measures.

Keywords: Drought Stress, Dryland Management, Osmotic Adjustment

Introduction

The aims of this article is to give information on the effects of drought stress on plant morphology, physiology, and biochemistry, as well as mitigation methods in drought stress management for plant production. Water is a vital requirement for the survival of plants. Plant tissues are composed mostly of these, which is about 80% to 95%, predominantly found in the cytoplasm and vacuoles [1] . However, some tissues have a content is about 10-15%, one of which is dormant seeds [2] . Water is a major factor in plant growth since it is needed by plants to carry out physiological processes [3]. In plants, these is the main molecule that makes up protoplasm (cytoplasm, nucleus, and organelles) [4]. Besides that these is a solvent for dissolved substances in cells. If water is used as a solvent for acidic or alkaline components, it will be positively charged (K^+, Ca^{++}, NH_4^+) or negatively charged (NO_3^-, SO_3^-, HPO_4^-), respectively. The functions of these as a medium for metabolic and physiological reactions in plants, in which metabolic and physiological activities can decrease when there is a lack of water and also plays a role as a medium for transporting essential nutrients and minerals from the soil so that a lack of water can reduce the rate of nutrient uptake from the soil by roots [5]. These is also one of the main factors determining plant production related to biomass production and transpiration rate [6]. Water will affect cell turgidity, thereby affecting the process of opening and closing stomata. The conversion of sunlight will be reduced if the stomata are closed, which will affect the photosynthesis results [7]. These is also affects transpiration in plants, in which more water will increase the transpiration rate and vice versa [8].

Plants will always be exposed to various stress conditions, including biotic stresses such as pests, pathogens, viruses, nematodes [9], and abiotic stresses, namely drought, water saturation, temperature, and salinity . One of the stresses influencing the growth and yield of cultivated plants is drought [10]. According to the agronomic point of view, drought is defined as the relationship between moisture and water availability in the soil. These absorption and dissolved mineral nutrients decrease when there is a lack in the soil [12]. Disruption in the absorption process disrupts metabolic processes, impacting plant physiological and morphological functions, which can affect yields [11]. Drought occurs due to climate change and soil type. All regions in the world with a share of seawater will experience El Nino, a condition in which the sea surface temperature (SML) warms up, resulting in a long drought that decreases the water availability, which is predicted to affect the rate of evapotranspiration [13]. In Indonesia, in the range of 2019, El Nino had an impact on the expansion of dryland areas almost three times compared to that in 2017 [14]. The characteristics of soil types are very diverse [15], so the ability of the soil to hold water in field capacity varies according to the soil texture [16,17]. Sandy soil type can hold water about 2.1 in/ft, clay can hold these around 3.8 in/ft, while clay soils can hold these around 4.4 in/ft [18].

In the soil these is divided into four types, including chemical, hygroscopic, capillary, and groundwater [19]. Chemical water located in the soil surface that still contains chemicals (from rain) and is a type of soil that is not available to plants. Hygroscopic is strongly bound by the soil (permeates). Capillary fills the capillary pores (infiltration) in the soil with a greater cohesive force than the adhesion force on soil particles, making it available to plants. Whereas groundwater can continue to fall to the bottom layer due to the influence of gravity (percolation). Available of these is defined as the condition or difference between the amount of the field capacity and the amount of the wilting point [20]. Field capacity is the amount of capillary in the soil, while the wilting point is the amount of hygroscopic water in the soil that makes water unavailable [21].

Water Deficit

The ideal soil composition consists of 45% mineral content, 25% water, 25% air, and 5% organic matter [22,23] . This condition will stabilize the water tension at field capacity (pF) on the soil, stabilizing the force of attraction between water molecules (cohesion) and between water molecules and soil particles (adhesion) becomes. If cohesion is stronger than adhesion, the water can't be bound by soil pores [24,25] . In addition to being influenced by the adhesive power, the soil's ability to bind water also depends on the type of soil. The higher the clay content of the soil, the lower the adhesion force, causing a low pF value, resulting in water saturation so that water is not available. On the other hand, low cohesion will result in a high pF value, which in turn causes a water deficit [26,27]. Besides being influenced by pF, it is also influenced by water potential [28,29]. At a pressure of 0 Mpa, the soil is saturated with water, while -0.33 Mpa at field capacity conditions and -1.5 to -3 Mpa is the permanent wilting point [30,31]. In addition to the influence of pressure, according to Easton [23] and Datta *et al.* [32], the volume of water in the soil also depends on the type of soil to bind water so that it will determine water saturation (sand: 39%, clay: 50%, clay: 54 %), field capacity (sand: 8-10%, clay: 20-35%, clay: 36-49%) and permanent wilting point (sand: 4%, clay: 9%, clay: 29%). A high pF value will lead to high percolation, resulting in water loss and a low groundwater potential. Otherwise, a low pF value causes low water holding capacity with the soil pores (adhesion), resulting in low groundwater potential.

In drought conditions, plants will lack water in the rhizosphere (around plant roots), decreasing groundwater potential (Ψ_w) and increasing osmotic potential in plant cells (Ψs), which decrease plant cell turgor pressure (Ψ_p) (-) [33,34] . Such conditions must be balanced by maintaining cell turgor pressure to remain in a positive condition. Turgor pressure (Ψ_p) that has a positive value depends on the ability of plant cells to balance the value of Ψ_w and the value of Ψ_s with a certain scheme. This condition is called osmotic adjustment in plant cells (osmotic adjustment), shown in an equation of $\Psi_w = \Psi_s + \Psi_p$ [35,36] .

Turgor pressure affects the shape, reaction, and cell changes in plants. Water deficit in grains (barley and corn) was reported to decrease cell turgor pressure [37,38]. Under decreased turgidity, water molecules leave the cell. If water continues to leave the cell, the cell loses flexibility, resulting in wilting [39]. To prevent water from leaving the cell, the cell applies an osmoregulation mechanism to maintain the turgor pressure remains positive (+). If transpiration continues to occur, while the water absorption process continues to decrease, the cell is no longer able to maintain turgidity, other than wilting, if the plant is unable to recover, the plant may die [40]. Water deficit in plants can affect morphology and physiology. At the morphological level, water deficit will cause the leaves to wither, the leaves to shrink, curling leaves, the small number of leaves, the elongated roots [41,42], and early flowering [43]. At the physiological level, it can disrupt metabolism, thereby affecting crop yields. The metabolic process is characterized by the formation of compounds in response to drought conditions, such as sugar [44,45], glycine-betaine [46,47], proline [48,49], and ABA [50,51].

Drought Responses

Drought causes plants to experience an increase in osmotic pressure, resulting in a decrease in cell turgor pressure. If the drought continues beyond the limit of permanent wilting, the plant may suffer damage and death [40,53]. As a form of anticipation, plants carry out certain mechanisms to keep physiological and metabolic processes running. Drought causes water deficit in plants, affecting their morphology [54]. There are three levels of water deficit, consisting of mild drought stress (lower water deficit), moderate drought stress (middle water deficit) when the water potential decreases, and severe drought stress (higher water deficit). Mild, moderate, and severe drought stress occurs when the water potential decreases to 0.1 MPa, up to 1.2 Mpa to 1.5 Mpa, and more than 1.5 MPa, respectively. This condition can decrease the relative water content (RWC) in plants, for example, leaves. Moderate to severe drought stress can decrease relative water content RWC in teak [55]. The decrease in RWC in soybean plants can reduce the water potential in the leaves [56]. In tomatoes, a decrease in RWC can affect fruit weight and the amount of chlorophyll in leaves [57]. Mild, moderate, and severe drought stress will reduce RWC by about 8-10%, 10-20%, and more than 20%, consecutively. The continuous severe drought stress will disrupt the physiological processes of the plant. Disruption of plant physiological processes ultimately results in decreased yields of several crops (tomato, corn, potato, rice, and wheat) [58-68].

Adaptation Strategy

According to Rini *et al*. [11], plants respond to drought stress by three mechanisms (escape, avoidance, and tolerance). Drought escape is a form of plant adaptation to drought stress by accelerating the generative phase. In this condition, the plant stops the vegetative phase and tries to produce seeds before drought stops its life cycle [69]. Wheat plants accelerate the generative phase and terminate vegetative growth to minimize water loss [70]. This strategy is common for plants to complete their life cycle as long as the environment is still possible before facing drought. In Arabidopsis plants, this strategy is carried out by using water efficiently for growth [71]. These mechanisms include early flowering and harvest age, as well as plant plasticity [72]. Drought avoidance is an adaptation of plants to maintain water availability under stress conditions, keeping the water potential in cells remains high. One of the common morphological indications is its effect on root elongation [11,73]. In potato plants, this strategy is indicated by the elongation of roots and differences in the number of shoots [74]. Differences in root morphology in Arabidopsis are used to increase water uptake so that the water content in the tissue remains balanced [75]. The physiological effects that occur may be a decrease in the rate of transpiration and a decrease in the area of transpiration, such as small leaf and a small number of leaves [76]. Drought tolerance is a condition for plants to survive despite experiencing drought stress (water deficit) [11].

Stress Signal Mechanisms

Plants respond to drought stress in the form of a sign, called signal perception (SP), due to the introduction of a stimulus to stress conditions. This signal begins with a disturbance in the balance of the cell wall so that signal activation will occur in the form of protein molecules [11] [72]. The difficulty of roots in absorbing water can provide a signal by modifying the cell membrane so as not to lose cell turgidity [77]. SP is assisted by components in the form of smaller molecules, such as diacylglycerol (DAG) and phosphatidic acids (PA), which are referred to as second messengers (SM) that will transmit SP as a form of stress signal in plants before signal transduction (ST) occurs [11]. Drought will cause changes in osmotic pressure in cells so that SP will stimulate the hydraulic signal (HS) in plant cells by trying to increase dissolved materials so that water does not leave the cell. HS in Arabidopsis plants is initiated by the AHK1 kinase (protein) compound, which functions as an osmo-sensor in the plant cell membrane layer [78]. Osmo-sensors in Arabidopsis plants are associated with calcium channels called hyperosmolality gated calcium-permeable channels (OSCA) that allow Ca^{2+} influx processes in cell membranes [79]. In addition to another OSCA, there is another osmo-sensor called MSL (mechanism sensitive like ion channels). MSL is an osmo-sensor found in plant cell membranes affecting the process of K^+ influx [80]. Another osmo-sensor found in plant cell membranes is receptor-like protein kinase (RLKs) which play an important role in inducing abscisic acid (ABA) as a signal form against drought stress [81].

After exposure to drought stimulates SP assisted by SM, the next step is ST initiation. ST is a protein kinase molecule that is a series of signals in plants experiencing abiotic stress, including drought, to stimulate certain protein kinases in response to stress [11]. Mitogen-activated protein kinase (MAPK) and Calcium-dependent protein kinase (CDPK) are types of ST in plants connected to target molecules in the MAPK cascade system, functioning as ST in the phosphorylase and dephosphorylation processes [82]. In cotton and arabidopsis plants, MAPK is found in leaf cell membranes and affects the regulation of stomata and growth (length) of plant roots [83,84]. MAPK interaction with sucrose nonfermenting related protein kinase-1 (SnRK1) also affects carbohydrate metabolism to be converted into simpler molecules during drought stress [85]. CDPK is an ST formed due to the influx of Ca^{2++} in plant cell membranes that affect ABA regulation and stomata regulation in potato plant leaves [86]. In strawberries, CDPK is identified on cell membranes in the form of FaCDPK appearing in the fruit ripening phase under drought stress conditions. This FaCDPK causes an increase in ABA in strawberry fruit [87]. In soybean plants, CDPK is identified as GmCDPK3, which can lead to an increase in proline and chlorophyll. This condition increases plant resistance to drought conditions [88]. In addition to MAPK and CDPK, drought stress leads to the production of ROS compounds in the form of hydroxyl peroxide (H_2O_2) and singlet oxygen (O_2^-), which decrease the amount of chlorophyll, thereby forcing plants to form antioxidant compounds, one of which is proline [89]. High ROS compounds can cause oxidative stress so that cells can die. Therefore, cells respond by activating antioxidant enzymes to prevent cell damage [90].

Physiological Effects and Mechanisms

Plant growth and development are related to cell division, elongation, and differentiation, which depend on water availability [91-93]. In 15 wheat genotypes, water deficit can reduce yields by 20% to 25% [94]. Moderate and severe water drought stress will increase the dry weight of wheat grain per 1000 grains by 1.95% to 2.07% as a result of the starch formation response [95]. There is no significant reduction in the yield of quinoa plants under drought stress. However, there is an increase in the amount of proline, glutamine, Na, K, and ABA and a decrease in the stomatal opening, thereby reducing transpiration [96]. Water deficit in rice plants is a limiting factor that can reduce yields up to 25.4% and affect root length as a strategy to deal with drought stress [97]. In some plants, water deficit inhibits flower formation [98] [99]. The conclusion is that water deficit can inhibit flowering, increase the number of solutes and reduce yields in plants.

Water deficit causes plants to carry out physiological responses by reducing transpiration, closing stomata, and reducing the number of leaves [11,72,73]. In tomato plants, a decrease in the rate of photosynthesis is due to a lack of water and a high rate of respiration, resulting in the efficient use of water [100]. The stomatal closure to suppress the transpiration rate is related to the efficiency of photosynthesis. In photosynthesis, the efficiency of light absorption and transformation is determined by chlorophyll fluorescence and electron transport [101]. Low light absorption by chlorophyll can result in low light waves, decreasing the CO_2 and energy absorbed [102,103]. The decrease in CO_2 uptake in canola and wheat plants can reduce the rate of photosynthesis and ultimately reduce biomass in production [104]. Water deficit leads to the production of radical compounds called ROS. If there is no balance between the rate of photosynthesis, the production of antioxidant compounds can be inhibited, as illustrated in the research on canola plants [105]. The decrease in the rate of photosynthesis is also influenced by the ABA response as a signal of drought stress, which results in regulation of stomatal closure [106,107]. ABA is formed in roots and transported to leaves to signal and regulate stomatal closure due to lack of water stimulated by certain genes such as NPF4.6 and DTX5.0 [108]. A further impact is the reduction of CO2 for photosynthesis. The decrease in the CO_2 carboxylation process and the closing of stomata due to abiotic stress can reduce the rate of photosynthesis, decreasing the number of functional Ribulose 1.5 bisphosphate carboxylae oxygenase (RuBisCo) in photosynthesis [109]. The conclusion is that drought stress causes morphological and physiological responses in plants. Morphological responses occur in root elongation, leaf size, and the number of leaves. Physiologically roots can respond by

transporting ABA to regulate stomatal closure to reduce evaporation. Closure of stomata results in low CO_2 absorption, causing the photosynthesis process to be not optimal.
The general response of plants to water deficit is to close their stomata, which is beneficial to reduce water loss [110,111]. In addition, water deficit can affect hydraulic conductivity due to hydraulic signals, gas exchange, water potential, and ABA determination in leaves (stomata) [107]. In wheat, stomatal conductivity results in transpiration efficiency, which is influenced by leaf transpiration and assimilation rate [112]. Water loss during the vegetative phase causes soybean plants to balance water potential (osmotic adjustment) by dropping leaves, reducing leaf size, closing stomata, and folding leaves for water usage efficiency through transpiration reduction, however this reduces leaf area index (LAI) and so reduces photosynthetic rate [113]. The stomatal closure is a plant response to drought stress, which can decrease transpiration and photosynthesis rate. However, this regulation is a complex mechanism interconnected between external (water availability) and internal (ABA response) factors.

The photosynthesis process is influenced by the activity of supporting enzymes, one of which is RuBisCo. RuBisCo plays a role in photosynthesis, namely photosystem II [114]. Under drought stress, the amount of light absorption is small, decreasing the activity of RuBisCo [115] [116]. Drought stress is often accompanied by an increase in temperature, resulting in photoinhibition, which can impair RuBisCo's ability to activate the photosystem II pathway [117]. This decrease occurs because the CO_2 carboxylase process by RuBisCo is not optimal [72]. Drought stress inhibits the RuBisCo enzyme, which can lead to a reduction in carboxylate assimilation. Hence, the regeneration of RuBP will ultimately inhibit the rate of photosystem II [118]. High temperatures and drought stress in rice, wheat, and corn restrict RuBisCo function by inhibiting the RuBisCo activase enzyme, which can reduce photosynthetic optimization [114]. Photosynthetic products are usually transported to parts of the plant. However, in drought conditions, there is a change in carbohydrate translocation in plants so that limited carbohydrates are translocated to places contributing to resisting drought stress [119,45]. Carbohydrates are translocated in the form of simple components to maintain osmotic balance, which is in roots are used for morphological growth to increase water uptake and ABA induction [120]. Increasing the amount of carbohydrates in plant parts during the vegetative and generative phases is a method used by plants to survive under drought stress [121].

The plants' response to drought stress is to maintain osmotic balance in cells [69,122]. One of the mechanism to maintain this balance is to form soluble compounds to hold water out of the cell (compatible solute) [123,124]. In addition, these soluble compounds are antioxidant compounds that protect cell membranes from damage caused by ROS, one of which is proline [47,125-127]. Proline and glycine-betaine are used as antioxidants and cell membrane protection from radical compounds (ROS) [128]. High proline in the leaves of rice, soybean, and sugarcane plantlets is a physiological indication of plants to resist water deficit [48,129,125]. In wheat cv. Chakwal 50, the proline content increased as a result of drought stress, indicating an osmotic adjustment process in cells in addition to free radical scavengers [130]. The presence of proline in soybean plants can increase water stress resistance and stabilize protein structure [131]. Proline is used as an indicator in drought-tolerant plants so that it is used as the basis for breeding drought-resistant transgenic plants [132]. Proline, in chloroplasts, is a synthesis of glutamate, which is reduced to glutamate semialdehyde (GSA) by the P5CS enzyme (encoded by two genes) and converted spontaneously to P5C (encoded by one gene) [126]. In mitochondria, proline undergoes catabolism with the help of proline oxidase (PDH) to form P5C, which is then converted to glutamate [123].

In simple terms, the water balance in plants can be described as the equal amount of water coming out (transpiration) and water coming in (absorption). The imbalance condition will interfere with plant physiology, causing plants to experience stress [133]. In relation to physiological processes, drought stress is related to turgor pressure, stomatal opening, photosynthetic rate, enzyme damage, and root density [72]. plant growth due to low CO2 absorption [134]. The direct inhibiting factor for plant growth is not water potential but osmotic potential and turgor pressure [135,136]. The influence of turgor pressure can result in osmotic adjustments in plants to reduce water loss [137]. Plants regulate water balance by generating phytohormones, such as ABA, through their roots. ABA is a plant mediator in response to drought, which is synthesized mostly in roots [138,108,139]. ABA is said to be the main internal signal allowing plants to resist drought, which is transported to the leaves to affect stomata closure to reduce transpiration [140,141,42]. ABA is a simple sequence of carotenoid compounds. In fungi, ABA is synthesized through the metileritritol phosphate (MEV) pathway, which begins with the formation of mevalonate. Meanwhile, ABA in plants is synthesized through the MEP pathway, starting with the formation of carotenoids into more specific compounds (zeaxanthin) [139]. Assisted by the zeaxanthin epoxidase (ZEP), zeaxanthin is converted to violaxanthin and turned to neoxanthin. In Arabidopsis, the gene involved in this process is ABA4. Neoxanthin will be converted into xanthine with NCEDs enzymes as activators (found in arabidopsis, corn, tomatoes, cowpea, and grains). In maize, the gene involved is known to be VIP14. Xanthine is converted to abscisic aldehyde and then to ABA. The genes involved in this process are ABA2 and ABA3 in Arabidopsis plants and TaNAC48 in wheat [142].

ABA formed in the roots is transported to the leaves and the flowers. NCED2 and NECD3 proteins are known to play a more dominant role in the synthesis of ABA in roots, while NCED5, NCED6, and NCED9 are more dominant in the flowering part. Apart from being an early signal of drought that will be transported to the leaves, ABA will also affect the growth of stressed plant roots by increasing water influx by the roots [143]. ABA transport to the leaves occurs with enzymes (such as CLE25) as activators. When ABA reaches the leaves, it becomes a signal for stomata to close [144]. Stomatal closure can be beneficial to reduce transpiration [145,146], but the rate of photosynthesis will decrease, photorespiration will increase, and the accumulation of ROS compounds will increase [147]. The ABA-mediated gene for stomatal closure in wheat is TaNAC48 [142]. When the stomata close, there is a lack of CO_2. The excess O_2 from photosynthesis is bound by RuBisCo molecules, and some of these compounds can form ROS chemicals. RuBisCo should be able to bind CO2 absorbed from PEP (in C4 plants). With the decrease in the amount of CO2, the O2 bound by RuBisCo can produce CO2, but more energy (ATP) is required, thereby reducing the efficiency of photosynthesis. When the stomata are closed, there will be a buildup of singlet oxygen (O^-) and hydroxide compounds (H_2O_2) as a result of photosynthesis, forming toxic ROS compounds. This condition is anticipated by forming direct antioxidant compounds (carotenoids, mannitol) and antioxidant enzymatic reactions, such as SOP, APX, and CAT, which can convert ROS compounds into O2 and H2O [90,148,149,76]. However, severe and long-duration stress causes an imbalance between ROS and antioxidants. If the ROS is higher than the antioxidant, it will attack the fatty acids on the membrane (PUFAs) so that the cell membrane will be damaged, and if the plant cannot adapt, the plant will be sensitive and die [150]. The increase in ROS compounds that are not matched by an increase in antioxidant compounds and other solute compounds causes membrane damage to plant cell walls and other responses such as proline formation and an increase in reaction enzymes such as SOP, APX, and CAT [76].

Plants such as tomato plants [151], sunflower plants [152], sugarcane [153] respond to drought stress by forming compatible solutes, namely sugars with low molecular weights that are osmoprotectant compounds (stress protecting agents) [154]. Regarding the function of trehalose, there are at least two supporting theories. The first theory is water replacement because it can form hydrogen bonds with surrounding structural molecules that function as a substitute for water, for example, trehalose with lipid molecules will function as membrane integrity guards during drought stress (changes in the membrane from a fluid phase to a gel phase). The second theory is water entrapment since it can play a role in collecting water by forming hydrogen bonds to form a water layer in the cell [155]. Trehalose is a disaccharide group formed from the breakdown of carbohydrates into two glucose molecules [156]. Plants under drought stress will increase ABA synthesis, playing a role in stomatal closure and stimulating signal transduction by forming a protein cascade, namely TPS1 protein. This protein will activate transcriptional genes such as the TreGP gene (TGP), which will play a role in the formation of trehalose as a compatible solute in cells that supports osmotic adjustment in cells [156,157].

Drought Stress Management

Drought stress has an impact on agriculture crop cultivation, thereby decreasing crop production. Therefore, it is necessary in these condition to require management to increase crop production. These condition has management variations so that appropriate strategies and technologies are needed as mitigation measures. Mitigation management can be done by:1) Use early maturing varieties and drought stress tolerance varieties. The use of early maturing to facing drought stress can be used to increase crop index (CI) and it will maintain high yields [158]. Drought tolerance varieties can respond and induces expression of drouht stress related genes so that the plant will survive in these conditions [159]. 2) using mechanical soil conservation such as making terraces and bed planting which are used to suppress surface water flow and hold back puddles. The terraces are supported and can help in binding soil particles and also to bind water longer whereas bed planting can enhances the water infiltration rate and can maintain mouisture conditions [160]. 3) applying a good irrigation system. Drought and water scarcity conditions need irrigation management, this should be seen within supply and demand management for plant [161]. 4) biological conservation using mulch to improve soil structure and to increase the ability of the soil to hold water. Mulching is one of the important management practice for conserving soil moisture in plants cultivation. That evaporates from soil with mulch will be condenses on the lower surfaces and go back to the soil thus conserving moisture [162]. 5) selecting drought-tolerant plants both in vitro and in vivo by using selector agents such as PEG. The in vitro screening using PEG-6000 is an alternative for the early selection of drought tolerance varieties, it is known through gene markers of varieties that are considered optimal growth in drought stress [163]. 6) applying osmo-protectant compounds, such as glycine betaine. Glycine betaine exogenous application can reducing the aggregation of ROS, that can improving SOD and CAT activities which will result in an osmotic adjustment mechanism [164].

Conclusion

Drought stress causes plant to be in a state of water deficit. Water deficit has an impact on cell division, cell elongation, cell differentiation, and a decrease in CO_2 fixation so that it can reduce photosynthetic results and the accumulation of ROS compounds, thereby decreasing crop production. These condition stimulates plants responses through morphological and physiological changes. Mitigation management can be done by several ways such as use tolerance varieties (early maturing), soil conservation, good irrigation system, use mulch as biological conservation, selection in vitro to screening drought stress tolerance varieties and exogenous application osmo-protectant like glycine betaine.

Acknowledgement

The authors would like to thank to Polytechnic of LPP Yogyakarta for supporting this study.

Conflict of interest

The authors declare no conflict of interest.

References

[1] Jaganathan Ganesh K, Song G, Liu Wei, et al. (2017) Relationship Between Seed Moisture Content and Acquisition of Impermeability in *Nelumbo nucifera* (Nelumbonaceae). Acta Botanica Brasilica Journal, 31(4): 639-644.

[2] Ferreira L Bernandes Da Silva, Fernandes NA, De Aquino LC, et al. (2017) Temperature and Seed Moisture Content Affect Electrical Conductivity Test in Pea Seed. Journal of Seed Science, 39(4): 410-416.

[3] Tatrai Z Attila, R Sanoubar, Z Pluhar, et al. (2016) Morphological and Physiological Plant Responses to Drought Stress in *Thymus citriodorus*. International Journal of Agronomy Hindawi Corporation, : 1-8

[4] Bhatla Satish C, MA Lal (2018) Plant Physiologi, Development and Metabolism. Springer Publhiser, Singapore: 1-9.

[5] Xue Ran, Yuying Shen, Petra Marschener (2017) Soil Water Content During and After Plant Growth Influence Nutrient Availability and Microbal Biomass. Journal of Soil Science and Plant Nutrition, 17(3): 702-715.

[6] Quemada C, JM Perez Esqudero, R Gonzalo, et al. (2021) Remote Sensing of Plant Water Content Monitoring: A Review. Remote Sensing Journal MDPI, 13(2088): 1-37

[7] Driesen E, W Van Den Ende, M De Proft, W Saeys (2020) Influence of Environmental Factors Light, CO2, Temperature and Relative Humidity on Stomatal Opening and Development: A Review. Agronomy Journal MDPI, 10(1975): 1-28.

[8] Henry C, GP Jhon, Ruihua Pan, et al. (2019) A Stomatal Safety Efficiency Trade off Constrains Responses to Leaf Dehydration. Nature Communication Journal, 10(3398): 1-9.

[9] Dresselhaus T, R Huckelhoven (2018) Biotic and Abiotic Stress Responses in Crop Plants. Agronomy Journal MDPI, 8(267): 1-6.

[10] Jena J, SK Sahoo, GK Dash (2020) An Introduction to Abiotic Stress in Plants. Advances in Agronomy Journal, 9: 163-183.

[11] Rini D Setyo, Budiarjo, I Gunawan, et al. (2020) The Mechanism of Plant Response to Drought Stress. Journal of Ilmu-ilmu Hayati LIP, 19(3B): 373-384.

[12] Badan Penanggulangan Bencana Daerah (BPBD) Yogyakarta Region (2019) Dry season is Coming, Beware of Drought. Musim Kemarau Datang, Waspada Kekeringan. http://www.bpbd.jogjaprov.go.id/musim-kemarau-datang-waspada-kekeringan. (Accessed on 19 September 2021)

[13] Ihuoma Samuel O, CA Madramootoo (2017) Recent Advances in Crop Water Stress Detection. Computers and Electronics in Agriculture Journal, 141: 267-275.

[14] Rismayantika F, R Saraswati, IPA Shidiq, et al. (2020) Identification of Dry Areas on Agricultural Land Using Normalized Difference Drought Index in Magetan Regency. IOP Conf. Series: Earth and Environmental Science, 540: 1-8.

[15] Tamara Dita (2021) 8 Jenis Tanah di Indonesia Beserta Karakteristik dan Manfaatnya. 8 Types of Soil in Indonesia and Their Characteristics and Benefits. https://m.kapanlagi.com/plus/8-jenis-jenis-tanah-di-indonesia-beserta-karakteristik-dan-manfaatnya-012b07-0.html. (Accessed on 27 September 2021)

[16] Al Khairi Yuhan (2019) Soil Structure and Texture-Definition, Types and Function, Struktur dan Tekstur Tanah-Pengertian, Jenis dan Fungsi Tanah. https://www.99.co/id/panduan/struktur-dan-tekstur-tanah-pengertian-jenis-hingga-fungsinya. (Accessed on 20 September 2021)

[17] Tanga KK, MN Kusuma, Musarofa, et al. (2020) The Process of Filtration and Dispersion of Sandy Loam Soil Types in River Water Treatment. Proceedings: Seminar Teknologi Kebumian dan Kelautan (SEMITAN II), 2(1): 1-4.

[18] Ball Jeff (2001) Soil and Water Relationship. https://www.noble.org/news/publications/ag-news-and-views/2001/september/soil-and-water-relationships/. (Accessed on 20 September 2021)

[19] Kompasiana (2017) Hygroscopic, Capillari and Soil Water Content. Air Higroskopis, Air Kapiler dan Kadar Air Tanah. http://petanibangga.blogspot.com/2017/12/air-higroskopis-air-kapiler-dan-kadar.html. (Accessed on 20 September 2021)

[20] Badan Meteorologi Klimatologi dan Geofisika (BMKG) Indonesia (2022) Level of Water Availability for Plants in December 2021. Tingkat Ketersediaan Air Bagi Tanaman-Desember 2021. https://www.bmkg.go.id/iklim/ketersediaan-air-tanah.bmkg?p=tingkat-ketersediaan-air-bagi-tanaman-desember-2021&tag=&lang=ID. (Accessed on 21 January 2022)

[21] Widnyana I Made Gede, Sumiyati , I Wayan Tika (2017) The Study of Wilting Point Pattern and Field Capacity in Cultivation of Sweet Pepper in Differents Planting Media. BETA (Biosistem dan teknik Pertanian) Journal, 5(1): 1-6.

[22] Kishor Singh K, A Khumar (2018) Composition of Soil, Waste Teatment of Soil, Inorganic and Organic Components in Soil and Soil Pollution by Addition of Pesticides and Fertillizers. Course M.Sc. Chemistry 2nd Year, 1-11. http://www.nou.ac.in/Online%20Resourses/10-5/Soil%20Composition%20and%20Organic%20Inorganic,%20Treatment%20for%20M.Sc.%20Part%20II%20,%20(I).pdf. (Accessed on 23 October 2021)

[23] Easton, Zachary M. (2016) Soil and Soil Water Relationship. Publication BSE-194P, 1-9. https://ext.vt.edu/content/dam/ext_vt_edu/topics/agriculture/water/documents/Soil-and-Soil-Water-Relationships.pdf. (Accessed on 23 October 2021)

[24] Salam Abdul Kadir (2020) Ilmu Tanah. Soil Science. Global Mandiri Publisher. Lampung, Indonesia

[25] Widoretno W, Harijati N, Mastuti R (2019) Plant Physiology. Hand Book, 4-17. https://nanopdf.com/queue/handout-retno-mastuti_pdf?queue_id=-1&x=1634895614&z=MTgyLjIuNjkuODE=. (Accessed on 23 October 2021)

[26] Khodijah S, Soemarno (2019) Studi Kemampuan Tanah Menyimpan Air Tersedia di Sentra Bawang Putih Kecamatan Pujon Kabupaten Malang. Jurnal Tanah dan Sumberdaya Lahan, 6 (2): 1405-1414.

[27] Haryati Umi (2014) Karakteristik Fisik Tanah Kawasan Budidaya Sayuran Dataran Tinggi, Hubungannya dengan Strategi Pengolahan Lahan. Jurnal Sumberdaya Lahan, 8 (2): 125-138.

[28] Markovic N, V Filipovic, T Legovic, et al. (2015) Evaluation of Different Soil Water Potential by Field Capacity Threshold in Combination With a Triggered Irrigation Module. Soil and Water Res., Journal, 10 (3): 164-171.

[29] Darmayanti F Dwi, T Sutikto (2019) Estimasi Total Air Tersedia Bagi Tanaman pada Berbagai Tekstur Tanah Menggunakan Metode Pengukuran Kandungan Air Jenuh. Jurnal Berkala Ilmiah Pertanian, 2 (4): 164-168.

[30] Barzegar A, A Yousefi, N Zargoosh (2016) Water Stress and Soil Compaction Impacts on Clover Growth and Nutrient Concentration. Eurasian Journal of Soil Science, 5(2): 139-145.

[31] Fields Jeb S, WC Fonteno, BE Jackson, et al. (2020) The Use of Dewpoint Hygrometry to Measure Low Water Potentials in Soilles Substrate Components and Composites. Journal Agronomy MDPI, 10(1393): 1-11.

[32] Datta S, S Taghvaeian, J Stivers (2017) Understanding Soil Water Content and Thresholds for Irrigation Management. Oklahoma Cooperation Extension Service BAE-1537, 1-9.

[33] Bueckert RA (2013) General Principles of Plant Water Relations. Prairie Soils and Crops Journal, 6(1): 107-118.

[34] Chavarria G, HP dos Santos (2014) Plant Water Relations: Absorption, Transport and Control Mechanism. Advances and Selected Plant Physiology Aspect. 106-132. https://ainfo.cnptia.embrapa.br/digital/bitstream/item/59779/1/InTech-Plant-water-relations-absorption-transport-and-control-mechanisms.pdf. (Accessed on 27 September 2021)

[35] Nonami H, Jhon S Boyer (1989) Turgor and Growth at Low Water Potentials. Plant Physiol. Journal, 89: 798-804.

[36] Fitter AH, RKM Hay (1994) Environmental Physiology of Plants. Translation. Third Print. Gadjah mada University Press: 148-150.

[37] Riboldi Lucas B, R Ferraz Oliviera, Luiz R Angelocci (2016) Leaf Turgor Pressure in Maize Plants Under Water Stress. Australian Journal of Crop Science, 10(6): 878-886.

[38] Istanbuli T, M Baum, H Tauchan , A Hamwieh (2020) Evaluation of Morpho-Physiologycal Traits Under Drought Stress Conditions in Barley (*Hordeum Vulgare*, L.). Photosynthetica Journal, 58(4): 1059-1067.

[39] Bernard SM (2015) Plant Water Relations. https://www.accessscience.com/media/EST/media/525300PV0001.pdf. (Accessed on 27 September 2021)

[40] Rao KV Madhava, AS Raghavendra, SJ Reddy (2006) Physiologi and Molecular Biology of Stress Tolerance in Plants. Published by Springer, Netherlands :15-31.

[41] Opalofia Loli, Yusniwati, Etti Swasti (2018) Drought Tolerance in Some of Rice Line Based on Morphological at Vegetative Stage. International Journal of Environment, Agriculture and Biotechnology, 3(6): 1995-2000.

[42] Chun Hyen Chung, Sanghun Lee, Young Dae Choi, et al. (2021) Effect of Drought Stress on Root Morphology and Spatial Distribution of Soybean and Adzuki Bean. Journal of Integrative Agriculture, 20(10): 2639-2651.

[43] Malinowska Marta, Iain Donnison, Paul Robson (2020) Morphological and Physiological Traits That Explain Yield Response to Drought Stress in Mischantus. Agronomy Journal, 10: 1-17.

[44] Yanli Du, Qiang Zhao, Liru Chen, et al. (2020) Effect of Drought Stress During Soybean R2-R6 Growth Stages on Sucrose Metabolism in Leaf and Seed. International Journal of Molecular Science, 21(618): 1-19.

[45] Tovignan T Klanvi, HA Sagbadja, C Diatta, et al. (2020) Terminal Drought Effect on Sugar Partioning and Metabolism is Modulated by Leaf Stay Green and Panicle Size in the Stem of Sweet Shorgum (*Shorgum bicolor*, L. Moench). CABI Agriculture and Bioscience Journal, 1(4): 1-11.

[46] Alaei S, Nasser Mahna, Jafar Hajilou, et al. (2016) The Effect of Glycine-Betain on Alleviation of Drought Stress in Strawberry Plant. Eco. Env. And Cons. Journal, 22(3): 1145-1150.

[47] Magana C Escalante, Luis F Aguilar C, IE Machado, et al. (2019) Contribution of Glycine Betaine and Proline to Water Deficit Tolerance in Papper Plant. Hort. Sci. Journal, 54(6): 1044-1054.

[48] Nasrin S, Shukanta Saha, Hasna Hena Begum, et al. (2020) Impact of Drought Stress on Growth Protein, Proline, Pigment Content and Antioxidant Enzyme Activities in Rice (*Oryza sativa* L. Var. BRRI Dhan-24), J. Bio. Sci., 29(1): 117-123.

[49] Maghsoudi Kobra, Yahya Emam, Ali Niazi, et al. (2018) P5CS Expression Level and Proline Accumulation in The Sensitive and Tolerant Wheat Cultivars Under Control and Drought Stress Condition in The Presence/Absence of Silikon and Salicylic Acid. Journal of Plant Interaction, 13(1): 461-471.

[50] Lei Wei, Shian Huang, Shaohu Tang, et al. (2016) Determination of Abcisic Acid and its Relationship to Drought Stress Based on Cowpea Varieties With Different Capability of Drought Resistence. American Journal of Biochemistry and Biotechnology, 12(1): 79-85.

[51] Wang Xiao, Qing Ji, Jingjing Xie, et al. (2021) Abcisic Acid and Jasmonic Acid are Involved in Drought Priming-Induced Tolerance to Drought in Wheat. The Crop Journal, CAAS, 9: 120-132.

[52] Hussain S, T Qadir, A Khaliq, et al. (2019) Drouhgt Stress in Plants: An Overview on Implications. Tolerance Mechanism and Agronomic Mitigation Strategies. Plant Science Today Journal, 6(4): 389-402.

[53] Ordog Vince (2011) Plant Physiology. http://www.esalq.usp.br/lepse/imgs/conteudo/Plant-Physiology-by-Vince-Ordog.pdf. (Accessed on 27 September 2021)

[54] Androcioli L Godoy, Douglas Mariani Z, Daniel Soares A, et al. (2020) Effect of Water Deficit on Morphoagronomic Physiological Traits of Common Bean Genotypes with Contrasting Drought Tolerance. Water Journal MDPI, 12(217): 1-13.

[55] Galeano Esteban, Tarcisio Sales V, Perla Novais de Oliveira, et al. (2019) Physiological and Molecular Responses to Drought Stress in Teak (*Tectona grandis*, L.f.). PLOS One Journal, 14(9): 1-26.

[56] Chowdhury JA, MA Karim, QA Khaliq, et al. (2017) Effect Drought Stress on Water Relation Traits of Four Soybean Genotype. SAARC Journal Agri., 15(2): 163-175.

[57] Sakya AT, E Sulistyaningsih, D Indradewa, et al. (2018) Physiological Characters and Tomato Yield Under Drought Stress. IOP Conf. Series: Earth and Enviromental, 200: 1-7.

[58] Nemeskeri Eszter, Lajos Heyles (2019) Physiological Responses of Selected Vegetable Crop Species to Water Stress. Agronomy Journal, 9(447): 1-19.

[59] Liu Jie, Tiantian Hu, Puyu Feng, et al. (2019) Tomato Yield and Water Use Efficiency Change With Various Soil Mouisture and Pottasium Levels During Different Growth Stages. Plos One Journal, 10(1371): 1-14.

[60] Song Libing, Jiming Lin, Jianqiang He (2019) Effect of Severe Water Stress on Maize Growth Processes in The Field. Sustainability Journal, 11: 1-18.

[61] Benjamin JG, DC Nielsen, MF Vigil, et al. (2014) Water Deficit Stress Effect on Corn (*Zea mays*, L.) Root: Shoot Ratio. Open Journal of Soil Science, 4: 151-160.

[62] Muthoni Jane, Hussein Shimelis (2020) Heat and Drought Stress and Their Implication on Potato Production Under Dry African Tropics. Australian Journal of Crop Science, 14(09): 1405-1414.

[63] Romero Angela P, Andres Alacron, Raul I Valbuena, et al. (2017) Physiological Assessment of Water Stress in Potato Using Spectral Information. Frontiers in Plant Science Journal, 8: 1-13.

[64] Rykaczewska Krystyna (2017) Impact of Heat and Drought stresses on Size and Quality of the Potato Yield. Plant Soli Environ Journal, 63(1): 40-46.

[65] Panda Debabrata, Swati Sakambari Mishra, et al. (2021) Drought Tolerance in Rice: Focus and Recent Mechanisms and Approaches. Rice Science Journal, 28(2): 1-17.

[66] Saha Shukanta, Hasna Hena Begum, Shamima Nasrin (2019) Effect of Drought Stress on Growth and Accumulation of Proline in Five Rice Varieties (*Oryza sativa*, L.). Journal Asiat. Soc. Bangladesh Sci., 45(2): 241-247.

[67] Nowsherwan I, G Shabbir, SI Malik, et al. (2018) Effect of Drought Stress on Different Physiological Traits in Bread Wheat. SAARC Journal Agri, 16(1): 1-6.

[68] Hooshmandi B (2019) Evaluation of Tolerance to Drought Stress in Wheat Genotypes. IDESIA (Chile) Journal, 37(2): 37-42.

[69] Abobatta Waleed Fouad (2019) Drought Adaptive Mechanism of Plants-a Review. Ology Journal. Advances in Agriculture and Environmental Science, 2(1): 62-65.

[70] Shavrukov Y, A Kurishbayev, S Jatayev, et al. (2017) Early Flowering as a Drought Escape Mechanism in Plants: How Can it Aid Wheat Production. Frontiers in Plants Science Journal, 8(1950): 1-8.

[71] Monroe J Grey, Tyler Powel, Nicholas Price, Jet al. (2018) Drought Adaptation in *Arabidopsis thaliana* by Extense Genetic Loss of Function. E Life Research Article, 7: 1-18.

[72] Farooq M, A. wahid, N Kobayashi, D. Fujita, et al. (2009) Plant Drought Stress: Effect, Mechanism and Management. Agron. Sustain. Dev. Journal, 29(2009): 185-212.

[73] Lestari E Gati (2006) Review Mechanism of Tolerance and Methods to Select Drought Resistance Plants. Berita Biology Journal, 8(3): 215-222.

[74] Gouveia Carla SS, Jose FT Gananca, HGM De Nobrega, et al. (2019) Drought Avoidance and Phenotypic Flexibility of Sweet Potato *Ipomoea batatas*, L. Lam.) Under Water Scarity Conditions. Not Bot. Hort. Agrobo, 47(4): 1034-1046.

[75] Bouzid M, F He, G Schmitz, et al. (2019) Arabidospis Species Deploy Distinct Strategies to Cope With Drought Stress. Annals of Botany Journal, 124: 27-40.

[76] Moradi Parviz (2016) Key Plant Products and Common Mechanisms Utilized by Plants in Water Deficit Stress Responses. Botanical Sciences Journal, 94(4): 657-671.

[77] Saladi Gaelle (2014) From Signal Perception to Gene Expression: Early Responses of Plant to Drought. Revue Agrobiologia Journal, 5: 5-10.

[78] Takahashi Fuminori, Takashi Kuromori, Kaoru Urano, et al. (2020) Drought Stress Responses and Resistance in Plant: From Celluler Responses to Long Distance Intercelluler Communication. Frontiers in Plant Science Journal, 11: 1-14

[79] Lamers J, Tom Van Der Meer, Christa Testerink (2020) How Plant Sense and Respond to Stressful Environments. Plant Physiologi Journal, 182: 1624-1635.

[80] Haswell ES, Paul EV (2015) The Ongoing Search for The Molecular Basis of Plant Osmosensing. Journal Gen Physiol., 145(5): 389-394.

[81] Ye Yaoyao, Yanfei Ding, Qiong Jiang, et al. (2017) The Role of Receptor Like Protein Kinase (RLKs) in Abiotic Stress Response in Plant. Plant Cell Rep. Journal, 36: 235-242.

[82] He Xiaowen, Chuanzeng Wang, Haibo Wang, et al. (2020) The Function of MAPK cascades in Response to Various Stresses in Horticulture Plants. Frointers in Plant Science Journal, 11: 1-12.

[83] Wang Chen, Wenjing Lu, Xiaowen He, et al. (2016) The Cotton Mitogen Activated Protein Kinase Kinase 3 Function in Drought Tolerance by Regulating Stomatal Responses and Root Growth. Plant and Physiol. Journal, 57(8): 1629-1642.

[84] Ho Hooi Ling (2015) Functional Roles of Plant Protein Kinases in Signal Transduction Pathways During Abiotic and Biotic Stress. Journal Biodivers. Biopros. Dev., 2(2): 1-8.

[85] Khorasgani Omid Askari (2018) Regulation of Trehalose/Sucrose-Non-Fermenting Related Protein Kinase 1 and its Signaling Pathways Involved in Drought Stress Responses. MOJ Sci., Rep. Journal, 5(2): 39-40

[86] Kardile Hemant B, Vikrant, NK Sharma, et al. (2018). Calcium Dependent Protein (CDPK) in Abiotic Stress Tolerance. Journal Pl. Sci. Res., 34(2): 253-259.

[87] Crizel R Lopes, Ellen CP, Isabel LV, et al. (2020) Genome Wide Identification and Characterization of The CDPK Gene Family Reveal Their Involvement in Abiotic Stress Response in *Fragaria x ananassa*. Scientific Report Journal, 10: 1-17.

[88] Wang Dan, Yuan Xia Liu, Qian Yu, et al. (2019) Functional Analysis of The Soybean GmCDPK3 Gene Responding to Drought and Salt Stresses. International Journal of Molecular Science MDPI, 20: 1-22.

[89] Nxele X, A Klein, BK Ndimba (2017) Drought and Salinity Stress Alter ROS Accumulation, Water Retention and Osmolyte Content in Shorgum Plants. South African Journal of Botany, 108: 261-266.

[90] Hasanuzzaman Mirza, MHMB Bhuyan, F Zulfiqar, et al. (2020) Reactive Oxygen Species and Antioxidant Defense in Plants Under Abiotic Stress: Revisiting The Crucial Role of a Universal Defense Regulator. Antioxidant Jurnal MDPI, 9(681): 1-52.

[91] Setter Tim L, BA Flannigan (2001) Water Deficit Inhibits Cell Division and Expression of Transcripts involved in Cell Proliferation and Endoreduplication in Maize Endosperm. Journal of Experimental Botany, 52(360): 1401-1408.

[92] Li Yizeng, Lijuan He, NAP Gonzales, J Graham, et al. (2017) Going with the Flow: Water Flux and Cell Shape During Cytokinesis. Biophysical Journal, 113: 2487-2495.

[93] Litvin Alexander G, MW Van Iersel, A Malladi (2016) Drought Stress ReducesStem Elongation and Alters Gibberellin Releated Gene Expression During Vegetative Growth of Tomato. J. Amer. Soc. Hort. Sci., 141(6): 591-597.

[94] Jahan Afrose, F Ahmed (2018) Effect of Drought Stress on Growth and Yield of Wheat Genotypes. Bangladesh Agron Journal, 20(2): 97-105.

[95] Zhao Wenhui, Leizen Liu, Qiu Shen, et al. (2020) Effect of Water Stress on Photosynthesis, Yield and Water Use Efficiency in Winter Wheat. Water Journal. MDPI, 12(2127): 1-19.

[96] Gamez Angie L, David Soba, AM Zammareno, et al. (2019) Effect of Water Stress During Grain Filling on Yield, Quality and Physiological Traits of Illpa and Rainbow Quinoa (*Chenopodium quinoa* Willd.) Cultivars. Plant Journal. MDPI, 8(173): 1-15.

[97] Zhang Jinmeng, Shiqiao Zhang, Min Cheng, et al. (2018) Effect of Drought on Agronomic Traits of Rice and Wheat: A Meta Analysis. Int. J. Environ. Res. Public health. MDPI, 15(839): 1-14.

[98] Pingping Wu, Wu Chubin, Zhou Biyan (2017) Drought Stress Induced Flowering and Enhances Carbohydrate Accumulation in *Averrhoa carambola*. Horticultural Plant Journal, 3(2): 60-66.

[99] Cui Yi, Shaowei Ning, Juliang Jin, et al. (2020) Quantitative Lasting Effects of Drought Stress at a Growth Stage on Soybean Evapotranspiration and Aboveground Biomass. Water Journal MDPI, 13(8): 1-19.

[100] Liang Guoting, Junhui Liu, Jingmin Zang (2020) Effect of Drought Stress on Photosyntetic and Physiological Parameters of Tomato. J. Amer. Soc. Hort. Sci., 145(1): 12-17.

[101] Wang Wensen, Cheng Wang, Dayu Pan, et al. (2018) Effect of Drought Stress on Photosyntetic and Chlorophyll Fluorescence Image of Soybean (*Glycinn max*) Seedlings. Int. J. Agric. and Biol Eng., 11(2): 196-172.

[102] Fathi A, DB Tari (2016) Effect of Drought Stress and its Mecanism in Plants. International Journal of Life Sciences, 10(1): 1-6.

[103] Nicolas Martin-St Paul, S Delzon, H Cochard (2017) Plant Resistence to Drought Depends on Timely Stomatal Closure. Ecology Letters Journal, 10(11): 1-13.

[104] Maliba Bheki G, PM Inbaraj, JM Berner (2019) Photosyntetic Responses of Canola and Wheat to Elevated of CO_2, O_3 and Water Deficit in Open Top Chambers. Plants Journal MDPI, 8(171): 1-16.

[105] Rezayian M, V Niknam, H Ebrahimzadeh (2018) Effect of Drought Stress on The Seedling Growth, Development and Metabolic Activity in Different Cultivars of Canola. Soil Science and Plant Nutrition Journal, 64(3): 360-369.

[106] Kai Hsu Po, Guillaume Dubeaux, Yohei Takahashi, et al. (2021) Signaling Mechanism in Abscisic Acid –Mediated Stomata Closure. The Plant Journal, 105: 307-321..

[107] Tombesi S, A Nardini, T Frioni, et al. (2015) Stomatal Closure is Induced by Hydraulic Signal and Maintained by ABA in Drought Stressed Grapevine. Scientific Report Journal, 5(12449): 1-12.

[108] Kuromori Takashi, Mitsunori Seo, Kazuo Shinozaki (2018) ABA Transport and Plant Water Stress Responses. Trends in Plant Science Journal, 23(6): 513-523.

[109] Muhammad Izhar, A Shalmani, M Ali, et al. (2021) Mechanism Regulating The Dynamics of Photosyntesis Under Abiotic Stress. Frontiers in Plant Science Journal, 11: 1-25.

[110] Sloan Brandon P, SE Thompson, Xue Feng (2021) Plant Hydraulic Transport Control Transpiration Response to Soil Water Stress. Hydrology and Earth System Sciences Journal. https://hess.copernicus.org/preprints/hess-2020-671/hess-2020-671.pdf. (Accessed on 27 September 2021)

[111] Buckley Thomas N (2019) How do Stomata Respond to Water Status?. New Phytologist Journal, 224: 21-36.

[112] Li Yuping, Hongbin Li, Yuanyuan Li, et al. (2017) Improving Water Use Efficiency by Decreasing Stomatal Conductance and Transpiration Rate to Maintain Higher ear Photosyntesic Rate in Drought Resistant Wheat. The Crop Journal, 5: 231-239.

[113] Sacita A Safitri, Tania June, Impron (2018) Soybean Adaptation to Water Stress on Vegetative and Generative Phase. Agrotech Journal, 3(2): 1-11.

[114] Perdomo Juan A, SC Bauca, EC Silva, et al. (2017) Rubisco and Rubisco Activase Play an Important Role in The Biochemical Limitations of Photosyntesis in Rice, Wheta and Maize Under High Temperature and Water Deficit. Frointers in Plant Science Journal, 8(490): 1-15.

[115] Shobhkhizi A, MF Rayni, HB Barzin, et al. (2014) Influence of Drought Stress on Photosynthetic enzymes, Chlorophyll, Protein and Relative Water Content in Crop Plants. International Journal of Biosciences, 5(7): 89-100.

[116] Parry Martin AJ, PJ Andralojc, Shahnaz Khan, et al. (2002) Rubisco Activity: Effects of Drought Stress. Annals of Botany Journal, 89: 833-839.

[117] Nouri M Zaman, Ali Maumeni, Setsuko Komatsu (2015) Abiotic Stresess: Insight in to Gene Regulation and Protein Expression in Photosyntetic Pathways of Plants. Int. J. Mol. Sci., 16: 20393-20416.

[118] Slattery Rebecca A, Donald R Ort (2019) Carbon Assimilation in Crops at High Temperature. Plant Cell Environ. Journal, 42: 2750-2758.

[119] Du Yanli, Qiang Zhao, Liru Chen, et al. (2020) Effect of Drought Stress During Soybean R2-R6 Growth Stages on Sucrose Metabolism in leaf and Seed. International Journal of Molecular Sciences MDPI, 21(618): 1-19.

[120] Falchi R, E Petrusa, M Zancani, et al. (2019) Summer Drought Stress: Differential Effect on Cane Anatomy and Non Structural Carbohydrate Conten in Overwintering Cabernet Sauvignonand Syrah Vines. Bio. Web. Conferences, 13: 1-6.

[121] Gupta S Devi, Manjri, A Singh, et al. (2018) Effect of Drought Stress on Carbohydrate Content in Drought Tolerant and Susceptible Chickpea Genotypes. International Journal of Chemical Studies, 6(2): 1674-1676.

[122] Blum Abraham (2016) Osmotic Adjustment is a Prime Drought Stress Adaptive Engine in Support of Plant Production. Plant, Cell and Environment. Jhon Wiley and Sons Ltd, 1-8.

[123] Singh Ashu, MK Sharma, RS Sengar (2017) Osmolytes: Proline Metabolism in Plants as Sensor of Abiotic Stress. Journal of Applied and Natural Science, 9(4): 2079-2092.

[124] Li Changning, Zhen Wang, Qian Nong, et al. (2021) Physiological Changes and Transcriptome Profiling in *Sacharum spontaneum* L. leaf Under Water Stress and re-Watering Conditions. Scientific Reports Journal, 11(5525): 1-14.

[125] Arteaga S, L Yabor, M Jose Diez, et al. (2020) The Use of Proline in Screening for Tolerance to Drought and Salinity in Common Bean (*Phaseolus vulgaris*, L.) Genotypes. Agronomy Journal MDPI, 10(817): 1016.

[126] Meena M, K Divyanshu, S Kumar, et al. (2019) Regulator of L-Proline Biosynthesis , Signal Transduction, Transport, Accumulation and its Vital Role in Plants During Variable Environmental Conditions. Heliyon Journal, 5: 1-20.

[127] Winaya Aris, Maftuchah, A Zainudin (2020) The Identification of Osmoprotectant Compunds from *Jatrhopa curcas* Linn. Plant for Natural Drought Stress Tolerance. 6th

International Conference on Energy and Environment Research ICEER. Energy Reports Journal, 6(2020): 626-630.

[128] Jabeen M, NA Akram, M Ashraf, et al. (2019) Assesment of Biochemical Changes in Spinach (*Spinacea oleracea*, L.) Subjected to Varying Water Regimes. Sains Malaysiana Journal, 48(3): 533-541.

[129] Mwenye O Jhon, L Van Rensburg, A Van Biljon, et al. (2016) The Role of Proline and Root Traits on Selection for Drought Stress Tolerance in Soybeans: a Review. South African Journal of Plant and Soil, 33(4): 245-256.

[130] Ahmeed M, Fayyaz Ul-Hassan, G Qadir, et al. (2017) Response of Proline Accumulation in Bread Wheat (*Triticum aestivum*, L.) Under Rainfed Conditions. Journal of Agricultural Meteorology, 74(3): 147-155.

[131] Nguyen TT Quynh, Le Thanh Huyen Trinh, Hoang Bao VP, et al. (2020) Evaluation of Proline, Soluble Sugar and ABA Content in Soybean *Glycine max* (L.) Under Drought Stress Memory. AIMS Bioengineering Journal, 7(3): 114-123.

[132] Kaur Gurpreet, B Asthir (2015) Proline: a Key Player in Plant Abiotic Stress Tolerance. Biologia Plantarium Journal, 59(4): 609-619.

[133] Balestrini R, W Chitarra, C Antoniou, et al. (2018) Improvement of Plant Performance Under Water Deficit With The Employment of Biological and Chemical Agents. The Journal of Agricultural Science, 156: 680-688.

[134] Ratzman G, L Zakharova, B Tietjen (2019) Optimal Leaf Water Status Regulation of Plants in Dryland. Scientific Report Journal, 9(3768): 1-9.

[135] Anderegg William R, A Wolf, AA Velez, et al. (2017) Plant Water Potential Improves Prediction of Empirical Stomatal Models. Plos One Journal, 12(10): 1-17.

[136] Turner Neil C (2018) Turgor Maintanance by Osmotic Adjusment: 40 Years of Progress. Journal of Experimental Botany, 69(13): 3223-3233.

[137] Nadeem Muhammad, Jiajia Li, M Yahya, et al. (2019) Research Progress and Perspective on Drought Stress in Legumes: A Review. International Journal of Molecular Sciences MDPI, 20(2541): 1-32.

[138] Ali Shahid, K Ayat, A Iqbal, et al. (2020) Implication of Absicic Acid in The Drought Stress Tolerance of Plants. Agronomy Journal MDPI, 10(1323): 1-28.

[139] Wang Xiao, Qing Li, Jingjing Xie, et al. (2021) Abcisic Acid and Jasmonic Acid are Involved in Drought Priming Induced Tolerance to Drought in Wheat. The Crop Journal CSSC, 9(2021): 120-132.

[140] Bharath P, S Gahir, Agepati S Raghavendra (2021) Abscisic Acid Induced Stomata Closure: An Important Component of Plant Defense Against Abiotic and Biotic Stress. Froinyer in Plant Science Journal, 12(615114): 1-18.

[141] Chen Jun, Yan Gong, Yuan Gao, et al. (2021) TaNAC48 Positively Regulates Drought Tolerance and ABA Responses in Wheat (*Triticum aestivum*, L.). The Crop Journal, 9: 785-793.

[142] Huber Annika E, PJ Melcher, MA Pineros, et al. (2019) Signal Coordination Before, During and After Stomatal Closure in Response to Drought Stress. New Phytologist Journal, 224(2019): 675-688.

[143] Sah S Kumar, KR Reddy, Jiaxu Li (2016) Absicic Acid and Abiotic Stress Tolerance in Crop Plants. Frontiers in Plant Sciance Journal, 7(571): 1-26.

[144] Valverde C De Ollas, Ian C Dodd (2016) Physiological Impacts of ABA –JA Interactions Under Water Limitation. Plant Mol. Biol. Journal, 91: 641-650.

[145] Anosheh H Pirasteh, AS Moucheshi, H Pakniyat, et al. (2016) Stomatal Responses to Drought Stress. Water Stress and Crop Plants: A Sustainable Approach. Volume 1. First Edition. 24-40.

[146] St Paul Nicolas KM, S Delzon, H Cochard (2017) Plant Resistance to Drought Depends on Timely Stomatal Closure. Ecology Letters Journal, 1-11.

[147] Abid Muhammad, S Ali, Lei Kang Qi, et al. (2018) Physiological and Biochemical Changes During Drought and Recovery Periods at Tillering and Jointing Stages in Wheat (*Triticum aestivul*, L). Scientific Reports Journal, 8(4615): 1-15.

[148] Laxa Miriam, M Liiebthal, W Telman, et al. (2019) The Role of Plant Antioxidant System in Drought Tolerance. Antioxidant Journal MDPI, 8(94): 1-31.

[149] Weng Mingyang, Lirong Cui, Fenling Liu, et al. (2015) Effects of Drought Stress on Antioxidant Enzymes in Seedlings of Different Wheat Genotypes. Pak. J. Bot., 47(1): 49-56.

[150] Nur Cahyo A, RH Murti, Eka TS Putra (2020) Effect of Drought on Physiological Processes, Growth and Yield of Rubber Tree (*Hevea brasiliensis* Mull. Arg.). Warta Perkaretan Journal, 39(1): 57-72.

[151] Zivanovic B, SM Komic, T Tosti, et al. (2020) Leaf Soluble Sugars and Free Amino Acids as Important Components of Abcisic Acid Mediated Drought Response in Tomato. Plants Journal MDPI, 9(1147): 1-17.

[152] Kosar F, NA Akram, M Ashraf, et al. (2018) Trehalose Induced Improvement in Growth, Photosynthetic Characteristics and Levels of Some Key Osmoprotectants in Sun Flower (*Helianthus annus*, L.) Under Drought Stress. Pak. J. Bot. Journal, 50(3): 955-961.

[153] Ferreira Thais HS, MS Tsunada, D Bassi, et al. (2017) Sugarcane Water Stress Tolerance Mechanisms and its Implications on Developing Biotechnology Solutions. Frointers in Plant Science, 8(1077): 1-18.

[154] Laguna K Alejandra, JLC Ponce, RR Medrano, et al. (2018) Trehalose Accumulation Provides Drought Tolerance to Genetically Modified Maize in Open Fields Trials. Pak. J. Agri. Sci. Journal, 55(4): 1009-1020.

[155] Mohammadkhani N, R Heidari (2008) Drought Induced Accumulation of Soluble Sugars and Proline in Two Maize Varieties. World Applied Sciences Journal, 3(3): 448-453.

[156] Hasanuzzaman Mirza, Alam M Mahabub, K Nahar, et al. (2014) Trehalose Induced Drought Stress Tolerance: A Comparative Study Among Different Brassica Species. Plant Omics Journal, 7(4): 271-283.

[157] Lunn J Edwards, I Delorge, CM Figueroa, et al. (2014) Small Molecules: From Structural Diversity to Signaling and Regulatory Roles, Trehalose Metabolism in Plants. The Plant Journal, 79 (2014): 544-567.

[158] Noviana I, Y Haryati, R Sari, et al. (2021) Adaptation to Climate Change by Using Drought Tolerance and Early Maturing Rice Varieties in Majalengka Regency. 1st International Conference on Sustainable Tropical Land Management. IOP Conf. Series. Earth and Environmental Science, 648 (2021): 1-8.

[159] Van Oosten MJ, A Costa, P Punzo, et al. (2016) Genetics of Drought Stress Tolerance in Crop Plants. Drought Stress tolerance in Plants. Chapter 2. Springer International Publishing Switzerland, 39-69.

[160] Rajanna GA, Anchal Dass and V Paramesha (2018) Excess Water Stress: Effects on Crop and Soil and Mitigation Strategies. Popular Kheti Journal, 6(3): 48-53.

[161] Pereira Luis S (2000) Management of Irrigation System to Cop With Drought. Medit Journal, 2 (2000): 33-38.

[162] Saleem MS, MAS Raza, S Ahmad, et al. (2016) Understanding and Mitigating the Impact of Drought Stress in Cotton - A Review, Journal Agri. Science, 53(3): 1-16.

[163] Perez CAH, FCG Merino, JLS Castillo, et al. (2021) In Vitro Screening of Sugarcane Cultivars (Saccharum spp. Hybrids) for Tolerance to Polyethylene Glycol Induced Water Stress. MDPI Journal Agronomy, 11(598): 1-13.

[164] Niu T, T Zhang, Y Qiao, et al. (2021) Glycinebetaine Mitigates Drought Stress Induced Oxidative Damages in Pears. Plos One Journal, 16(11): 1-20 .

Table 1. Water status relationship between water potential and soil water volume

Water Status	Water Potential Status		Soil Water Status			Availability to Plant
	pF	Mpa	Sand	Clay	Loam	
Saturation	0	0	39%	50%	54%	Unavailable
Field Capacity	(-) 1-2,5	(-) 0,33	8-10%	20-35%	36-49%	Available
Wilting Point	(-) 4,2	(-) 1,5	4%	9%	29%	Unavailable

Source: [23,32] - modified

Table 2. Plants responses to drought stress

	Response		
	Morphology	**Physiology**	**Biochemical**
Drought Stress	Strengthens the roots system (roots elongated)	Stomatal closure	ABA synthesis
	Reduce leaf surface area	Reduce CO_2 fixation	Decreased activity of rubisco
	Rolling the leaves	Decreasing photosynthesis	Accumulation of solute compounds (proline, glycine-betaine, sugar)
	Dropping leaves	Increased ROS compounds	Increased antioxidant compounds
	Early flowering		Drought tolerant gene expression

Source: [52] - modified

Table 3. Relationship between drought stress and the sensitivity of plant metabolic processes

Affected process	Sensitivity															
	Very susceptible						Susceptible					Unsusceptible				
(-) decreased	Pressure (Bar) (-)															
(+) increased	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Cell growth (-)																
Cell wall synthesis (-)*																
Protein synthesis (-)*																
Proto-chlorophyll formation (-)**																
Nitrate reductase (-)																
ABA Synthesis (+)																
Stomatal conductivity (-)																
Fixation of CO_2 (-)																
Respiration																
Xylem conductivity (-)***																
Proline synthesis (+)																
Sugar synthesis (+)																

Note: *= fast growing tissue; **= etiolated leaves; ***= xylem dimension factor
Source: [36] - modified

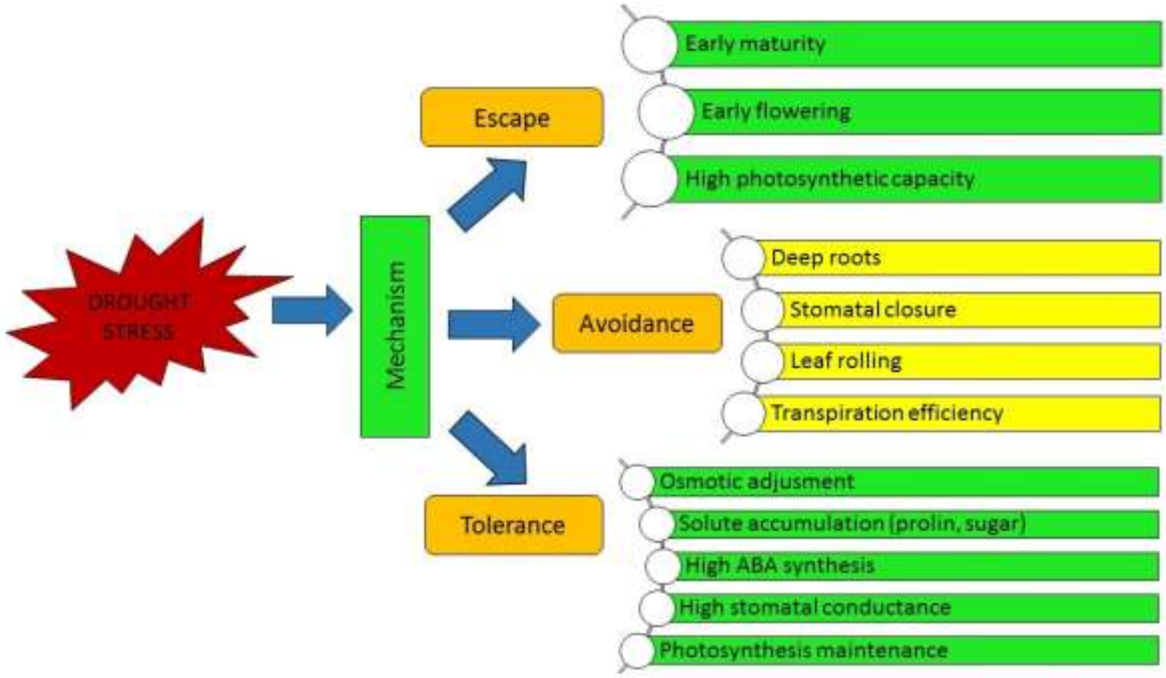


Figure 1. Crops mechanism in drought stress [65] - modified

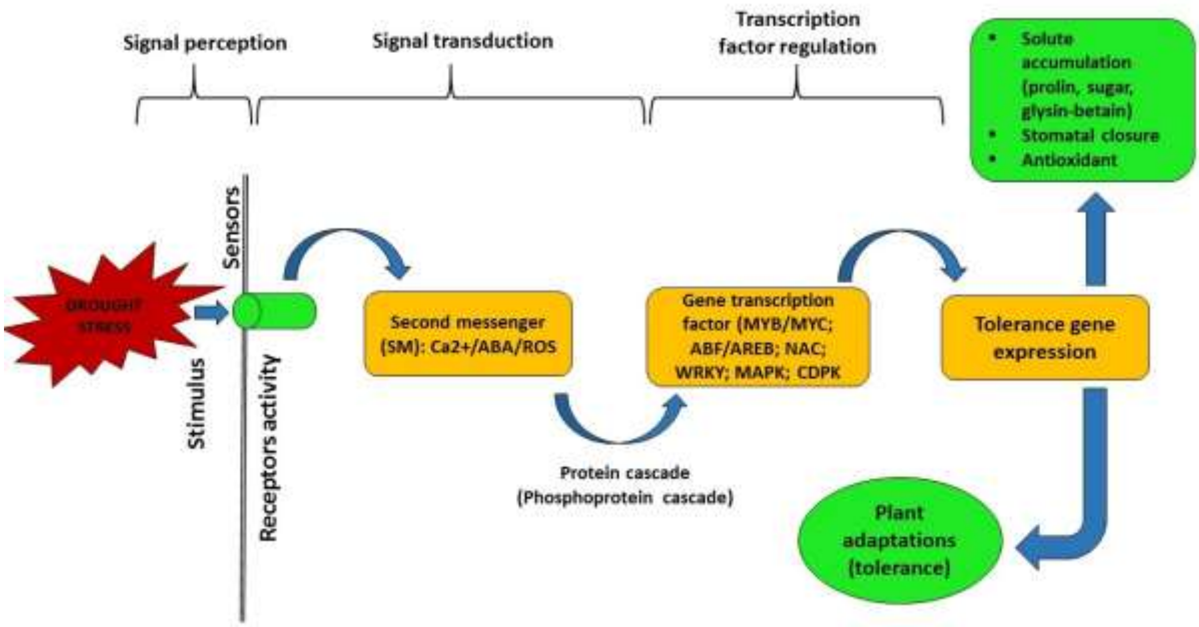


Figure 2. Signaling plant networks against drought stress [11,72] - modified

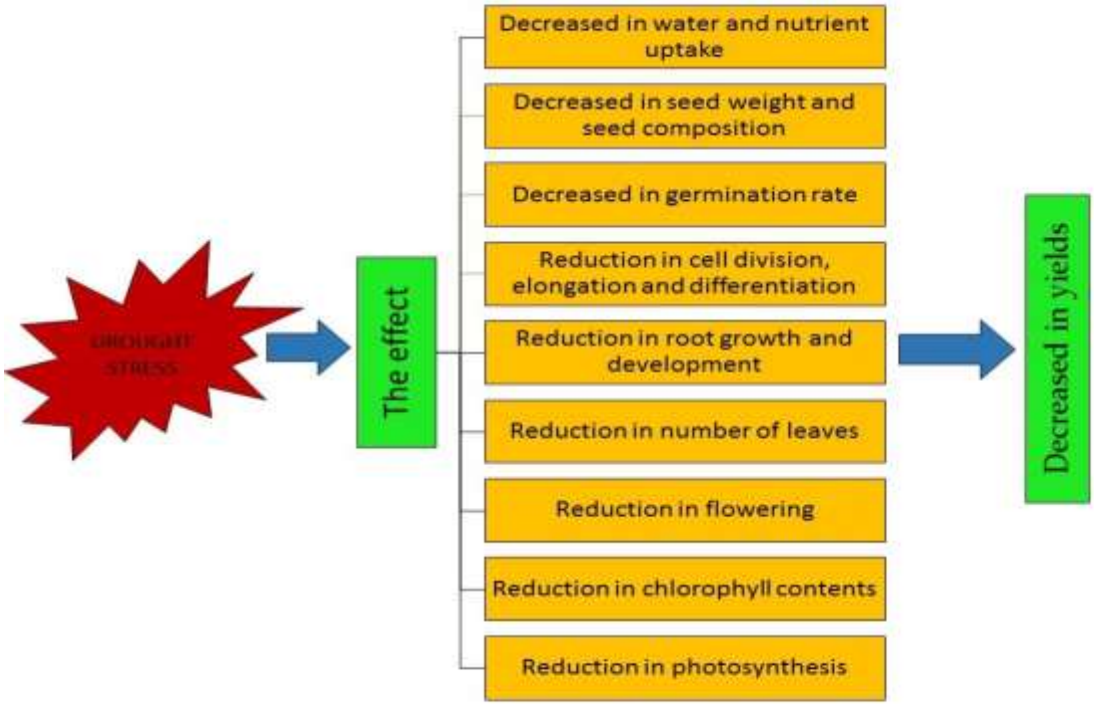


Figure 3. The impact of drought stress on crops [137] - modified

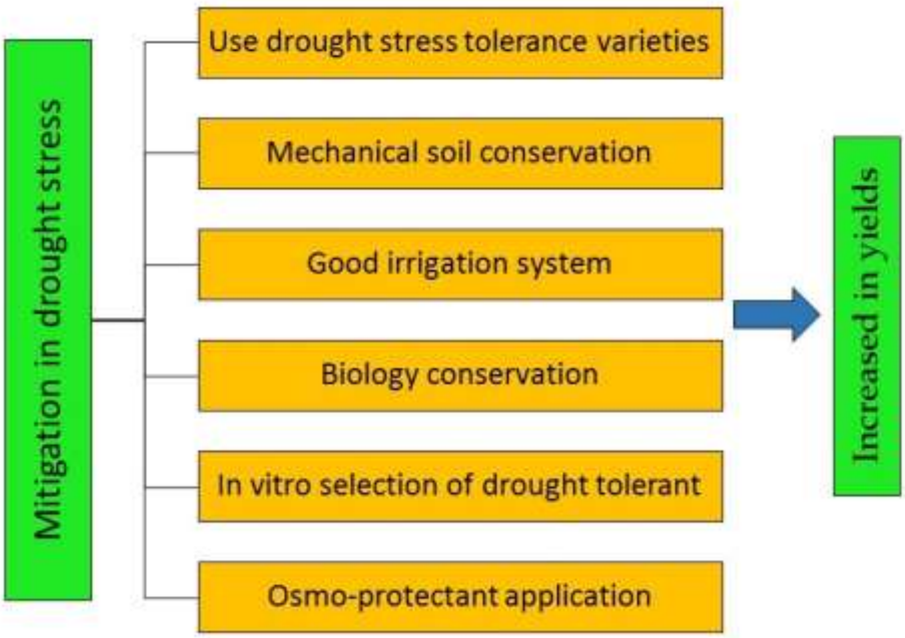


Figure 4. Mitigation in drought stress

Dear,

Editor in Chief Reviews in Agricultural Science,

I am Saktiyono Sigit Tri Pamungkas, representing on behalf of the manuscript (Suwarto, Suprayogi and Noor Farid). I wish to submit a second revision of my paper according to the reviewers comment.

LIST OF CHANGE

Title: Drought Stress: Responses and Mechanism in Plants
Author: Saktiyono S.T. Pamungkas[1)*], Suwarto[2)], Suprayogi[2)], Noor Farid[2)]

Reviewer 1 and 2

No.	Reviewer Comment	Response
Overall Comments		
1.	Reviewer 1 Figure 1, 2, 3. Use clearer color, red color cannot be seen clearly. And use high resolution picture for all figures, I check that the quality still too low.	Thank you very much for your comment. I have revised it: - I have changed all the red color of the figures (1,2 and 3), I hope this is clearer. You can find in line 889, 892 and 895. - I have corrected and have changed all the resolutions of the figures (1,2,3 and 4) to use the dimensions of 10240 x 5760 pixels and a resolutions of 768 dpi. You can find in line 889, 892, 895 and 898.
2.	Reviewer 2 Improve the format of all figures and tables while referring the published article of this journal.	Thank you very much for your comment. I have revised it: - I have have changed all the resolutions of the figures (1,2,3 and 4) to use the dimensions of 10240 x 5760 pixels and a resolutions of 768 dpi. You can find in line 889, 892, 895 and 898. - I have improve the all of tables (1,2 and 3) by increasing the font size, I hope all the tables can be read clearly. You can find in line 879, 882 and 885.

Best regards,
Saktiyono Sigit Tri Pamungkas
Department of Plantation, Vocational Education, Polytechnic of LPP Yogyakarta
Jl. LPP No: 1 A, Balapan, Klitren, Gondokusuman, Yogyakarta,Special District of Yogyakarta, 55222, Indonesia

Title: Drought Stress: Responses and Mechanism in Plants

Total number of words: 9,899 words

Author: Saktiyono S.T. Pamungkas[1)*], Suwarto[2)], Suprayogi[2)], Noor Farid[2)]
Affiliation[1)]: Department of Plantation, Polytechnic of LPP, Yogyakarta
Address[1)]: Jl. LPP No: 1 A, Balapan, Gondokusuman, Yogyakarta, 55222, Indonesia
[*]Corresponding author: Email: skt@polteklpp.ac.id
Affiliation[2)]: Departement of Plant Breeding, Agriculture Faculty, University of Jenderal Soedirman, Purwokerto

Address[2)]: Jl. DR. Soeparno No: 63, Karangwangkal, Purwokerto Utara, Banyumas, 53122, Indonesia

Abstract:

The function of water for plants is crucial, including playing the roles in metabolic reactions. The aims of this article is to give information on the effects of drought stress on plant morphology, physiology, and biochemistry, as well as mitigation methods in drought stress management for plant production. Plants manage drought stress using a mechanisms, namely drought escape, drought avoidance and drought tolerance. Drought escape is the ability of plants to accelerate flowering or life cycle, drought avoidance is the ability of plants to reduce water loss and increase water absorption through morphological changes in the root system, drought tolerance is the plant adaptation to drought by changes in plant physiological and biochemical processes. Physiological changes that occur include closing the stomata and decreased photosynthesis. The biochemical responses include the synthesis of solute compounds as a form of osmotic adjustment in the cell called osmotic adjustment to reduce water loss from the cell. The biochemical indicators are the increased concentrations of abscisic acid (ABA), proline, and sugar (trehalose). ABA acts as a signal to stimulate stomatal closure to reduce the transpiration rate. Proline is an indicator of plants adapting to drought stress, playing a role in the osmotic adjustment of cells to retain in the cell. Trehalose is a compatible sugar acting as an osmoprotectant, it can maintain the integrity of cell membranes (water replacement) and form hydrogen bonds (water entrapment). Plants under drought stress conditions can adapt by making morphological, physiological, and biochemical responses by osmotic adjustment. These conditions need to be managed so that appropriate strategies and technologies are needed as mitigation measures.

Keywords: Drought Stress, Dryland Management, Osmotic Adjustment

Introduction

The aims of this article is to give information on the effects of drought stress on plant morphology, physiology, and biochemistry, as well as mitigation methods in drought stress management for plant production. Water is a vital requirement for the survival of plants. Plant tissues are composed mostly of these, which is about 80% to 95%, predominantly found in the cytoplasm and vacuoles [1] . However, some tissues have a content is about 10-15%, one of which is dormant seeds [2] . Water is a major factor in plant growth since it is needed by plants to carry out physiological processes [3]. In plants, these is the main molecule that makes up protoplasm (cytoplasm, nucleus, and organelles) [4]. Besides that these is a solvent for dissolved substances in cells. If water is used as a solvent for acidic or alkaline components, it will be positively charged (K^+, Ca^{++}, NH_4^+) or negatively charged (NO_3^-, SO_3^-, HPO_4^-), respectively. The functions of these as a medium for metabolic and physiological reactions in plants, in which metabolic and physiological activities can decrease when there is a lack of water and also plays a role as a medium for transporting essential nutrients and minerals from the soil so that a lack of water can reduce the rate of nutrient uptake from the soil by roots [5]. These is also one of the main factors determining plant production related to biomass production and transpiration rate [6]. Water will affect cell turgidity, thereby affecting the process of opening and closing stomata. The conversion of sunlight will be reduced if the stomata are closed, which will affect the photosynthesis results [7]. These is also affects transpiration in plants, in which more water will increase the transpiration rate and vice versa [8].

Plants will always be exposed to various stress conditions, including biotic stresses such as pests, pathogens, viruses, nematodes [9], and abiotic stresses, namely drought, water saturation, temperature, and salinity . One of the stresses influencing the growth and yield of cultivated plants is drought [10]. According to the agronomic point of view, drought is defined as the relationship between moisture and water availability in the soil. These absorption and dissolved mineral nutrients decrease when there is a lack in the soil [12]. Disruption in the absorption process disrupts metabolic processes, impacting plant physiological and morphological functions, which can affect yields [11]. Drought occurs due to climate change and soil type. All regions in the world with a share of seawater will experience El Nino, a condition in which the sea surface temperature (SML) warms up, resulting in a long drought that decreases the water availability, which is predicted to affect the rate of evapotranspiration [13]. In Indonesia, in the range of 2019, El Nino had an impact on the expansion of dryland areas almost three times compared to that in 2017 [14]. The characteristics of soil types are very diverse [15], so the ability of the soil to hold water in field capacity varies according to the soil texture [16,17]. Sandy soil type can hold water about 2.1 in/ft, clay can hold these around 3.8 in/ft, while clay soils can hold these around 4.4 in/ft [18].

In the soil these is divided into four types, including chemical, hygroscopic, capillary, and groundwater [19]. Chemical water located in the soil surface that still contains chemicals (from rain) and is a type of soil that is not available to plants. Hygroscopic is strongly bound by the soil (permeates). Capillary fills the capillary pores (infiltration) in the soil with a greater cohesive force than the adhesion force on soil particles, making it available to plants. Whereas groundwater can continue to fall to the bottom layer due to the influence of gravity (percolation). Available of these is defined as the condition or difference between the amount of the field capacity and the amount of the wilting point [20]. Field capacity is the amount of capillary in the soil, while the wilting point is the amount of hygroscopic water in the soil that makes water unavailable [21].

Water Deficit

The ideal soil composition consists of 45% mineral content, 25% water, 25% air, and 5% organic matter [22,23] . This condition will stabilize the water tension at field capacity (pF) on the soil, stabilizing the force of attraction between water molecules (cohesion) and between water molecules and soil particles (adhesion) becomes. If cohesion is stronger than adhesion, the water can't be bound by soil pores [24,25] . In addition to being influenced by the adhesive power, the soil's ability to bind water also depends on the type of soil. The higher the clay content of the soil, the lower the adhesion force, causing a low pF value, resulting in water saturation so that water is not available. On the other hand, low cohesion will result in a high pF value, which in turn causes a water deficit [26,27]. Besides being influenced by pF, it is also influenced by water potential [28,29]. At a pressure of 0 Mpa, the soil is saturated with water, while -0.33 Mpa at field capacity conditions and -1.5 to -3 Mpa is the permanent wilting point [30,31]. In addition to the influence of pressure, according to Easton [23] and Datta *et al.* [32], the volume of water in the soil also depends on the type of soil to bind water so that it will determine water saturation (sand: 39%, clay: 50%, clay: 54 %), field capacity (sand: 8-10%, clay: 20-35%, clay: 36-49%) and permanent wilting point (sand: 4%, clay: 9%, clay: 29%). A high pF value will lead to high percolation, resulting in water loss and a low groundwater potential. Otherwise, a low pF value causes low water holding capacity with the soil pores (adhesion), resulting in low groundwater potential.

In drought conditions, plants will lack water in the rhizosphere (around plant roots), decreasing groundwater potential (Ψ_w) and increasing osmotic potential in plant cells (Ψs), which decrease plant cell turgor pressure (Ψ_p) (-) [33,34] . Such conditions must be balanced by maintaining cell turgor pressure to remain in a positive condition. Turgor pressure (Ψ_p) that has a positive value depends on the ability of plant cells to balance the value of Ψ_w and the value of Ψ_s with a certain scheme. This condition is called osmotic adjustment in plant cells (osmotic adjustment), shown in an equation of $\Psi_w = \Psi_s + \Psi_p$ [35,36] .

Turgor pressure affects the shape, reaction, and cell changes in plants. Water deficit in grains (barley and corn) was reported to decrease cell turgor pressure [37,38]. Under decreased turgidity, water molecules leave the cell. If water continues to leave the cell, the cell loses flexibility, resulting in wilting [39]. To prevent water from leaving the cell, the cell applies an osmoregulation mechanism to maintain the turgor pressure remains positive (+). If transpiration continues to occur, while the water absorption process continues to decrease, the cell is no longer able to maintain turgidity, other than wilting, if the plant is unable to recover, the plant may die [40]. Water deficit in plants can affect morphology and physiology. At the morphological level, water deficit will cause the leaves to wither, the leaves to shrink, curling leaves, the small number of leaves, the elongated roots [41,42], and early flowering [43]. At the physiological level, it can disrupt metabolism, thereby affecting crop yields. The metabolic process is characterized by the formation of compounds in response to drought conditions, such as sugar [44,45], glycine-betaine [46,47], proline [48,49], and ABA [50,51].

Drought Responses

Drought causes plants to experience an increase in osmotic pressure, resulting in a decrease in cell turgor pressure. If the drought continues beyond the limit of permanent wilting, the plant may suffer damage and death [40,53]. As a form of anticipation, plants carry out certain mechanisms to keep physiological and metabolic processes running. Drought causes water deficit in plants, affecting their morphology [54]. There are three levels of water deficit, consisting of mild drought stress (lower water deficit), moderate drought stress (middle water deficit) when the water potential decreases, and severe drought stress (higher water deficit). Mild, moderate, and severe drought stress occurs when the water potential decreases to 0.1 MPa, up to 1.2 Mpa to 1.5 Mpa, and more than 1.5 MPa, respectively. This condition can decrease the relative water content (RWC) in plants, for example, leaves. Moderate to severe drought stress can decrease relative water content RWC in teak [55]. The decrease in RWC in soybean plants can reduce the water potential in the leaves [56]. In tomatoes, a decrease in RWC can affect fruit weight and the amount of chlorophyll in leaves [57]. Mild, moderate, and severe drought stress will reduce RWC by about 8-10%, 10-20%, and more than 20%, consecutively. The continuous severe drought stress will disrupt the physiological processes of the plant. Disruption of plant physiological processes ultimately results in decreased yields of several crops (tomato, corn, potato, rice, and wheat) [58-68].

Adaptation Strategy

According to Rini *et al*. [11], plants respond to drought stress by three mechanisms (escape, avoidance, and tolerance). Drought escape is a form of plant adaptation to drought stress by accelerating the generative phase. In this condition, the plant stops the vegetative phase and tries to produce seeds before drought stops its life cycle [69]. Wheat plants accelerate the generative phase and terminate vegetative growth to minimize water loss [70]. This strategy is common for plants to complete their life cycle as long as the environment is still possible before facing drought. In Arabidopsis plants, this strategy is carried out by using water efficiently for growth [71]. These mechanisms include early flowering and harvest age, as well as plant plasticity [72]. Drought avoidance is an adaptation of plants to maintain water availability under stress conditions, keeping the water potential in cells remains high. One of the common morphological indications is its effect on root elongation [11,73]. In potato plants, this strategy is indicated by the elongation of roots and differences in the number of shoots [74]. Differences in root morphology in Arabidopsis are used to increase water uptake so that the water content in the tissue remains balanced [75]. The physiological effects that occur may be a decrease in the rate of transpiration and a decrease in the area of transpiration, such as small leaf and a small number of leaves [76]. Drought tolerance is a condition for plants to survive despite experiencing drought stress (water deficit) [11].

Stress Signal Mechanisms

Plants respond to drought stress in the form of a sign, called signal perception (SP), due to the introduction of a stimulus to stress conditions. This signal begins with a disturbance in the balance of the cell wall so that signal activation will occur in the form of protein molecules [11] [72]. The difficulty of roots in absorbing water can provide a signal by modifying the cell membrane so as not to lose cell turgidity [77]. SP is assisted by components in the form of smaller molecules, such as diacylglycerol (DAG) and phosphatidic acids (PA), which are referred to as second messengers (SM) that will transmit SP as a form of stress signal in plants before signal transduction (ST) occurs [11]. Drought will cause changes in osmotic pressure in cells so that SP will stimulate the hydraulic signal (HS) in plant cells by trying to increase dissolved materials so that water does not leave the cell. HS in Arabidopsis plants is initiated by the AHK1 kinase (protein) compound, which functions as an osmo-sensor in the plant cell membrane layer [78]. Osmo-sensors in Arabidopsis plants are associated with calcium channels called hyperosmolality gated calcium-permeable channels (OSCA) that allow Ca^{2+} influx processes in cell membranes [79]. In addition to another OSCA, there is another osmo-sensor called MSL (mechanism sensitive like ion channels). MSL is an osmo-sensor found in plant cell membranes affecting the process of K^{+} influx [80]. Another osmo-sensor found in plant cell membranes is receptor-like protein kinase (RLKs) which play an important role in inducing abscisic acid (ABA) as a signal form against drought stress [81].

After exposure to drought stimulates SP assisted by SM, the next step is ST initiation. ST is a protein kinase molecule that is a series of signals in plants experiencing abiotic stress, including drought, to stimulate certain protein kinases in response to stress [11]. Mitogen-activated protein kinase (MAPK) and Calcium-dependent protein kinase (CDPK) are types of ST in plants connected to target molecules in the MAPK cascade system, functioning as ST in the phosphorylase and dephosphorylation processes [82]. In cotton and arabidopsis plants, MAPK is found in leaf cell membranes and affects the regulation of stomata and growth (length) of plant roots [83,84]. MAPK interaction with sucrose nonfermenting related protein kinase-1 (SnRK1) also affects carbohydrate metabolism to be converted into simpler molecules during drought stress [85]. CDPK is an ST formed due to the influx of Ca^{2++} in plant cell membranes that affect ABA regulation and stomata regulation in potato plant leaves [86]. In strawberries, CDPK is identified on cell membranes in the form of FaCDPK appearing in the fruit ripening phase under drought stress conditions. This FaCDPK causes an increase in ABA in strawberry fruit [87]. In soybean plants, CDPK is identified as GmCDPK3, which can lead to an increase in proline and chlorophyll. This condition increases plant resistance to drought conditions [88]. In addition to MAPK and CDPK, drought stress leads to the production of ROS compounds in the form of hydroxyl peroxide (H_2O_2) and singlet oxygen (O_2^-), which decrease the amount of chlorophyll, thereby forcing plants to form antioxidant compounds, one of which is proline [89]. High ROS compounds can cause oxidative stress so that cells can die. Therefore, cells respond by activating antioxidant enzymes to prevent cell damage [90].

Physiological Effects and Mechanisms

Plant growth and development are related to cell division, elongation, and differentiation, which depend on water availability [91-93]. In 15 wheat genotypes, water deficit can reduce yields by 20% to 25% [94]. Moderate and severe water drought stress will increase the dry weight of wheat grain per 1000 grains by 1.95% to 2.07% as a result of the starch formation response [95]. There is no significant reduction in the yield of quinoa plants under drought stress. However, there is an increase in the amount of proline, glutamine, Na, K, and ABA and a decrease in the stomatal opening, thereby reducing transpiration [96]. Water deficit in rice plants is a limiting factor that can reduce yields up to 25.4% and affect root length as a strategy to deal with drought stress [97]. In some plants, water deficit inhibits flower formation [98] [99]. The conclusion is that water deficit can inhibit flowering, increase the number of solutes and reduce yields in plants.

Water deficit causes plants to carry out physiological responses by reducing transpiration, closing stomata, and reducing the number of leaves [11,72,73]. In tomato plants, a decrease in the rate of photosynthesis is due to a lack of water and a high rate of respiration, resulting in the efficient use of water [100]. The stomatal closure to suppress the transpiration rate is related to the efficiency of photosynthesis. In photosynthesis, the efficiency of light absorption and transformation is determined by chlorophyll fluorescence and electron transport [101]. Low light absorption by chlorophyll can result in low light waves, decreasing the CO_2 and energy absorbed [102,103]. The decrease in CO_2 uptake in canola and wheat plants can reduce the rate of photosynthesis and ultimately reduce biomass in production [104]. Water deficit leads to the production of radical compounds called ROS. If there is no balance between the rate of photosynthesis, the production of antioxidant compounds can be inhibited, as illustrated in the research on canola plants [105]. The decrease in the rate of photosynthesis is also influenced by the ABA response as a signal of drought stress, which results in regulation of stomatal closure [106,107]. ABA is formed in roots and transported to leaves to signal and regulate stomatal closure due to lack of water stimulated by certain genes such as NPF4.6 and DTX5.0 [108]. A further impact is the reduction of CO2 for photosynthesis. The decrease in the CO_2 carboxylation process and the closing of stomata due to abiotic stress can reduce the rate of photosynthesis, decreasing the number of functional Ribulose 1.5 bisphosphate carboxylae oxygenase (RuBisCo) in photosynthesis [109]. The conclusion is that drought stress causes morphological and physiological responses in plants. Morphological responses occur in root elongation, leaf size, and the number of leaves. Physiologically roots can respond by transporting ABA to regulate stomatal closure to reduce evaporation. Closure of stomata results in low CO_2 absorption, causing the photosynthesis process to be not optimal. The general response of plants to water deficit is to close their stomata, which is beneficial to reduce water loss [110,111]. In addition, water deficit can affect hydraulic conductivity due to hydraulic signals, gas exchange, water potential, and ABA determination in leaves (stomata) [107]. In wheat, stomatal conductivity results in transpiration efficiency, which is influenced by leaf transpiration and assimilation rate [112]. Water loss during the vegetative phase causes soybean plants to balance water potential (osmotic adjustment) by dropping leaves, reducing leaf size, closing stomata, and folding leaves for water usage efficiency through transpiration reduction, however this reduces leaf area index (LAI) and so reduces photosynthetic rate [113]. The stomatal closure is a plant response to drought stress, which can decrease transpiration and photosynthesis rate. However, this regulation is a complex mechanism interconnected between external (water availability) and internal (ABA response) factors.

The photosynthesis process is influenced by the activity of supporting enzymes, one of which is RuBisCo. RuBisCo plays a role in photosynthesis, namely photosystem II [114]. Under drought stress, the amount of light absorption is small, decreasing the activity of RuBisCo [115] [116]. Drought stress is often accompanied by an increase in temperature, resulting in photoinhibition, which can impair RuBisCo's ability to activate the photosystem II pathway [117]. This decrease occurs because the CO_2 carboxylase process by RuBisCo is not optimal [72]. Drought stress inhibits the RuBisCo enzyme, which can lead to a reduction in carboxylate assimilation. Hence, the regeneration of RuBP will ultimately inhibit the rate of photosystem II [118]. High temperatures and drought stress in rice, wheat, and corn restrict RuBisCo function by inhibiting the RuBisCo activase enzyme, which can reduce photosynthetic optimization [114]. Photosynthetic products are usually transported to parts of the plant. However, in drought conditions, there is a change in carbohydrate translocation in plants so that limited carbohydrates are translocated to places contributing to resisting drought stress [119,45]. Carbohydrates are translocated in the form of simple components to maintain osmotic balance, which is in roots are used for morphological growth to increase water uptake and ABA induction [120]. Increasing the amount of carbohydrates in plant parts during the vegetative and generative phases is a method used by plants to survive under drought stress [121].

The plants' response to drought stress is to maintain osmotic balance in cells [69,122]. One of the mechanism to maintain this balance is to form soluble compounds to hold water out of the cell (compatible solute) [123,124]. In addition, these soluble compounds are antioxidant compounds that protect cell membranes from damage caused by ROS, one of which is proline [47,125-127]. Proline and glycine-betaine are used as antioxidants and cell membrane protection from radical compounds (ROS) [128]. High proline in the leaves of rice, soybean, and sugarcane plantlets is a physiological indication of plants to resist water deficit [48,129,125]. In wheat cv. Chakwal 50, the proline content increased as a result of drought stress, indicating an osmotic adjustment process in cells in addition to free radical scavengers [130]. The presence of proline in soybean plants can increase water stress resistance and stabilize protein structure [131]. Proline is used as an indicator in drought-tolerant plants so that it is used as the basis for breeding drought-resistant transgenic plants [132]. Proline, in chloroplasts, is a synthesis of glutamate, which is reduced to glutamate semialdehyde (GSA) by the P5CS enzyme (encoded by two genes) and converted spontaneously to P5C (encoded by one gene) [126]. In mitochondria, proline undergoes catabolism with the help of proline oxidase (PDH) to form P5C, which is then converted to glutamate [123].

In simple terms, the water balance in plants can be described as the equal amount of water coming out (transpiration) and water coming in (absorption). The imbalance condition will interfere with plant physiology, causing plants to experience stress [133]. In relation to physiological processes, drought stress is related to turgor pressure, stomatal opening, photosynthetic rate, enzyme damage, and root density [72]. plant growth due to low CO2 absorption [134]. The direct inhibiting factor for plant growth is not water potential but osmotic potential and turgor pressure [135,136]. The influence of turgor pressure can result in osmotic adjustments in plants to reduce water loss [137]. Plants regulate water balance by generating phytohormones, such as ABA, through their roots. ABA is a plant mediator in response to drought, which is synthesized mostly in roots [138,108,139]. ABA is said to be the main internal signal allowing plants to resist drought, which is transported to the leaves to affect stomata closure to reduce transpiration [140,141,42]. ABA is a simple sequence of carotenoid compounds. In fungi, ABA is synthesized through the metileritritol phosphate (MEV) pathway, which begins with the formation of mevalonate. Meanwhile, ABA in plants is synthesized through the MEP pathway, starting with the formation of carotenoids into more specific compounds (zeaxanthin) [139]. Assisted by the zeaxanthin epoxidase (ZEP), zeaxanthin is converted to violaxanthin and turned to neoxanthin. In Arabidopsis, the gene involved in this process is ABA4. Neoxanthin will be converted into xanthine with NCEDs enzymes as activators (found in arabidopsis, corn, tomatoes, cowpea, and grains). In maize, the gene involved is known to be VIP14. Xanthine is converted to abscisic aldehyde and then to ABA. The genes involved in this process are ABA2 and ABA3 in Arabidopsis plants and TaNAC48 in wheat [142].

ABA formed in the roots is transported to the leaves and the flowers. NCED2 and NECD3 proteins are known to play a more dominant role in the synthesis of ABA in roots, while NCED5, NCED6, and NCED9 are more dominant in the flowering part. Apart from being an early signal of drought that will be transported to the leaves, ABA will also affect the growth of stressed plant roots by increasing water influx by the roots [143]. ABA transport to the leaves occurs with enzymes (such as CLE25) as activators. When ABA reaches the leaves, it becomes a signal for stomata to close [144]. Stomatal closure can be beneficial to reduce transpiration [145,146], but the rate of photosynthesis will decrease, photorespiration will increase, and the accumulation of ROS compounds will increase [147]. The ABA-mediated gene for stomatal closure in wheat is TaNAC48 [142]. When the stomata close, there is a lack of CO_2. The excess O_2 from photosynthesis is bound by RuBisCo molecules, and some of these compounds can form ROS chemicals. RuBisCo should be able to bind CO2 absorbed from PEP (in C4 plants). With the decrease in the amount of CO2, the O2 bound by RuBisCo can produce CO2, but more energy (ATP) is required, thereby reducing the efficiency of photosynthesis. When the stomata are closed, there will be a buildup of singlet oxygen (O^-) and hydroxide compounds (H_2O_2) as a result of photosynthesis, forming toxic ROS compounds. This condition is anticipated by forming direct antioxidant compounds (carotenoids, mannitol) and antioxidant enzymatic reactions, such as SOP, APX, and CAT, which can convert ROS compounds into O2 and H2O [90,148,149,76]. However, severe and long-duration stress causes an imbalance between ROS and antioxidants. If the ROS is higher than the antioxidant, it will attack the fatty acids on the membrane (PUFAs) so that the cell membrane will be damaged, and if the plant cannot adapt, the plant will be sensitive and die [150]. The increase in ROS compounds that are not matched by an increase in antioxidant compounds and other solute compounds causes membrane damage to plant cell walls and other responses such as proline formation and an increase in reaction enzymes such as SOP, APX, and CAT [76].

Plants such as tomato plants [151], sunflower plants [152], sugarcane [153] respond to drought stress by forming compatible solutes, namely sugars with low molecular weights that are osmoprotectant compounds (stress protecting agents) [154]. Regarding the function of trehalose, there are at least two supporting theories. The first theory is water replacement because it can form hydrogen bonds with surrounding structural molecules that function as a substitute for water, for example, trehalose with lipid molecules will function as membrane integrity guards during drought stress (changes in the membrane from a fluid phase to a gel phase). The second theory is water entrapment since it can play a role in collecting water by forming hydrogen bonds to form a water layer in the cell [155]. Trehalose is a disaccharide group formed from the breakdown of carbohydrates into two glucose molecules [156]. Plants under drought stress will increase ABA synthesis, playing a role in stomatal closure and stimulating signal transduction by forming a protein cascade, namely TPS1 protein. This protein will activate transcriptional genes such as the TreGP gene (TGP), which will play a role in the formation of trehalose as a compatible solute in cells that supports osmotic adjustment in cells [156,157].

Drought Stress Management

Drought stress has an impact on agriculture crop cultivation, thereby decreasing crop production. Therefore, it is necessary in these condition to require management to increase crop production. These condition has management variations so that appropriate strategies and technologies are needed as mitigation measures. Mitigation management can be done by:1) Use early maturing varieties and drought stress tolerance varieties. The use of early maturing to facing drought stress can be used to increase crop index (CI) and it will maintain high yields [158]. Drought tolerance varieties can respond and induces expression of drouht stress related genes so that the plant will survive in these conditions [159]. 2) using mechanical soil conservation such as making terraces and bed planting which are used to suppress surface water flow and hold back puddles. The terraces are supported and can help in binding soil particles and also to bind water longer whereas bed planting can enhances the water infiltration rate and can maintain mouisture conditions [160]. 3) applying a good irrigation system. Drought and water scarcity conditions need irrigation management, this should be seen within supply and demand management for plant [161]. 4) biological conservation using mulch to improve soil structure and to increase the ability of the soil to hold water. Mulching is one of the important management practice for conserving soil moisture in plants cultivation. That evaporates from soil with mulch will be condenses on the lower surfaces and go back to the soil thus conserving moisture [162]. 5) selecting drought-tolerant plants both in vitro and in vivo by using selector agents such as PEG. The in vitro screening using PEG-6000 is an alternative for the early selection of drought tolerance varieties, it is known through gene markers of varieties that are considered optimal growth in drought stress [163]. 6) applying osmo-protectant compounds, such as glycine betaine. Glycine betaine exogenous application can reducing the aggregation of ROS, that can improving SOD and CAT activities which will result in an osmotic adjustment mechanism [164].

Conclusion

Drought stress causes plant to be in a state of water deficit. Water deficit has an impact on cell division, cell elongation, cell differentiation, and a decrease in CO_2 fixation so that it can reduce photosynthetic results and the accumulation of ROS compounds, thereby decreasing crop production. These condition stimulates plants responses through morphological and physiological changes. Mitigation management can be done by several ways such as use tolerance varieties (early maturing), soil conservation, good irrigation system, use mulch as biological conservation, selection in vitro to screening drought stress tolerance varieties and exogenous application osmo-protectant like glycine betaine.

Acknowledgement

The authors would like to thank to Polytechnic of LPP Yogyakarta for supporting this study.

Conflict of interest

The authors declare no conflict of interest.

References

[1] Jaganathan Ganesh K, Song G, Liu Wei, et al. (2017) Relationship Between Seed Moisture Content and Acquisition of Impermeability in *Nelumbo nucifera* (Nelumbonaceae). Acta Botanica Brasilica Journal, 31(4): 639-644.

[2] Ferreira L Bernandes Da Silva, Fernandes NA, De Aquino LC, et al. (2017) Temperature and Seed Moisture Content Affect Electrical Conductivity Test in Pea Seed. Journal of Seed Science, 39(4): 410-416.

[3] Tatrai Z Attila, R Sanoubar, Z Pluhar, et al. (2016) Morphological and Physiological Plant Responses to Drought Stress in *Thymus citriodorus*. International Journal of Agronomy Hindawi Corporation, : 1-8

[4] Bhatla Satish C, MA Lal (2018) Plant Physiologi, Development and Metabolism. Springer Publhiser, Singapore: 1-9.

[5] Xue Ran, Yuying Shen, Petra Marschener (2017) Soil Water Content During and After Plant Growth Influence Nutrient Availability and Microbal Biomass. Journal of Soil Science and Plant Nutrition, 17(3): 702-715.

[6] Quemada C, JM Perez Esqudero, R Gonzalo, et al. (2021) Remote Sensing of Plant Water Content Monitoring: A Review. Remote Sensing Journal MDPI, 13(2088): 1-37

[7] Driesen E, W Van Den Ende, M De Proft, W Saeys (2020) Influence of Environmental Factors Light, CO2, Temperature and Relative Humidity on Stomatal Opening and Development: A Review. Agronomy Journal MDPI, 10(1975): 1-28.

[8] Henry C, GP Jhon, Ruihua Pan, et al. (2019) A Stomatal Safety Efficiency Trade off Constrains Responses to Leaf Dehydration. Nature Communication Journal, 10(3398): 1-9.

[9] Dresselhaus T, R Huckelhoven (2018) Biotic and Abiotic Stress Responses in Crop Plants. Agronomy Journal MDPI, 8(267): 1-6.

[10] Jena J, SK Sahoo, GK Dash (2020) An Introduction to Abiotic Stress in Plants. Advances in Agronomy Journal, 9: 163-183.

[11] Rini D Setyo, Budiarjo, I Gunawan, et al. (2020) The Mechanism of Plant Response to Drought Stress. Journal of Ilmu-ilmu Hayati LIP, 19(3B): 373-384.

[12] Badan Penanggulangan Bencana Daerah (BPBD) Yogyakarta Region (2019) Dry season is Coming, Beware of Drought. Musim Kemarau Datang, Waspada Kekeringan. http://www.bpbd.jogjaprov.go.id/musim-kemarau-datang-waspada-kekeringan. (Accessed on 19 September 2021)

[13] Ihuoma Samuel O, CA Madramootoo (2017) Recent Advances in Crop Water Stress Detection. Computers and Electronics in Agriculture Journal, 141: 267-275.

[14] Rismayantika F, R Saraswati, IPA Shidiq, et al. (2020) Identification of Dry Areas on Agricultural Land Using Normalized Difference Drought Index in Magetan Regency. IOP Conf. Series: Earth and Environmental Science, 540: 1-8.

[15] Tamara Dita (2021) 8 Jenis Tanah di Indonesia Beserta Karakteristik dan Manfaatnya. 8 Types of Soil in Indonesia and Their Characteristics and Benefits. https://m.kapanlagi.com/plus/8-jenis-jenis-tanah-di-indonesia-beserta-karakteristik-dan-manfaatnya-012b07-0.html. (Accessed on 27 September 2021)

[16] Al Khairi Yuhan (2019) Soil Structure and Texture-Definition, Types and Function, Struktur dan Tekstur Tanah-Pengertian, Jenis dan Fungsi Tanah. https://www.99.co/id/panduan/struktur-dan-tekstur-tanah-pengertian-jenis-hingga-fungsinya. (Accessed on 20 September 2021)

[17] Tanga KK, MN Kusuma, Musarofa, et al. (2020) The Process of Filtration and Dispersion of Sandy Loam Soil Types in River Water Treatment. Proceedings: Seminar Teknologi Kebumian dan Kelautan (SEMITAN II), 2(1): 1-4.

[18] Ball Jeff (2001) Soil and Water Relationship. https://www.noble.org/news/publications/ag-news-and-views/2001/september/soil-and-water-relationships/. (Accessed on 20 September 2021)

[19] Kompasiana (2017) Hygroscopic, Capillari and Soil Water Content. Air Higroskopis, Air Kapiler dan Kadar Air Tanah. http://petanibangga.blogspot.com/2017/12/air-higroskopis-air-kapiler-dan-kadar.html. (Accessed on 20 September 2021)

[20] Badan Meteorologi Klimatologi dan Geofisika (BMKG) Indonesia (2022) Level of Water Availability for Plants in December 2021. Tingkat Ketersediaan Air Bagi Tanaman-Desember 2021. https://www.bmkg.go.id/iklim/ketersediaan-air-tanah.bmkg?p=tingkat-ketersediaan-air-bagi-tanaman-desember-2021&tag=&lang=ID. (Accessed on 21 January 2022)

[21] Widnyana I Made Gede, Sumiyati , I Wayan Tika (2017) The Study of Wilting Point Pattern and Field Capacity in Cultivation of Sweet Pepper in Differents Planting Media. BETA (Biosistem dan teknik Pertanian) Journal, 5(1): 1-6.

[22] Kishor Singh K, A Khumar (2018) Composition of Soil, Waste Teatment of Soil, Inorganic and Organic Components in Soil and Soil Pollution by Addition of Pesticides and Fertillizers. Course M.Sc. Chemistry 2nd Year, 1-11. http://www.nou.ac.in/Online%20Resourses/10-5/Soil%20Composition%20and%20Organic%20Inorganic,%20Treatment%20for%20M.Sc.%20Part%20II%20,%20(I).pdf. (Accessed on 23 October 2021)

[23] Easton, Zachary M. (2016) Soil and Soil Water Relationship. Publication BSE-194P, 1-9. https://ext.vt.edu/content/dam/ext_vt_edu/topics/agriculture/water/documents/Soil-and-Soil-Water-Relationships.pdf. (Accessed on 23 October 2021)

[24] Salam Abdul Kadir (2020) Ilmu Tanah. Soil Science. Global Mandiri Publisher. Lampung, Indonesia

[25] Widoretno W, Harijati N, Mastuti R (2019) Plant Physiology. Hand Book, 4-17. https://nanopdf.com/queue/handout-retno-mastuti_pdf?queue_id=-1&x=1634895614&z=MTgyLjIuNjkuODE=. (Accessed on 23 October 2021)

[26] Khodijah S, Soemarno (2019) Studi Kemampuan Tanah Menyimpan Air Tersedia di Sentra Bawang Putih Kecamatan Pujon Kabupaten Malang. Jurnal Tanah dan Sumberdaya Lahan, 6 (2): 1405-1414.

[27] Haryati Umi (2014) Karakteristik Fisik Tanah Kawasan Budidaya Sayuran Dataran Tinggi, Hubungannya dengan Strategi Pengolahan Lahan. Jurnal Sumberdaya Lahan, 8 (2): 125-138.

[28] Markovic N, V Filipovic, T Legovic, et al. (2015) Evaluation of Different Soil Water Potential by Field Capacity Threshold in Combination With a Triggered Irrigation Module. Soil and Water Res., Journal, 10 (3): 164-171.

[29] Darmayanti F Dwi, T Sutikto (2019) Estimasi Total Air Tersedia Bagi Tanaman pada Berbagai Tekstur Tanah Menggunakan Metode Pengukuran Kandungan Air Jenuh. Jurnal Berkala Ilmiah Pertanian, 2 (4): 164-168.

[30] Barzegar A, A Yousefi, N Zargoosh (2016) Water Stress and Soil Compaction Impacts on Clover Growth and Nutrient Concentration. Eurasian Journal of Soil Science, 5(2): 139-145.

[31] Fields Jeb S, WC Fonteno, BE Jackson, et al. (2020) The Use of Dewpoint Hygrometry to Measure Low Water Potentials in Soilles Substrate Components and Composites. Journal Agronomy MDPI, 10(1393): 1-11.

[32] Datta S, S Taghvaeian, J Stivers (2017) Understanding Soil Water Content and Thresholds for Irrigation Management. Oklahoma Cooperation Extension Service BAE-1537, 1-9.

[33] Bueckert RA (2013) General Principles of Plant Water Relations. Prairie Soils and Crops Journal, 6(1): 107-118.

[34] Chavarria G, HP dos Santos (2014) Plant Water Relations: Absorption, Transport and Control Mechanism. Advances and Selected Plant Physiology Aspect. 106-132. https://ainfo.cnptia.embrapa.br/digital/bitstream/item/59779/1/InTech-Plant-water-relations-absorption-transport-and-control-mechanisms.pdf. (Accessed on 27 September 2021)

[35] Nonami H, Jhon S Boyer (1989) Turgor and Growth at Low Water Potentials. Plant Physiol. Journal, 89: 798-804.

[36] Fitter AH, RKM Hay (1994) Environmental Physiology of Plants. Translation. Third Print. Gadjah mada University Press: 148-150.

[37] Riboldi Lucas B, R Ferraz Oliviera, Luiz R Angelocci (2016) Leaf Turgor Pressure in Maize Plants Under Water Stress. Australian Journal of Crop Science, 10(6): 878-886.

[38] Istanbuli T, M Baum, H Tauchan , A Hamwieh (2020) Evaluation of Morpho-Physiologycal Traits Under Drought Stress Conditions in Barley (*Hordeum Vulgare*, L.). Photosynthetica Journal, 58(4): 1059-1067.

[39] Bernard SM (2015) Plant Water Relations. https://www.accessscience.com/media/EST/media/525300PV0001.pdf. (Accessed on 27 September 2021)

[40] Rao KV Madhava, AS Raghavendra, SJ Reddy (2006) Physiologi and Molecular Biology of Stress Tolerance in Plants. Published by Springer, Netherlands :15-31.

[41] Opalofia Loli, Yusniwati, Etti Swasti (2018) Drought Tolerance in Some of Rice Line Based on Morphological at Vegetative Stage. International Journal of Environment, Agriculture and Biotechnology, 3(6): 1995-2000.

[42] Chun Hyen Chung, Sanghun Lee, Young Dae Choi, et al. (2021) Effect of Drought Stress on Root Morphology and Spatial Distribution of Soybean and Adzuki Bean. Journal of Integrative Agriculture, 20(10): 2639-2651.

[43] Malinowska Marta, Iain Donnison, Paul Robson (2020) Morphological and Physiological Traits That Explain Yield Response to Drought Stress in Mischantus. Agronomy Journal, 10: 1-17.

[44] Yanli Du, Qiang Zhao, Liru Chen, et al. (2020) Effect of Drought Stress During Soybean R2-R6 Growth Stages on Sucrose Metabolism in Leaf and Seed. International Journal of Molecular Science, 21(618): 1-19.

[45] Tovignan T Klanvi, HA Sagbadja, C Diatta, et al. (2020) Terminal Drought Effect on Sugar Partioning and Metabolism is Modulated by Leaf Stay Green and Panicle Size in the Stem of Sweet Shorgum (*Shorgum bicolor*, L. Moench). CABI Agriculture and Bioscience Journal, 1(4): 1-11.

[46] Alaei S, Nasser Mahna, Jafar Hajilou, et al. (2016) The Effect of Glycine-Betain on Alleviation of Drought Stress in Strawberry Plant. Eco. Env. And Cons. Journal, 22(3): 1145-1150.

[47] Magana C Escalante, Luis F Aguilar C, IE Machado, et al. (2019) Contribution of Glycine Betaine and Proline to Water Deficit Tolerance in Papper Plant. Hort. Sci. Journal, 54(6): 1044-1054.

[48] Nasrin S, Shukanta Saha, Hasna Hena Begum, et al. (2020) Impact of Drought Stress on Growth Protein, Proline, Pigment Content and Antioxidant Enzyme Activities in Rice (*Oryza sativa* L. Var. BRRI Dhan-24), J. Bio. Sci., 29(1): 117-123.

[49] Maghsoudi Kobra, Yahya Emam, Ali Niazi, et al. (2018) P5CS Expression Level and Proline Accumulation in The Sensitive and Tolerant Wheat Cultivars Under Control and Drought Stress Condition in The Presence/Absence of Silikon and Salicylic Acid. Journal of Plant Interaction, 13(1): 461-471.

[50] Lei Wei, Shian Huang, Shaohu Tang, et al. (2016) Determination of Abcisic Acid and its Relationship to Drought Stress Based on Cowpea Varieties With Different Capability of Drought Resistence. American Journal of Biochemistry and Biotechnology, 12(1): 79-85.

[51] Wang Xiao, Qing Ji, Jingjing Xie, et al. (2021) Abcisic Acid and Jasmonic Acid are Involved in Drought Priming-Induced Tolerance to Drought in Wheat. The Crop Journal, CAAS, 9: 120-132.

[52] Hussain S, T Qadir, A Khaliq, et al. (2019) Drouhgt Stress in Plants: An Overview on Implications. Tolerance Mechanism and Agronomic Mitigation Strategies. Plant Science Today Journal, 6(4): 389-402.

[53] Ordog Vince (2011) Plant Physiology. http://www.esalq.usp.br/lepse/imgs/conteudo/Plant-Physiology-by-Vince-Ordog.pdf. (Accessed on 27 September 2021)

[54] Androcioli L Godoy, Douglas Mariani Z, Daniel Soares A, et al. (2020) Effect of Water Deficit on Morphoagronomic Physiological Traits of Common Bean Genotypes with Contrasting Drought Tolerance. Water Journal MDPI, 12(217): 1-13.

[55] Galeano Esteban, Tarcisio Sales V, Perla Novais de Oliveira, et al. (2019) Physiological and Molecular Responses to Drought Stress in Teak (*Tectona grandis*, L.f.). PLOS One Journal, 14(9): 1-26.

[56] Chowdhury JA, MA Karim, QA Khaliq, et al. (2017) Effect Drought Stress on Water Relation Traits of Four Soybean Genotype. SAARC Journal Agri., 15(2): 163-175.

[57] Sakya AT, E Sulistyaningsih, D Indradewa, et al. (2018) Physiological Characters and Tomato Yield Under Drought Stress. IOP Conf. Series: Earth and Enviromental, 200: 1-7.

[58] Nemeskeri Eszter, Lajos Heyles (2019) Physiological Responses of Selected Vegetable Crop Species to Water Stress. Agronomy Journal, 9(447): 1-19.

[59] Liu Jie, Tiantian Hu, Puyu Feng, et al. (2019) Tomato Yield and Water Use Efficiency Change With Various Soil Mouisture and Pottasium Levels During Different Growth Stages. Plos One Journal, 10(1371): 1-14.

[60] Song Libing, Jiming Lin, Jianqiang He (2019) Effect of Severe Water Stress on Maize Growth Processes in The Field. Sustainability Journal, 11: 1-18.

[61] Benjamin JG, DC Nielsen, MF Vigil, et al. (2014) Water Deficit Stress Effect on Corn (*Zea mays*, L.) Root: Shoot Ratio. Open Journal of Soil Science, 4: 151-160.

[62] Muthoni Jane, Hussein Shimelis (2020) Heat and Drought Stress and Their Implication on Potato Production Under Dry African Tropics. Australian Journal of Crop Science, 14(09): 1405-1414.

[63] Romero Angela P, Andres Alacron, Raul I Valbuena, et al. (2017) Physiological Assessment of Water Stress in Potato Using Spectral Information. Frontiers in Plant Science Journal, 8: 1-13.

[64] Rykaczewska Krystyna (2017) Impact of Heat and Drought stresses on Size and Quality of the Potato Yield. Plant Soli Environ Journal, 63(1): 40-46.

[65] Panda Debabrata, Swati Sakambari Mishra, et al. (2021) Drought Tolerance in Rice: Focus and Recent Mechanisms and Approaches. Rice Science Journal, 28(2): 1-17.

[66] Saha Shukanta, Hasna Hena Begum, Shamima Nasrin (2019) Effect of Drought Stress on Growth and Accumulation of Proline in Five Rice Varieties (*Oryza sativa*, L.). Journal Asiat. Soc. Bangladesh Sci., 45(2): 241-247.

[67] Nowsherwan I, G Shabbir, SI Malik, et al. (2018) Effect of Drought Stress on Different Physiological Traits in Bread Wheat. SAARC Journal Agri, 16(1): 1-6.

[68] Hooshmandi B (2019) Evaluation of Tolerance to Drought Stress in Wheat Genotypes. IDESIA (Chile) Journal, 37(2): 37-42.

[69] Abobatta Waleed Fouad (2019) Drought Adaptive Mechanism of Plants-a Review. Ology Journal. Advances in Agriculture and Environmental Science, 2(1): 62-65.

[70] Shavrukov Y, A Kurishbayev, S Jatayev, et al. (2017) Early Flowering as a Drought Escape Mechanism in Plants: How Can it Aid Wheat Production. Frontiers in Plants Science Journal, 8(1950): 1-8.

[71] Monroe J Grey, Tyler Powel, Nicholas Price, Jet al. (2018) Drought Adaptation in *Arabidopsis thaliana* by Extense Genetic Loss of Function. E Life Research Article, 7: 1-18.

[72] Farooq M, A. wahid, N Kobayashi, D. Fujita, et al. (2009) Plant Drought Stress: Effect, Mechanism and Management. Agron. Sustain. Dev. Journal, 29(2009): 185-212.

[73] Lestari E Gati (2006) Review Mechanism of Tolerance and Methods to Select Drought Resistance Plants. Berita Biology Journal, 8(3): 215-222.

[74] Gouveia Carla SS, Jose FT Gananca, HGM De Nobrega, et al. (2019) Drought Avoidance and Phenotypic Flexibility of Sweet Potato *Ipomoea batatas*, L. Lam.) Under Water Scarity Conditions. Not Bot. Hort. Agrobo, 47(4): 1034-1046.

[75] Bouzid M, F He, G Schmitz, et al. (2019) Arabidospis Species Deploy Distinct Strategies to Cope With Drought Stress. Annals of Botany Journal, 124: 27-40.

[76] Moradi Parviz (2016) Key Plant Products and Common Mechanisms Utilized by Plants in Water Deficit Stress Responses. Botanical Sciences Journal, 94(4): 657-671.

[77] Saladi Gaelle (2014) From Signal Perception to Gene Expression: Early Responses of Plant to Drought. Revue Agrobiologia Journal, 5: 5-10.

[78] Takahashi Fuminori, Takashi Kuromori, Kaoru Urano, et al. (2020) Drought Stress Responses and Resistance in Plant: From Celluler Responses to Long Distance Intercelluler Communication. Frontiers in Plant Science Journal, 11: 1-14

[79] Lamers J, Tom Van Der Meer, Christa Testerink (2020) How Plant Sense and Respond to Stressful Environments. Plant Physiologi Journal, 182: 1624-1635.

[80] Haswell ES, Paul EV (2015) The Ongoing Search for The Molecular Basis of Plant Osmosensing. Journal Gen Physiol., 145(5): 389-394.

[81] Ye Yaoyao, Yanfei Ding, Qiong Jiang, et al. (2017) The Role of Receptor Like Protein Kinase (RLKs) in Abiotic Stress Response in Plant. Plant Cell Rep. Journal, 36: 235-242.

[82] He Xiaowen, Chuanzeng Wang, Haibo Wang, et al. (2020) The Function of MAPK cascades in Response to Various Stresses in Horticulture Plants. Frointers in Plant Science Journal, 11: 1-12.

[83] Wang Chen, Wenjing Lu, Xiaowen He, et al. (2016) The Cotton Mitogen Activated Protein Kinase Kinase 3 Function in Drought Tolerance by Regulating Stomatal Responses and Root Growth. Plant and Physiol. Journal, 57(8): 1629-1642.

[84] Ho Hooi Ling (2015) Functional Roles of Plant Protein Kinases in Signal Transduction Pathways During Abiotic and Biotic Stress. Journal Biodivers. Biopros. Dev., 2(2): 1-8.

[85] Khorasgani Omid Askari (2018) Regulation of Trehalose/Sucrose-Non-Fermenting Related Protein Kinase 1 and its Signaling Pathways Involved in Drought Stress Responses. MOJ Sci., Rep. Journal, 5(2): 39-40

[86] Kardile Hemant B, Vikrant, NK Sharma, et al. (2018). Calcium Dependent Protein (CDPK) in Abiotic Stress Tolerance. Journal Pl. Sci. Res., 34(2): 253-259.

[87] Crizel R Lopes, Ellen CP, Isabel LV, et al. (2020) Genome Wide Identification and Characterization of The CDPK Gene Family Reveal Their Involvement in Abiotic Stress Response in *Fragaria x ananassa*. Scientific Report Journal, 10: 1-17.

[88] Wang Dan, Yuan Xia Liu, Qian Yu, et al. (2019) Functional Analysis of The Soybean GmCDPK3 Gene Responding to Drought and Salt Stresses. International Journal of Molecular Science MDPI, 20: 1-22.

[89] Nxele X, A Klein, BK Ndimba (2017) Drought and Salinity Stress Alter ROS Accumulation, Water Retention and Osmolyte Content in Shorgum Plants. South African Journal of Botany, 108: 261-266.

[90] Hasanuzzaman Mirza, MHMB Bhuyan, F Zulfiqar, et al. (2020) Reactive Oxygen Species and Antioxidant Defense in Plants Under Abiotic Stress: Revisiting The Crucial Role of a Universal Defense Regulator. Antioxidant Jurnal MDPI, 9(681): 1-52.

[91] Setter Tim L, BA Flannigan (2001) Water Deficit Inhibits Cell Division and Expression of Transcripts involved in Cell Proliferation and Endoreduplication in Maize Endosperm. Journal of Experimental Botany, 52(360): 1401-1408.

[92] Li Yizeng, Lijuan He, NAP Gonzales, J Graham, et al. (2017) Going with the Flow: Water Flux and Cell Shape During Cytokinesis. Biophysical Journal, 113: 2487-2495.

[93] Litvin Alexander G, MW Van Iersel, A Malladi (2016) Drought Stress ReducesStem Elongation and Alters Gibberellin Releated Gene Expression During Vegetative Growth of Tomato. J. Amer. Soc. Hort. Sci., 141(6): 591-597.

[94] Jahan Afrose, F Ahmed (2018) Effect of Drought Stress on Growth and Yield of Wheat Genotypes. Bangladesh Agron Journal, 20(2): 97-105.

[95] Zhao Wenhui, Leizen Liu, Qiu Shen, et al. (2020) Effect of Water Stress on Photosynthesis, Yield and Water Use Efficiency in Winter Wheat. Water Journal. MDPI, 12(2127): 1-19.

[96] Gamez Angie L, David Soba, AM Zammareno, et al. (2019) Effect of Water Stress During Grain Filling on Yield, Quality and Physiological Traits of Illpa and Rainbow Quinoa (*Chenopodium quinoa* Willd.) Cultivars. Plant Journal. MDPI, 8(173): 1-15.

[97] Zhang Jinmeng, Shiqiao Zhang, Min Cheng, et al. (2018) Effect of Drought on Agronomic Traits of Rice and Wheat: A Meta Analysis. Int. J. Environ. Res. Public health. MDPI, 15(839): 1-14.

[98] Pingping Wu, Wu Chubin, Zhou Biyan (2017) Drought Stress Induced Flowering and Enhances Carbohydrate Accumulation in *Averrhoa carambola*. Horticultural Plant Journal, 3(2): 60-66.

[99] Cui Yi, Shaowei Ning, Juliang Jin, et al. (2020) Quantitative Lasting Effects of Drought Stress at a Growth Stage on Soybean Evapotranspiration and Aboveground Biomass. Water Journal MDPI, 13(8): 1-19.

[100] Liang Guoting, Junhui Liu, Jingmin Zang (2020) Effect of Drought Stress on Photosyntetic and Physiological Parameters of Tomato. J. Amer. Soc. Hort. Sci., 145(1): 12-17.

[101] Wang Wensen, Cheng Wang, Dayu Pan, et al. (2018) Effect of Drought Stress on Photosyntetic and Chlorophyll Fluorescence Image of Soybean (*Glycinn max*) Seedlings. Int. J. Agric. and Biol Eng., 11(2): 196-172.

[102] Fathi A, DB Tari (2016) Effect of Drought Stress and its Mecanism in Plants. International Journal of Life Sciences, 10(1): 1-6.

[103] Nicolas Martin-St Paul, S Delzon, H Cochard (2017) Plant Resistence to Drought Depends on Timely Stomatal Closure. Ecology Letters Journal, 10(11): 1-13.

[104] Maliba Bheki G, PM Inbaraj, JM Berner (2019) Photosyntetic Responses of Canola and Wheat to Elevated of CO_2, O_3 and Water Deficit in Open Top Chambers. Plants Journal MDPI, 8(171): 1-16.

[105] Rezayian M, V Niknam, H Ebrahimzadeh (2018) Effect of Drought Stress on The Seedling Growth, Development and Metabolic Activity in Different Cultivars of Canola. Soil Science and Plant Nutrition Journal, 64(3): 360-369.

[106] Kai Hsu Po, Guillaume Dubeaux, Yohei Takahashi, et al. (2021) Signaling Mechanism in Abscisic Acid –Mediated Stomata Closure. The Plant Journal, 105: 307-321..

[107] Tombesi S, A Nardini, T Frioni, et al. (2015) Stomatal Closure is Induced by Hydraulic Signal and Maintained by ABA in Drought Stressed Grapevine. Scientific Report Journal, 5(12449): 1-12.

[108] Kuromori Takashi, Mitsunori Seo, Kazuo Shinozaki (2018) ABA Transport and Plant Water Stress Responses. Trends in Plant Science Journal, 23(6): 513-523.

[109] Muhammad Izhar, A Shalmani, M Ali, et al. (2021) Mechanism Regulating The Dynamics of Photosyntesis Under Abiotic Stress. Frontiers in Plant Science Journal, 11: 1-25.

[110] Sloan Brandon P, SE Thompson, Xue Feng (2021) Plant Hydraulic Transport Control Transpiration Response to Soil Water Stress. Hydrology and Earth System Sciences Journal. https://hess.copernicus.org/preprints/hess-2020-671/hess-2020-671.pdf. (Accessed on 27 September 2021)

[111] Buckley Thomas N (2019) How do Stomata Respond to Water Status?. New Phytologist Journal, 224: 21-36.

[112] Li Yuping, Hongbin Li, Yuanyuan Li, et al. (2017) Improving Water Use Efficiency by Decreasing Stomatal Conductance and Transpiration Rate to Maintain Higher ear Photosyntesic Rate in Drought Resistant Wheat. The Crop Journal, 5: 231-239.

[113] Sacita A Safitri, Tania June, Impron (2018) Soybean Adaptation to Water Stress on Vegetative and Generative Phase. Agrotech Journal, 3(2): 1-11.

[114] Perdomo Juan A, SC Bauca, EC Silva, et al. (2017) Rubisco and Rubisco Activase Play an Important Role in The Biochemical Limitations of Photosyntesis in Rice, Wheta and Maize Under High Temperature and Water Deficit. Frointers in Plant Science Journal, 8(490): 1-15.

[115] Shobhkhizi A, MF Rayni, HB Barzin, et al. (2014) Influence of Drought Stress on Photosynthetic enzymes, Chlorophyll, Protein and Relative Water Content in Crop Plants. International Journal of Biosciences, 5(7): 89-100.

[116] Parry Martin AJ, PJ Andralojc, Shahnaz Khan, et al. (2002) Rubisco Activity: Effects of Drought Stress. Annals of Botany Journal, 89: 833-839.

[117] Nouri M Zaman, Ali Maumeni, Setsuko Komatsu (2015) Abiotic Stresess: Insight in to Gene Regulation and Protein Expression in Photosyntetic Pathways of Plants. Int. J. Mol. Sci., 16: 20393-20416.

[118] Slattery Rebecca A, Donald R Ort (2019) Carbon Assimilation in Crops at High Temperature. Plant Cell Environ. Journal, 42: 2750-2758.

[119] Du Yanli, Qiang Zhao, Liru Chen, et al. (2020) Effect of Drought Stress During Soybean R2-R6 Growth Stages on Sucrose Metabolism in leaf and Seed. International Journal of Molecular Sciences MDPI, 21(618): 1-19.

[120] Falchi R, E Petrusa, M Zancani, et al. (2019) Summer Drought Stress: Differential Effect on Cane Anatomy and Non Structural Carbohydrate Conten in Overwintering Cabernet Sauvignonand Syrah Vines. Bio. Web. Conferences, 13: 1-6.

[121] Gupta S Devi, Manjri, A Singh, et al. (2018) Effect of Drought Stress on Carbohydrate Content in Drought Tolerant and Susceptible Chickpea Genotypes. International Journal of Chemical Studies, 6(2): 1674-1676.

[122] Blum Abraham (2016) Osmotic Adjustment is a Prime Drought Stress Adaptive Engine in Support of Plant Production. Plant, Cell and Environment. Jhon Wiley and Sons Ltd, 1-8.

[123] Singh Ashu, MK Sharma, RS Sengar (2017) Osmolytes: Proline Metabolism in Plants as Sensor of Abiotic Stress. Journal of Applied and Natural Science, 9(4): 2079-2092.

[124] Li Changning, Zhen Wang, Qian Nong, et al. (2021) Physiological Changes and Transcriptome Profiling in *Sacharum spontaneum* L. leaf Under Water Stress and re-Watering Conditions. Scientific Reports Journal, 11(5525): 1-14.

[125] Arteaga S, L Yabor, M Jose Diez, et al. (2020) The Use of Proline in Screening for Tolerance to Drought and Salinity in Common Bean (*Phaseolus vulgaris*, L.) Genotypes. Agronomy Journal MDPI, 10(817): 1016.

[126] Meena M, K Divyanshu, S Kumar, et al. (2019) Regulator of L-Proline Biosynthesis , Signal Transduction, Transport, Accumulation and its Vital Role in Plants During Variable Environmental Conditions. Heliyon Journal, 5: 1-20.

[127] Winaya Aris, Maftuchah, A Zainudin (2020) The Identification of Osmoprotectant Compunds from *Jatrhopa curcas* Linn. Plant for Natural Drought Stress Tolerance. 6th

International Conference on Energy and Environment Research ICEER. Energy Reports Journal, 6(2020): 626-630.

[128] Jabeen M, NA Akram, M Ashraf, et al. (2019) Assesment of Biochemical Changes in Spinach (*Spinacea oleracea*, L.) Subjected to Varying Water Regimes. Sains Malaysiana Journal, 48(3): 533-541.

[129] Mwenye O Jhon, L Van Rensburg, A Van Biljon, et al. (2016) The Role of Proline and Root Traits on Selection for Drought Stress Tolerance in Soybeans: a Review. South African Journal of Plant and Soil, 33(4): 245-256.

[130] Ahmeed M, Fayyaz Ul-Hassan, G Qadir, et al. (2017) Response of Proline Accumulation in Bread Wheat (*Triticum aestivum*, L.) Under Rainfed Conditions. Journal of Agricultural Meteorology, 74(3): 147-155.

[131] Nguyen TT Quynh, Le Thanh Huyen Trinh, Hoang Bao VP, et al. (2020) Evaluation of Proline, Soluble Sugar and ABA Content in Soybean *Glycine max* (L.) Under Drought Stress Memory. AIMS Bioengineering Journal, 7(3): 114-123.

[132] Kaur Gurpreet, B Asthir (2015) Proline: a Key Player in Plant Abiotic Stress Tolerance. Biologia Plantarium Journal, 59(4): 609-619.

[133] Balestrini R, W Chitarra, C Antoniou, et al. (2018) Improvement of Plant Performance Under Water Deficit With The Employment of Biological and Chemical Agents. The Journal of Agricultural Science, 156: 680-688.

[134] Ratzman G, L Zakharova, B Tietjen (2019) Optimal Leaf Water Status Regulation of Plants in Dryland. Scientific Report Journal, 9(3768): 1-9.

[135] Anderegg William R, A Wolf, AA Velez, et al. (2017) Plant Water Potential Improves Prediction of Empirical Stomatal Models. Plos One Journal, 12(10): 1-17.

[136] Turner Neil C (2018) Turgor Maintanance by Osmotic Adjusment: 40 Years of Progress. Journal of Experimental Botany, 69(13): 3223-3233.

[137] Nadeem Muhammad, Jiajia Li, M Yahya, et al. (2019) Research Progress and Perspective on Drought Stress in Legumes: A Review. International Journal of Molecular Sciences MDPI, 20(2541): 1-32.

[138] Ali Shahid, K Ayat, A Iqbal, et al. (2020) Implication of Absicic Acid in The Drought Stress Tolerance of Plants. Agronomy Journal MDPI, 10(1323): 1-28.

[139] Wang Xiao, Qing Li, Jingjing Xie, et al. (2021) Abcisic Acid and Jasmonic Acid are Involved in Drought Priming Induced Tolerance to Drought in Wheat. The Crop Journal CSSC, 9(2021): 120-132.

[140] Bharath P, S Gahir, Agepati S Raghavendra (2021) Abscisic Acid Induced Stomata Closure: An Important Component of Plant Defense Against Abiotic and Biotic Stress. Froinyer in Plant Science Journal, 12(615114): 1-18.

[141] Chen Jun, Yan Gong, Yuan Gao, et al. (2021) TaNAC48 Positively Regulates Drought Tolerance and ABA Responses in Wheat (*Triticum aestivum*, L.). The Crop Journal, 9: 785-793.

[142] Huber Annika E, PJ Melcher, MA Pineros, et al. (2019) Signal Coordination Before, During and After Stomatal Closure in Response to Drought Stress. New Phytologist Journal, 224(2019): 675-688.

[143] Sah S Kumar, KR Reddy, Jiaxu Li (2016) Absicic Acid and Abiotic Stress Tolerance in Crop Plants. Frontiers in Plant Sciance Journal, 7(571): 1-26.

[144] Valverde C De Ollas, Ian C Dodd (2016) Physiological Impacts of ABA –JA Interactions Under Water Limitation. Plant Mol. Biol. Journal, 91: 641-650.

[145] Anosheh H Pirasteh, AS Moucheshi, H Pakniyat, et al. (2016) Stomatal Responses to Drought Stress. Water Stress and Crop Plants: A Sustainable Approach. Volume 1. First Edition. 24-40.

[146] St Paul Nicolas KM, S Delzon, H Cochard (2017) Plant Resistance to Drought Depends on Timely Stomatal Closure. Ecology Letters Journal, 1-11.

[147] Abid Muhammad, S Ali, Lei Kang Qi, et al. (2018) Physiological and Biochemical Changes During Drought and Recovery Periods at Tillering and Jointing Stages in Wheat (*Triticum aestivul*, L). Scientific Reports Journal, 8(4615): 1-15.

[148] Laxa Miriam, M Liiebthal, W Telman, et al. (2019) The Role of Plant Antioxidant System in Drought Tolerance. Antioxidant Journal MDPI, 8(94): 1-31.

[149] Weng Mingyang, Lirong Cui, Fenling Liu, et al. (2015) Effects of Drought Stress on Antioxidant Enzymes in Seedlings of Different Wheat Genotypes. Pak. J. Bot., 47(1): 49-56.

[150] Nur Cahyo A, RH Murti, Eka TS Putra (2020) Effect of Drought on Physiological Processes, Growth and Yield of Rubber Tree (*Hevea brasiliensis* Mull. Arg.). Warta Perkaretan Journal, 39(1): 57-72.

[151] Zivanovic B, SM Komic, T Tosti, et al. (2020) Leaf Soluble Sugars and Free Amino Acids as Important Components of Abcisic Acid Mediated Drought Response in Tomato. Plants Journal MDPI, 9(1147): 1-17.

[152] Kosar F, NA Akram, M Ashraf, et al. (2018) Trehalose Induced Improvement in Growth, Photosynthetic Characteristics and Levels of Some Key Osmoprotectants in Sun Flower (*Helianthus annus*, L.) Under Drought Stress. Pak. J. Bot. Journal, 50(3): 955-961.

[153] Ferreira Thais HS, MS Tsunada, D Bassi, et al. (2017) Sugarcane Water Stress Tolerance Mechanisms and its Implications on Developing Biotechnology Solutions. Frointers in Plant Science, 8(1077): 1-18.

[154] Laguna K Alejandra, JLC Ponce, RR Medrano, et al. (2018) Trehalose Accumulation Provides Drought Tolerance to Genetically Modified Maize in Open Fields Trials. Pak. J. Agri. Sci. Journal, 55(4): 1009-1020.

[155] Mohammadkhani N, R Heidari (2008) Drought Induced Accumulation of Soluble Sugars and Proline in Two Maize Varieties. World Applied Sciences Journal, 3(3): 448-453.

[156] Hasanuzzaman Mirza, Alam M Mahabub, K Nahar, et al. (2014) Trehalose Induced Drought Stress Tolerance: A Comparative Study Among Different Brassica Species. Plant Omics Journal, 7(4): 271-283.

[157] Lunn J Edwards, I Delorge, CM Figueroa, et al. (2014) Small Molecules: From Structural Diversity to Signaling and Regulatory Roles, Trehalose Metabolism in Plants. The Plant Journal, 79 (2014): 544-567.

[158] Noviana I, Y Haryati, R Sari, et al. (2021) Adaptation to Climate Change by Using Drought Tolerance and Early Maturing Rice Varieties in Majalengka Regency. 1st International Conference on Sustainable Tropical Land Management. IOP Conf. Series. Earth and Environmental Science, 648 (2021): 1-8.

[159] Van Oosten MJ, A Costa, P Punzo, et al. (2016) Genetics of Drought Stress Tolerance in Crop Plants. Drought Stress tolerance in Plants. Chapter 2. Springer International Publishing Switzerland, 39-69.

[160] Rajanna GA, Anchal Dass and V Paramesha (2018) Excess Water Stress: Effects on Crop and Soil and Mitigation Strategies. Popular Kheti Journal, 6(3): 48-53.

[161] Pereira Luis S (2000) Management of Irrigation System to Cop With Drought. Medit Journal, 2 (2000): 33-38.

[162] Saleem MS, MAS Raza, S Ahmad, et al. (2016) Understanding and Mitigating the Impact of Drought Stress in Cotton - A Review, Journal Agri. Science, 53(3): 1-16.

[163] Perez CAH, FCG Merino, JLS Castillo, et al. (2021) In Vitro Screening of Sugarcane Cultivars (Saccharum spp. Hybrids) for Tolerance to Polyethylene Glycol Induced Water Stress. MDPI Journal Agronomy, 11(598): 1-13.

[164] Niu T, T Zhang, Y Qiao, et al. (2021) Glycinebetaine Mitigates Drought Stress Induced Oxidative Damages in Pears. Plos One Journal, 16(11): 1-20 .

Table 1. Water status relationship between water potential and soil water volume

Water Status	Water Potential Status		Soil Water Status			Availability to Plant
	pF	Mpa	Sand	Clay	Loam	
Saturation	0	0	39%	50%	54%	Unavailable
Field Capacity	(-) 1-2,5	(-) 0,33	8-10%	20-35%	36-49%	Available
Wilting Point	(-) 4,2	(-) 1,5	4%	9%	29%	Unavailable

Source: [23,32] - modified

Table 2. Plants responses to drought stress

Drought Stress	Response		
	Morphology	**Physiology**	**Biochemical**
	Strengthens the roots system (roots elongated)	Stomatal closure	ABA synthesis
	Reduce leaf surface area	Reduce CO_2 fixation	Decreased activity of rubisco
	Rolling the leaves	Decreasing photosynthesis	Accumulation of solute compounds (proline, glycine-betaine, sugar)
	Dropping leaves	Increased ROS compounds	Increased antioxidant compounds
	Early flowering		Drought tolerant gene expression

Source: [52] - modified

Table 3. Relationship between drought stress and the sensitivity of plant metabolic processes

Affected process	Sensitivity															
	Very susceptible						Susceptible					Unsusceptible				
(-) decreased	Pressure (Bar) (-)															
(+) increased	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Cell growth (-)																
Cell wall synthesis (-)*																
Protein synthesis (-)*																
Proto-chlorophyll formation (-)**																
Nitrate reductase (-)																
ABA Synthesis (+)																
Stomatal conductivity (-)																
Fixation of CO_2 (-)																
Respiration																
Xylem conductivity (-)***																
Proline synthesis (+)																
Sugar synthesis (+)																

Note: *= fast growing tissue; **= etiolated leaves; ***= xylem dimension factor
Source: [36] - modified

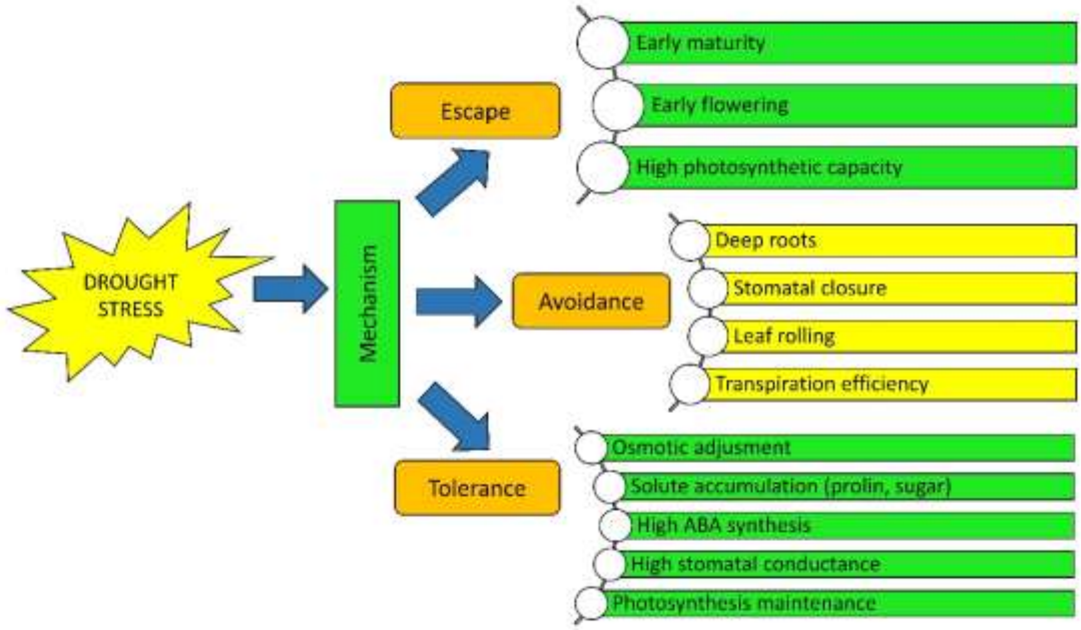


Figure 1. Crops mechanism in drought stress [65] - modified

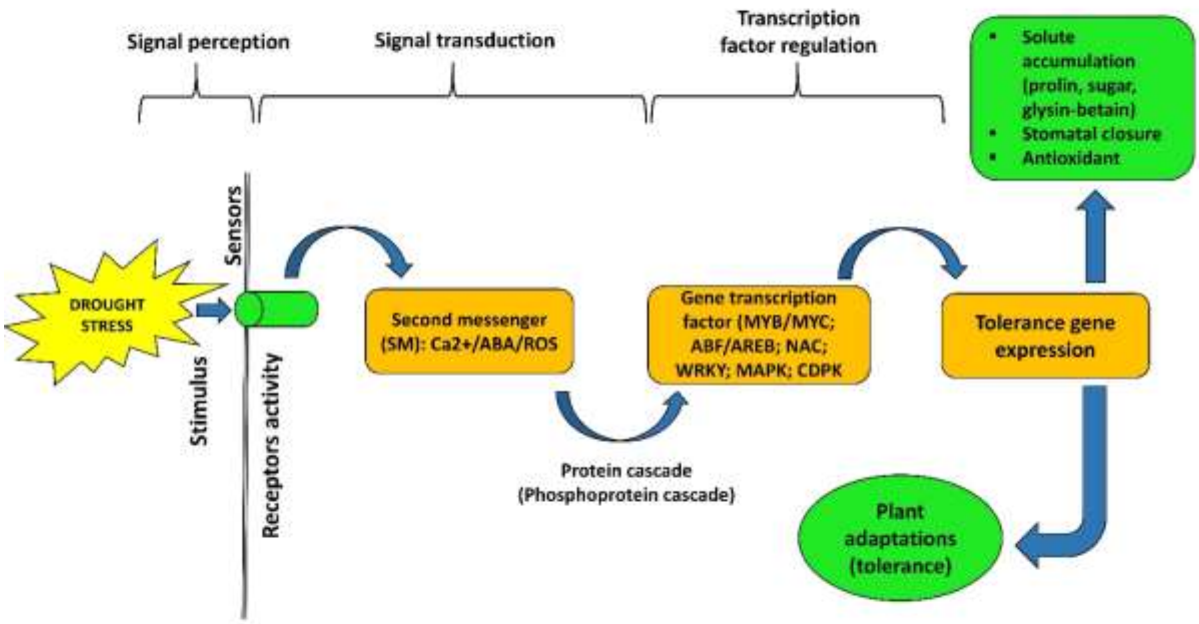


Figure 2. Signaling plant networks against drought stress [11,72] - modified

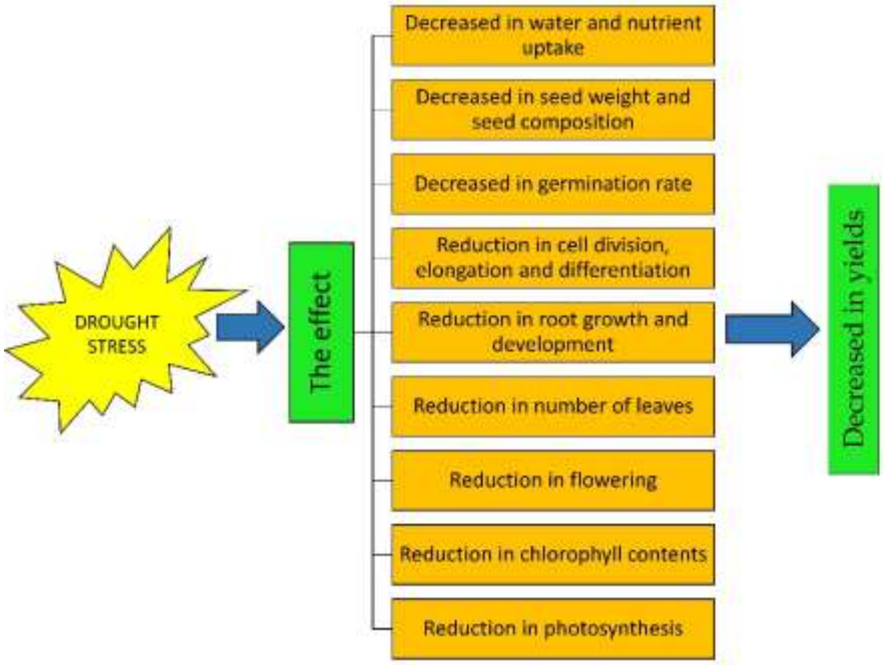


Figure 3. The impact of drought stress on crops [137] - modified

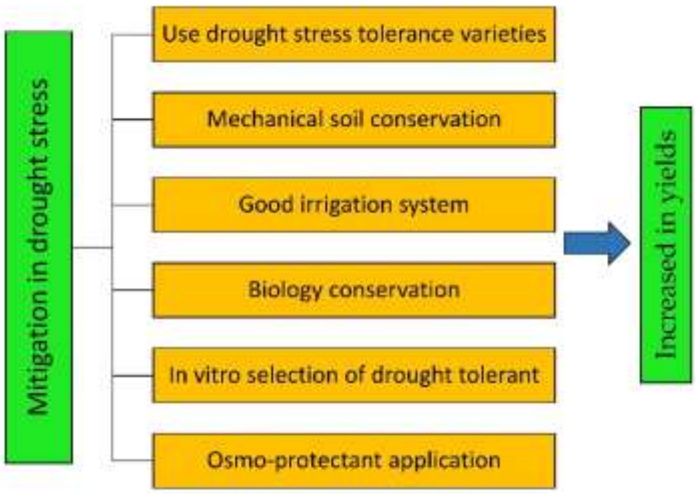


Figure 4. Mitigation in drought stress

Dear

Editor in Chief Reviews in Agricultural Science,

I am Saktiyono Sigit Tri Pamungkas, representing on behalf of the manuscript (Suwarto, Suprayogi and Noor Farid). I wish to submit a review article entitled “Drought Stress: Responses and Mechanism in Plants” for consideration Reviews in Agricultural Science.

We confirm that this paper is original and has not been published elsewhere, nor is it currently under consideration for publication elsewhere.

In this paper, I explain how the impact of drought stress on plants that will affect growth and development in morphology, physiology and biochemistry, so that it affects crop yields and how to minimize drought stress for agricultural crop cultivation. I hope this paper can be used as a basic knowledge about the impact of drought stress so that early mitigation can be carried out in agricultural crop cultivation. I believe that this manuscript is appropriate for publication by Reviews in Agricultural Science because it matches with journal’s Aims & Scope**.**

I have no conflicts of interest to disclose.

Please address all correspondence concerning this manuscript to me at skt@polteklpp.ac.id

Thank you for your consideration of this manuscript.

Best regards,

Saktiyono Sigit Tri Pamungkas

Department of Plantation, Vocational Education, Polytechnic of LPP Yogyakarta

Jl. LPP No: 1 A, Balapan, Klitren, Gondokusuman, Yogyakarta,Special District of Yogyakarta, 55222, Indonesia