7

Appendix

Supporting Data Results

Photosynthesis

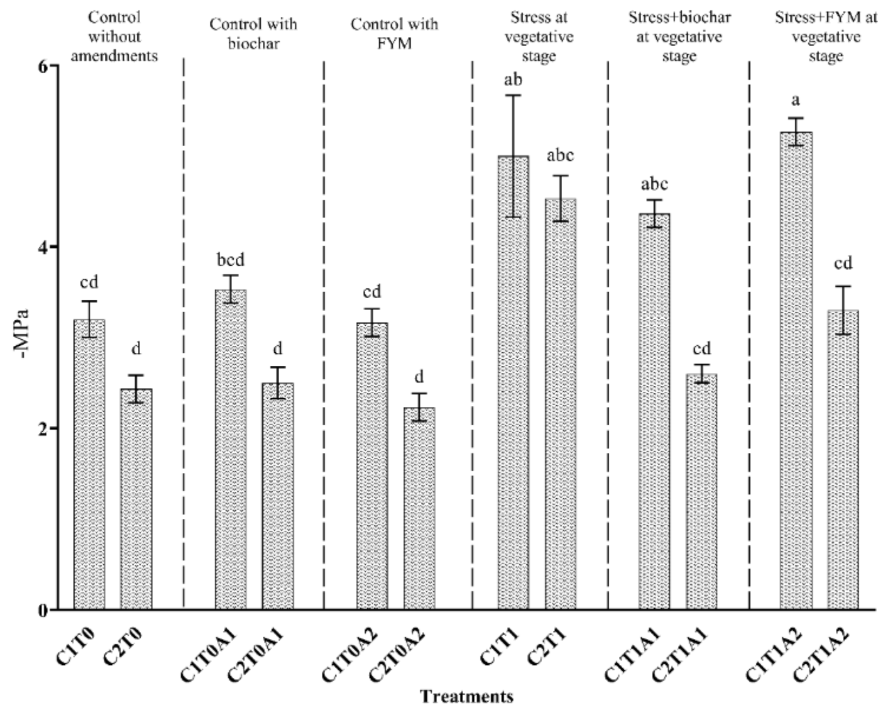
Exposure to drought at vegetative stage significantly reduced the photosynthesis up to 32% and 17% under *Vigna radiata* and *Lathyrus sativus* cultivation respectively. Amending the soils with biochar and exposure to drought at vegetative stage significantly enhanced the photosynthesis up to 189% in *Vigna radiata* and up to 239% in *Lathyrus sativus* crops. Under well-watered condition, amending the soil with biochar or FYM enhanced the photosynthesis up to 121%.

Similarly, exposure to drought at reproductive stage reduced the photosynthesis up to 70% in *Vigna radiata* crops and up to 53% in *Lathyrus sativus* crops. Amending the soil with biochar significantly enhanced the photosynthesis up to 183% in either of the crops the exposed to drought at reproductive stage. Moreover, FYM as a soil amendment significantly enhanced the photosynthesis in both the crops up to 300%.

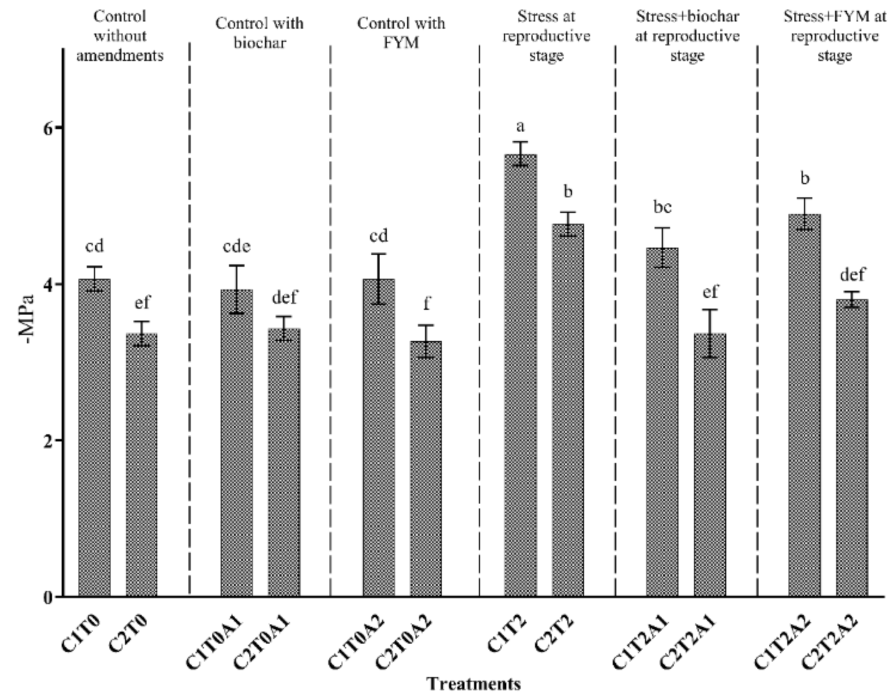
Leaf Water Potential

Exposure to drought at vegetative stage of *Lathyrus sativus* and *Vigna radiata* significantly reduced the leaf water potential up to 56% and 86% respectively. Amending the soils with biochar or FYM mitigated the loss in the leaf water potential up to 42% and 25% respectively, except for *Vigna radiata* soils under the application of FYM in both the years.

During the reproductive stage of both the crops, a significant increase in the leaf water potential was noted (up to 50%). Amending the soil with biochar and FYM successfully mitigated the leaf water potential up to 26% and 29% respectively.



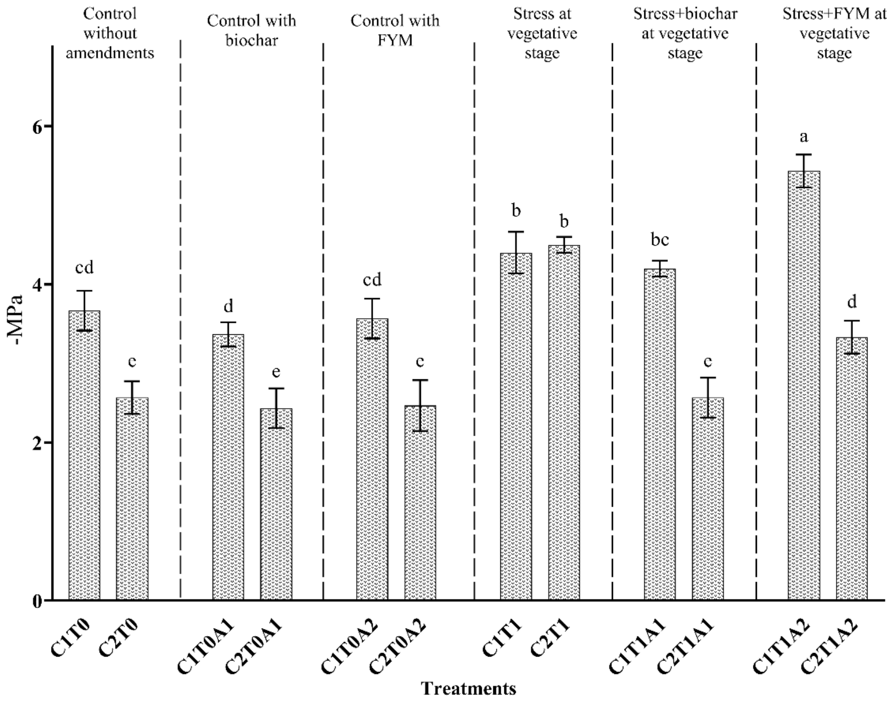
(a)



(b)

*Different lowercase letters above each column indicate significant differences between treatments at 5% level of significance (P≤ 0.05) according to Tukey's Honestly Significant Difference (HSD)

Figure 7.1: Leaf water potential as affected by application of biochar and FYM as soil amendments and drought exposure at (a) vegetative and (b) reproductive stage in year 1.



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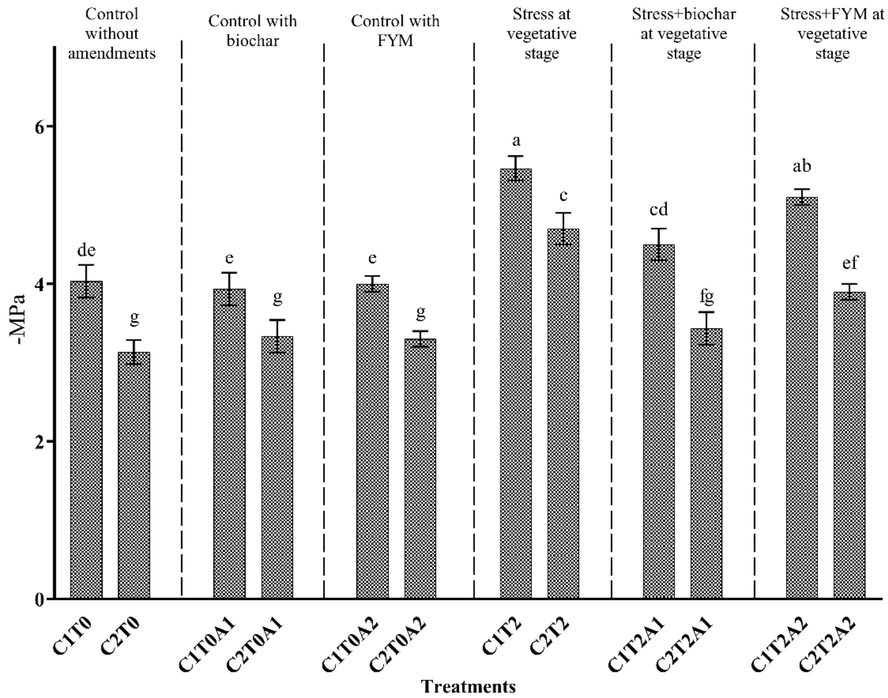
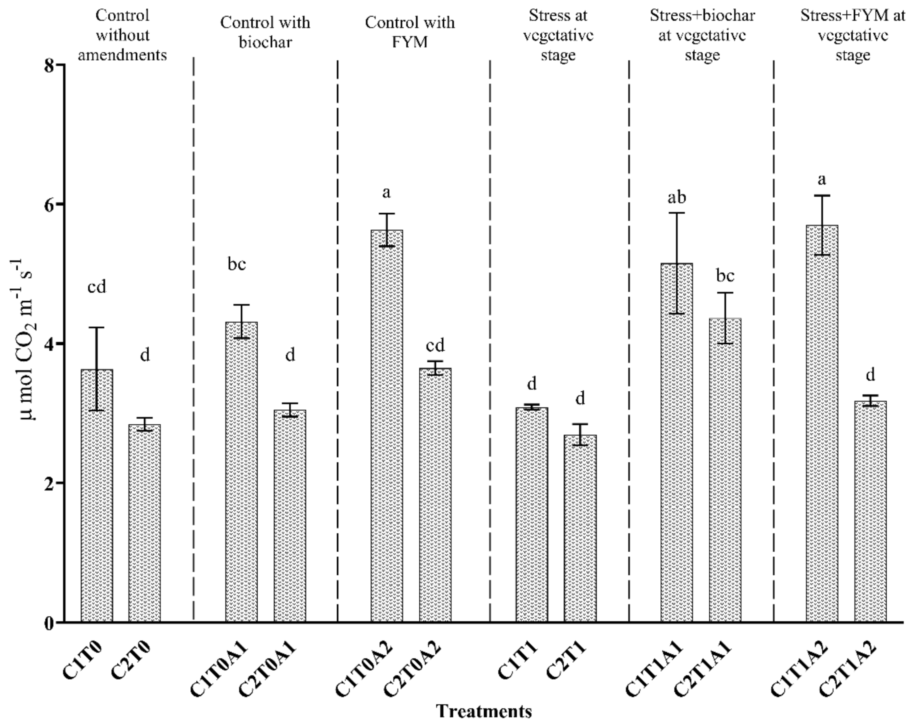


(b)

*Different lowercase letters above each column indicate significant differences between treatments at 5% level of significance (P≤ 0.05) according to Tukey's Honestly Significant Difference (HSD)

Figure 7.2: Leaf water potential as affected by application of biochar and FYM as soil amendments and drought exposure at (a) vegetative and (b) reproductive stage in year 2.



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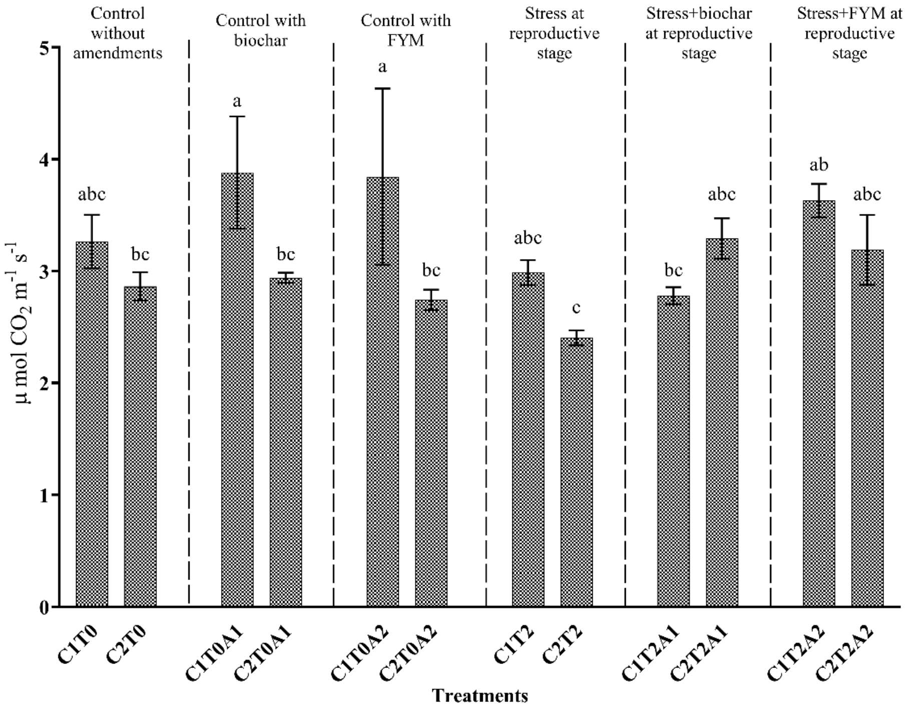
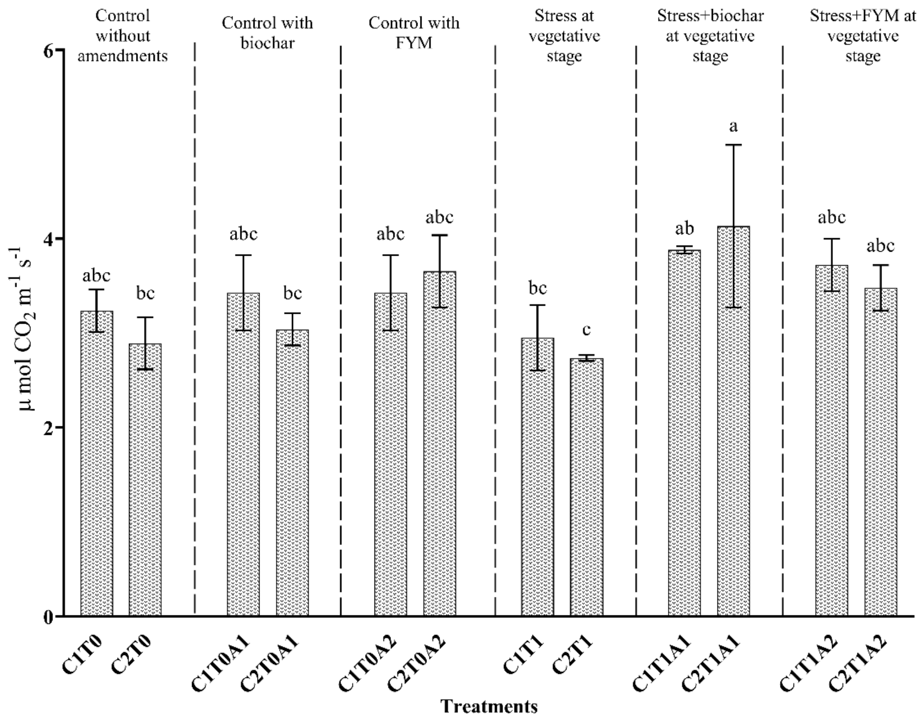


(b)

*Different lowercase letters above each column indicate significant differences between treatments at 5% level of significance ($P \leq 0.05$) according to Tukey's Honestly Significant Difference (HSD)

Figure 7.3: Photosynthesis as affected by application of biochar and FYM as soil amendments and under drought at (a) vegetative and (b) reproductive stage in year 1.



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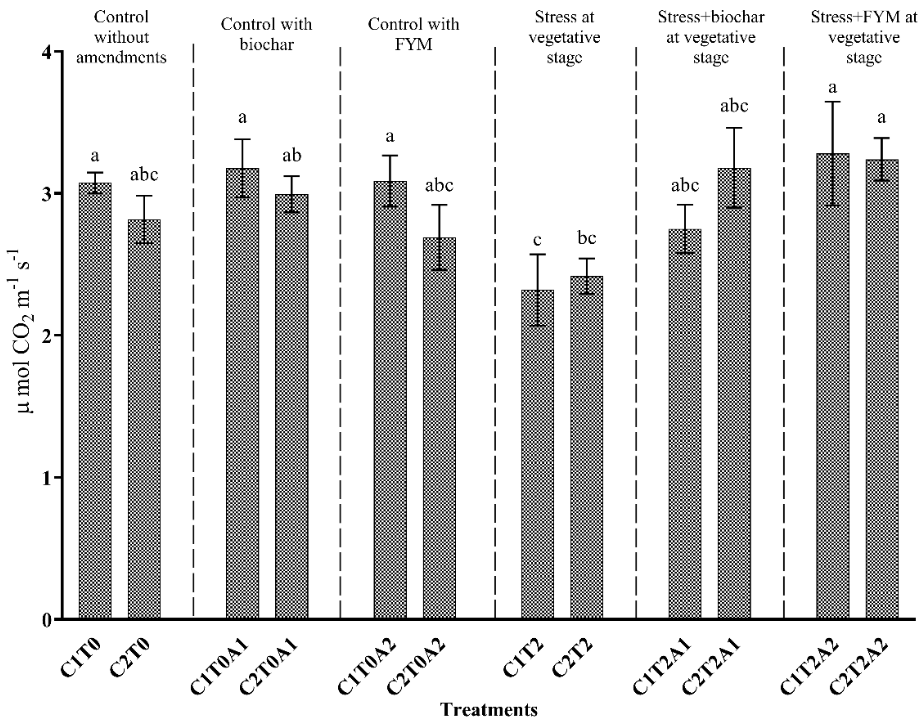


(b)

*Different lowercase letters above each column indicate significant differences between treatments at 5% level of significance (P≤ 0.05) according to Tukey's Honestly Significant Difference (HSD)

Figure 7.4: Photosynthesis as affected by application of biochar and FYM as soil amendments and under drought at (a) vegetative and (b) reproductive stage in year 2.

Peroxidase Activity

Exposure to drought at vegetative stage significantly enhanced the peroxidase activity of *Vigna radiata* and *Lathyrus sativus* crops up to 225% and 76% respectively. Amending the soils with biochar and FYM mitigated the increased peroxidase activity up to 46% and 43% correspondingly.

Similarly, under drought at reproductive stage an increase in the peroxidase activity was documented in *Vigna radiata* (up to 74%) and *Lathyrus sativus* (up to 99%). Amending the soils with biochar or FYM significantly lowered the enhanced peroxidase activity in *Vigna radiata* (up to 60% and 50% respectively) and *Lathyrus sativus* (up to 56% and 37% correspondingly) when exposed to drought at reproductive stage.

Superoxide dismutase activity

Drought at vegetative stage significantly enhanced the SOD activity of the crops (up to 69% and 116% in *Vigna radiata* and *Lathyrus sativus* crops, respectively). Amending the soils with biochar or FYM successfully lessened the enhanced SOD activity in *Vigna radiata* (up to 34%) and *Lathyrus sativus* (up to 34%).

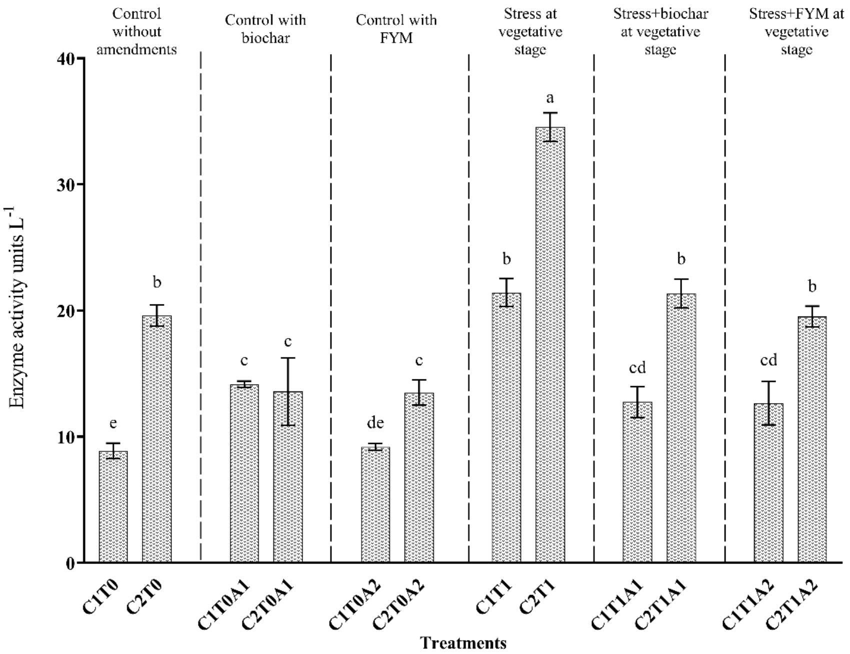
Similarly, exposure to drought at vegetative stage in both the years of cultivation recorded a significant increase in the SOD activity in both the crops (up to 107%). Application of biochar or FYM proved to be successful in mitigating the excessive SOD activity in *Vigna radiata* (up to 48% and 45% correspondingly) and *Lathyrus sativus* (up to 47% and 42% respectively) crops.

Leaf Proline content

Under drought at vegetative stage, a significant increase in proline content was documented in *Vigna radiata* (up to 42%) and *Lathyrus sativus* crops (up to 22%). Amending the soil with biochar or FYM significantly lowered the increase in proline content in *Vigna radiata* (up to 23% and 19% respectively) and *Lathyrus sativus* crops (up to 20% and 29% correspondingly).

Similarly, under drought at reproductive stage, an increase in proline content was noted in both the crops (up to 61%). Amending the soils with biochar or FYM significantly mitigated the increased proline content in *Vigna radiata* crops (up to 36%

and 37% correspondingly) as well as *Lathyrus sativus* crops (up to 31% and 27% respectively).



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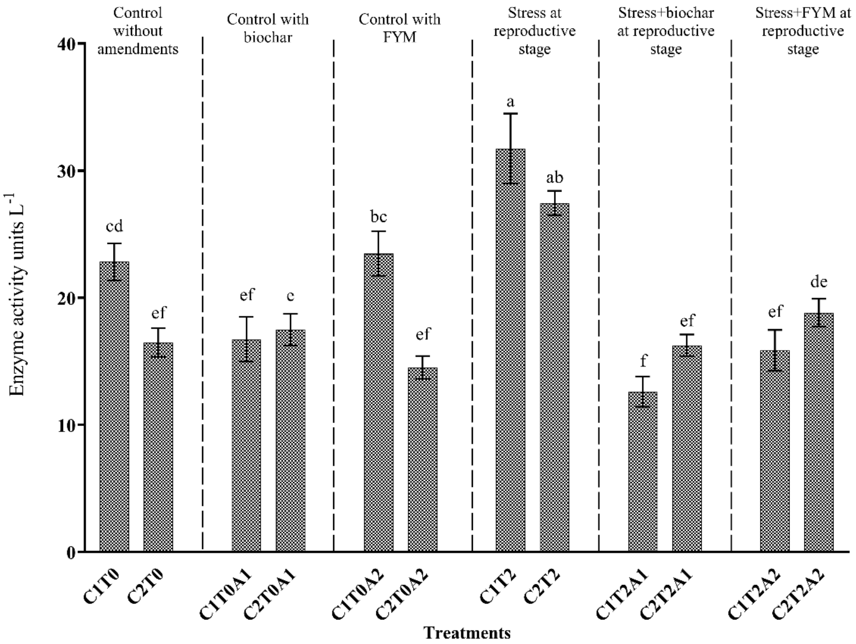
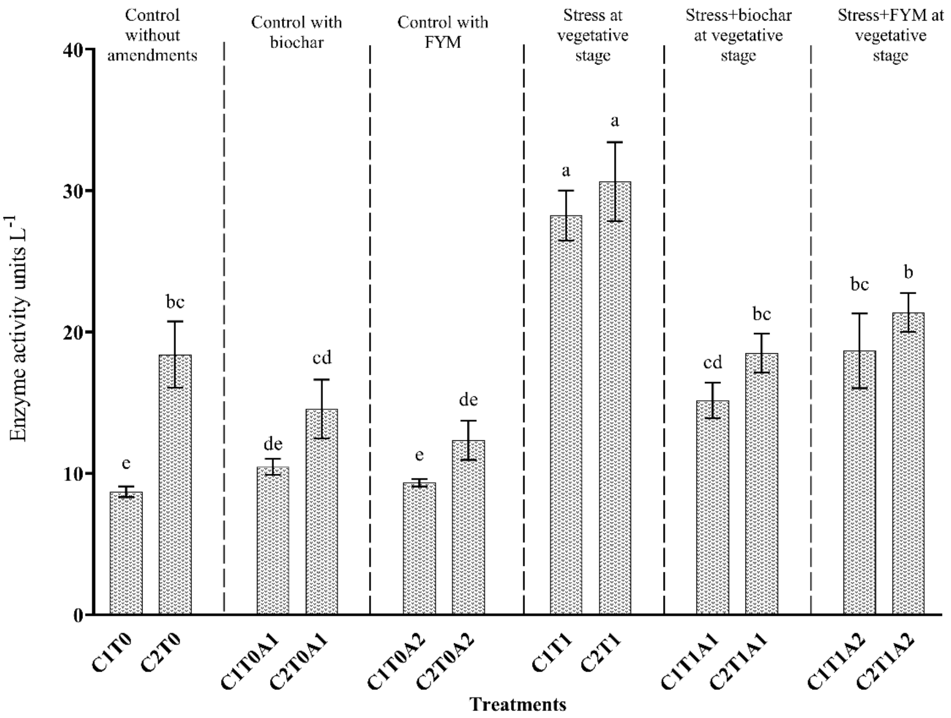


(b)

*Different lowercase letters above each column indicate significant differences between treatments at 5% level of significance (P≤ 0.05) according to Tukey's Honestly Significant Difference (HSD)

Figure 7.5: Peroxidase activity as affected by application of biochar and FYM as soil amendments and under drought at (a) vegetative and (b) reproductive stage in year 1.



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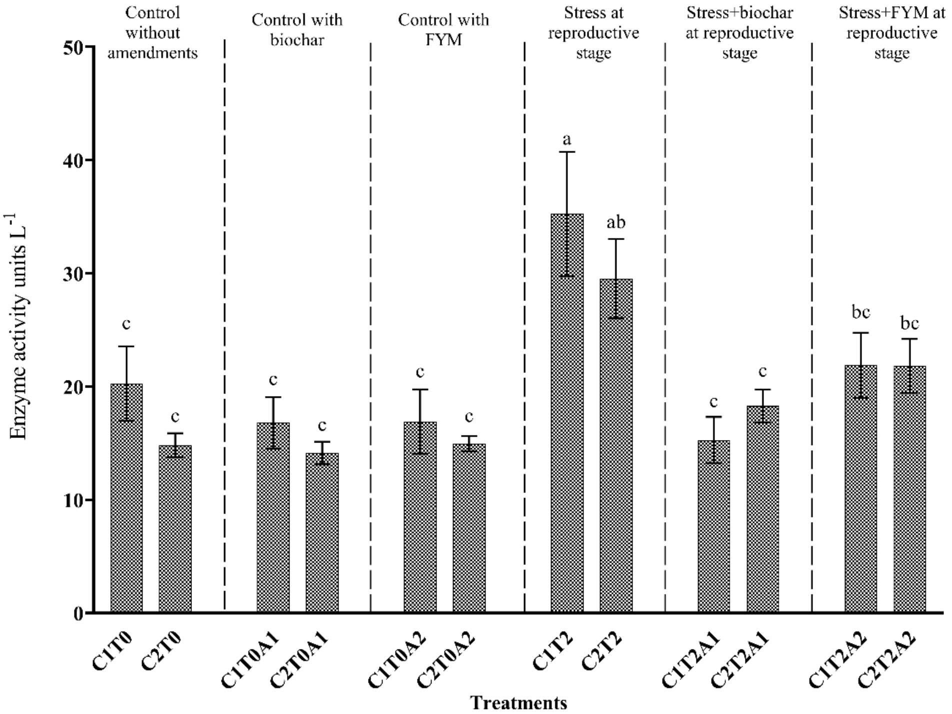
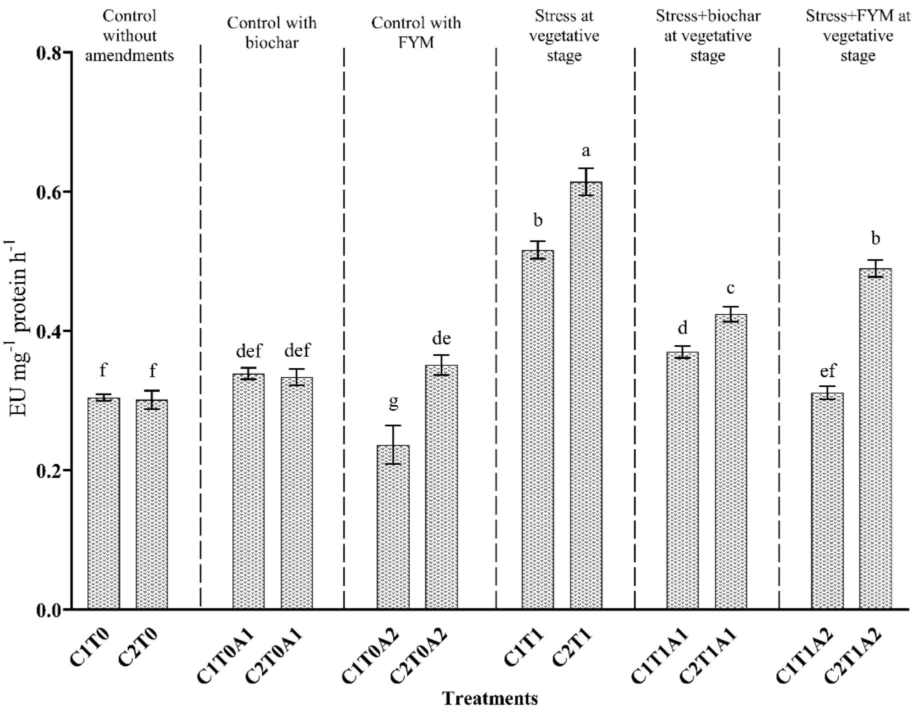


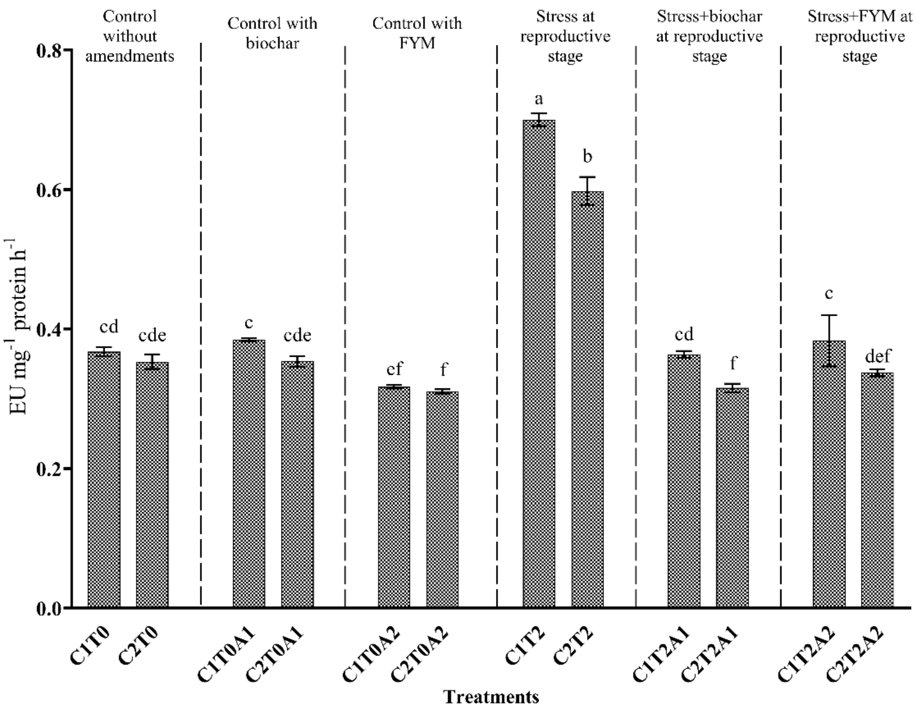
(b)

*Different lowercase letters above each column indicate significant differences between treatments at 5% level of significance (P≤ 0.05) according to Tukey's Honestly Significant Difference (HSD)

Figure 7.6: Peroxidase activity as affected by application of biochar and FYM as soil amendments and under drought at (a) vegetative and (b) reproductive stage in year 2.



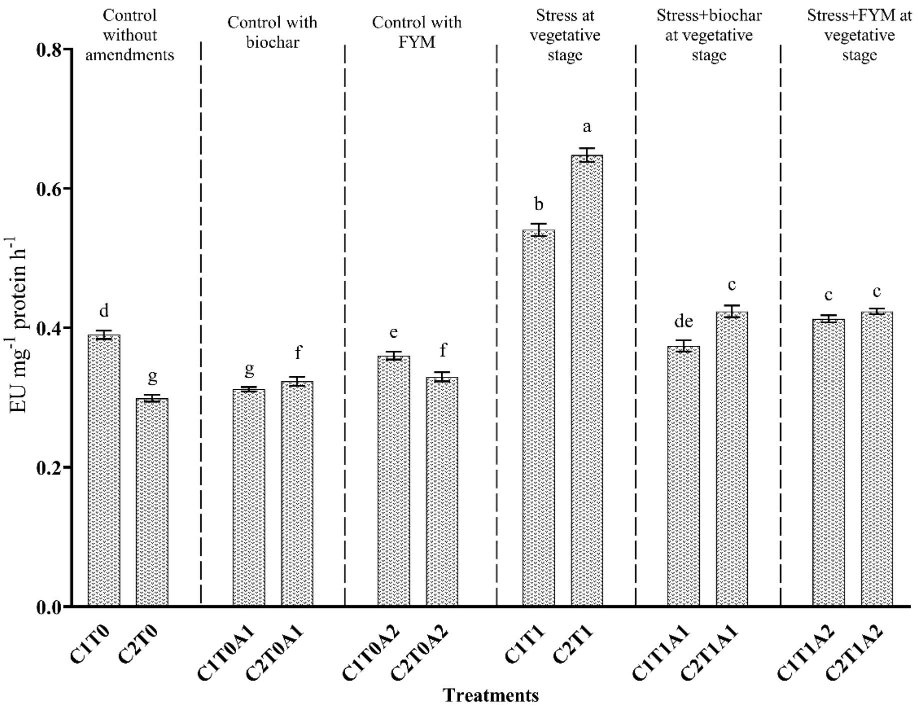
(a)



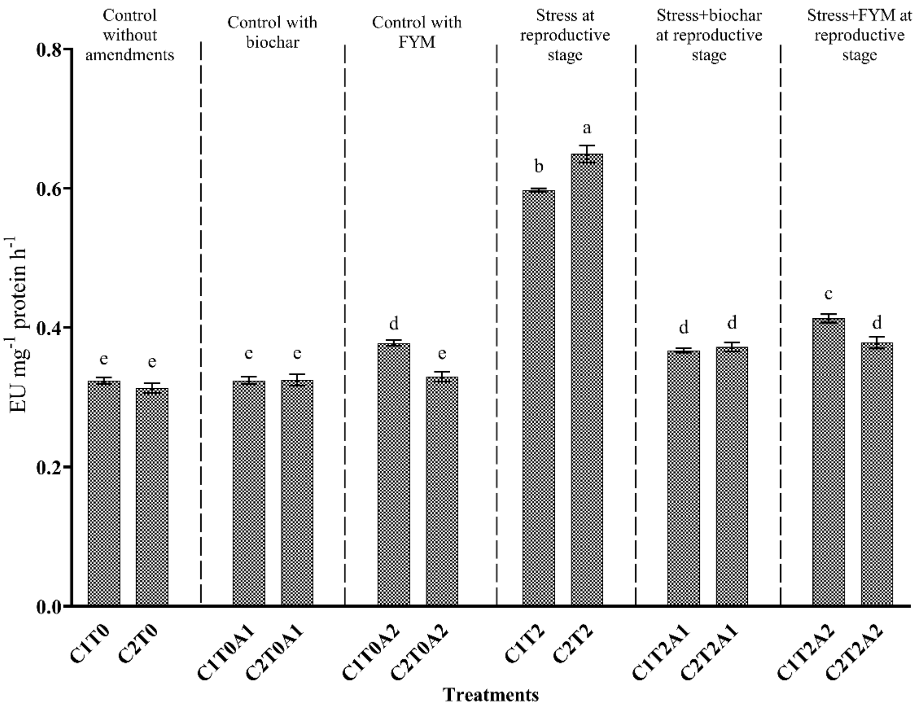
(b)

*Different lowercase letters above each column indicate significant differences between treatments at 5% level of significance (P≤ 0.05) according to Tukey's Honestly Significant Difference (HSD)

Figure 7.7: Superoxide dismutase activity as affected by application of biochar and FYM as soil amendments and under drought at (a) vegetative and (b) reproductive stage in year 1.



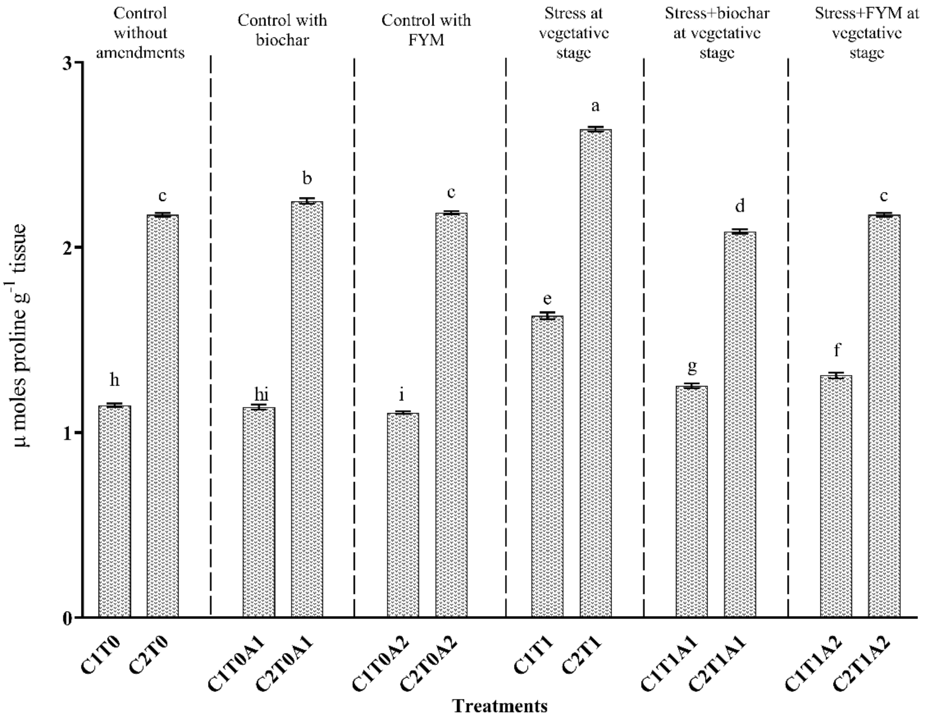
(a)



(b)

*Different lowercase letters above each column indicate significant differences between treatments at 5% level of significance (P≤ 0.05) according to Tukey's Honestly Significant Difference (HSD)

Figure 7.8: Superoxide dismutase activity as affected by application of biochar and FYM as soil amendments and under drought at (a) vegetative and (b) reproductive stage in year 2.



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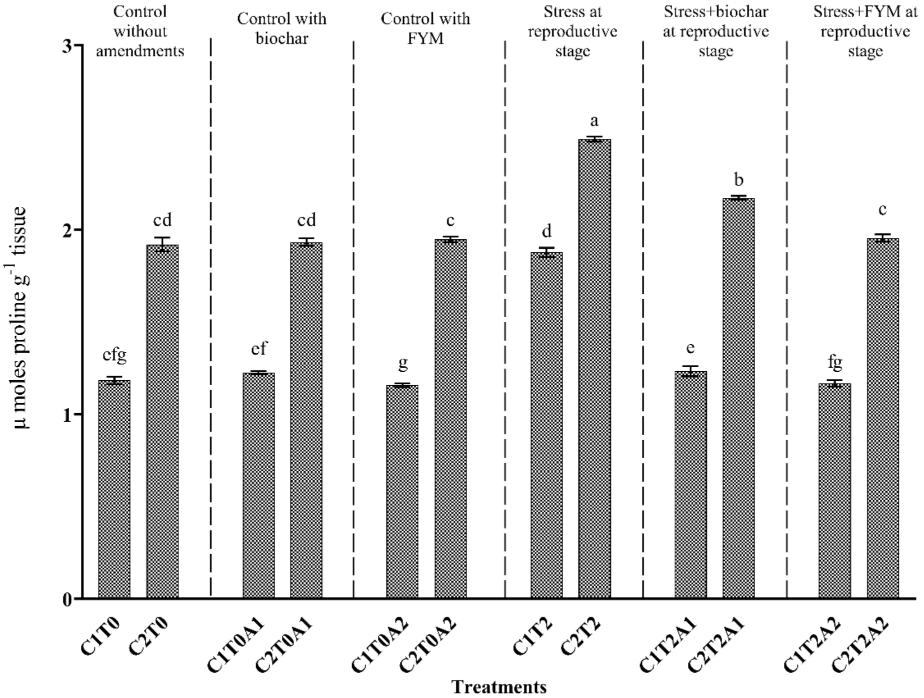
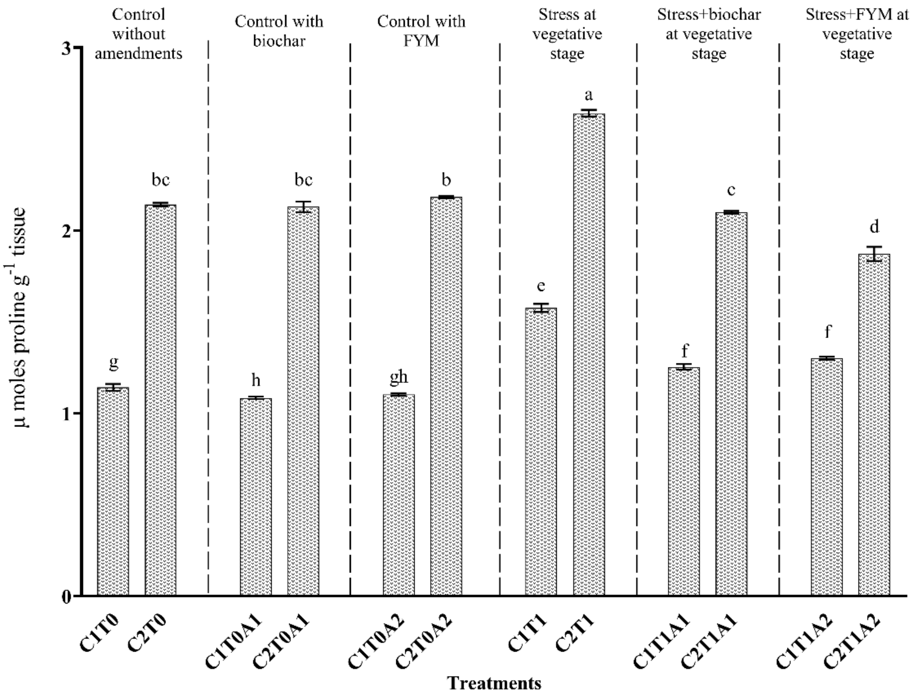


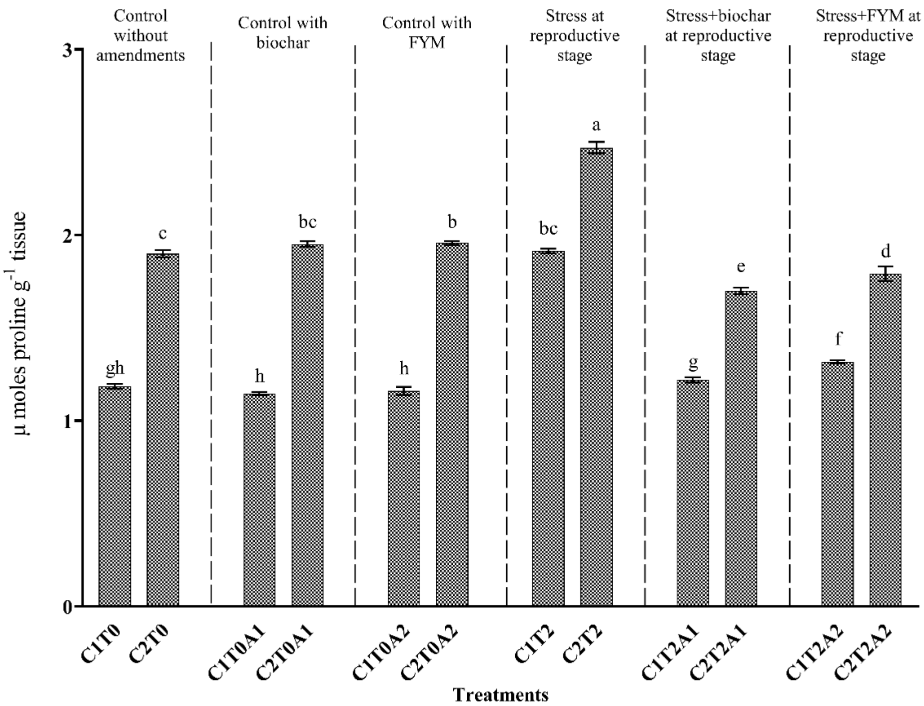
(b)

*Different lowercase letters above each column indicate significant differences between treatments at 5% level of significance ($P \leq 0.05$) according to Tukey's Honestly Significant Difference (HSD)

Figure 7.9: Leaf proline as affected by application of biochar and FYM as soil amendments and under drought at (a) vegetative and (b) reproductive stage in year 1.



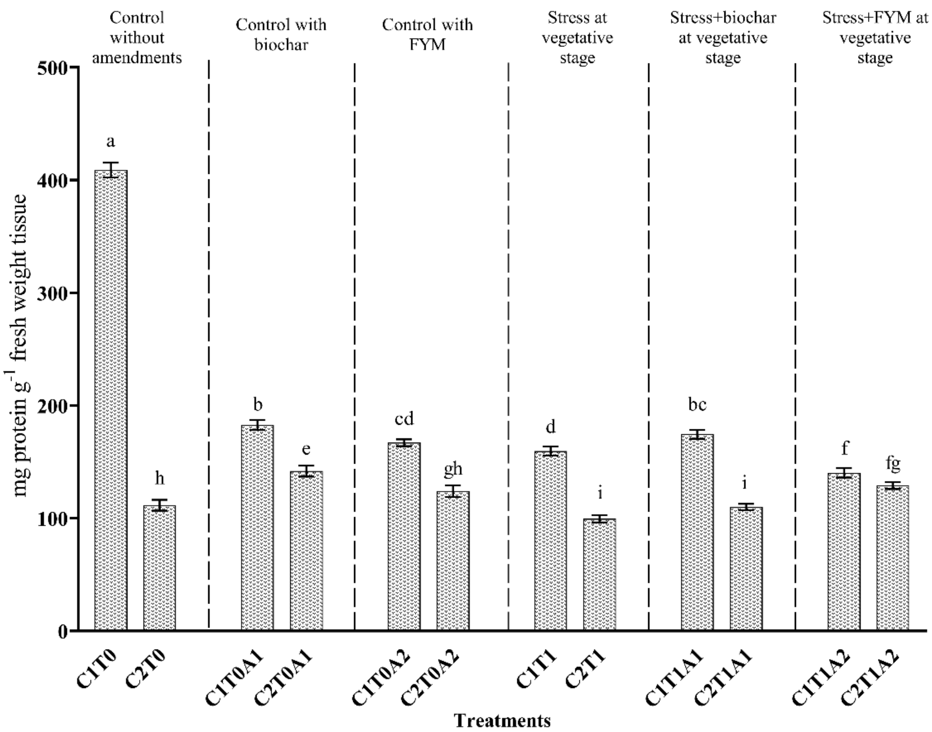
(a)



(b)

*Different lowercase letters above each column indicate significant differences between treatments at 5% level of significance ($P \leq 0.05$) according to Tukey's Honestly Significant Difference (HSD)

Figure 7.10. Leaf proline as affected by application of biochar and FYM as soil amendments and under drought at (a) vegetative and (b) reproductive stage in year 2.



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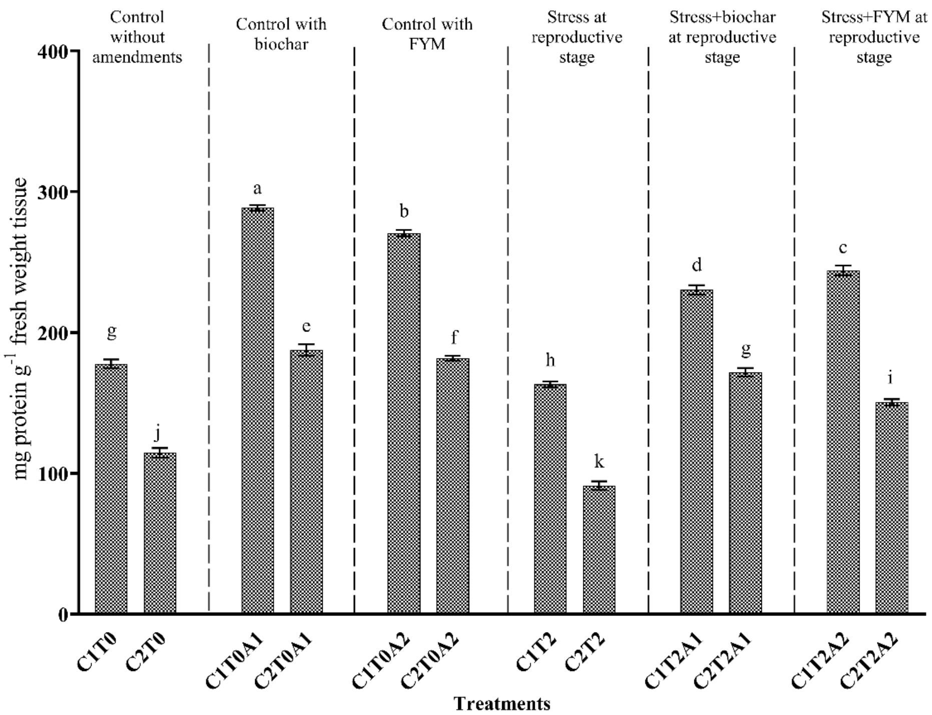
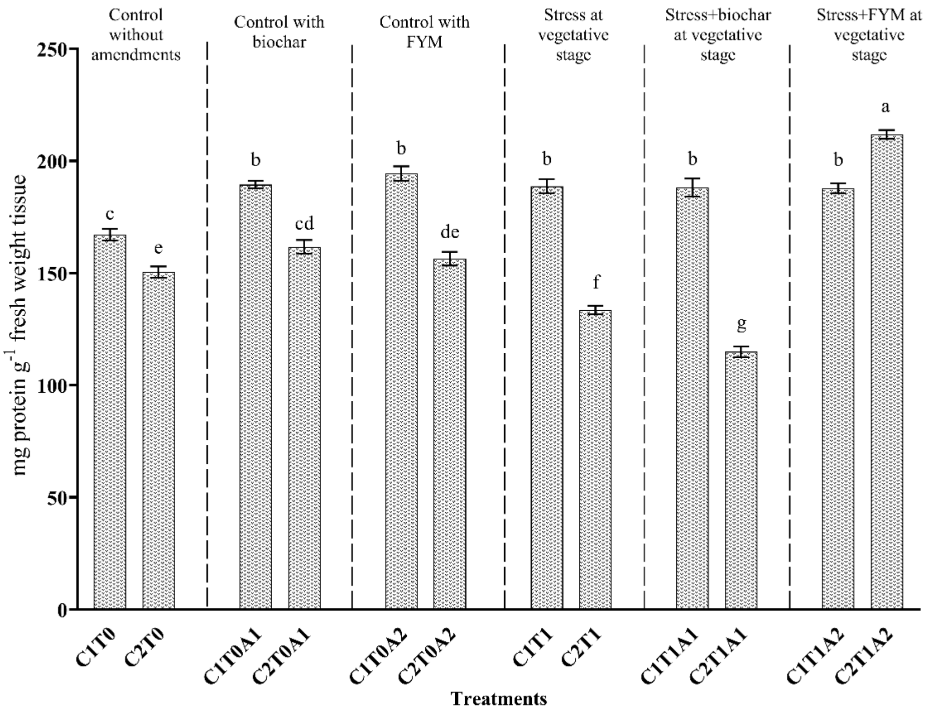


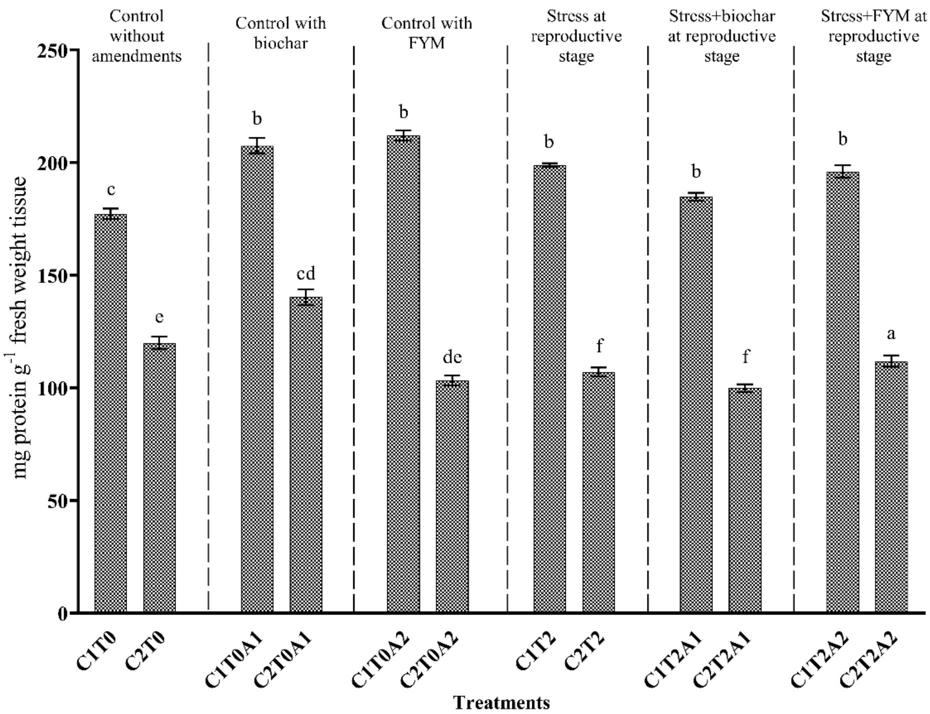
(b)

*Different lowercase letters above each column indicate significant differences between treatments at 5% level of significance (P≤ 0.05) according to Tukey's Honestly Significant Difference (HSD)

Figure 7.11. Leaf protein as affected by application of biochar and FYM as soil amendments and under drought at (a) vegetative and (b) reproductive stage in year 1.



(a)



(b)

*Different lowercase letters above each column indicate significant differences between treatments at 5% level of significance ($P \leq 0.05$) according to Tukey's Honestly Significant Difference (HSD)

Figure 7.12. Leaf protein as affected by application of biochar and FYM as soil amendments and under drought at (a) vegetative and (b) reproductive stage in year 2.

Table 7.1: Table showing correlation matrix amongst leaf water potential, photosynthesis, leaf proline, POD, and SOD of the crops as affected by drought at vegetative stage and application of soil amendments in year 1.

Parameters	Leaf water potential	Photosynthesis	Leaf proline	Leaf Protein	POD	SOD
Leaf water potential	1					
Photosynthesis	0.269	1				
Leaf proline	-0.317	-.729**	1			
Leaf Protein	0.005	0.088	-0.598*	1		
POD	0.234	-0.583*	0.727**	-0.531	1	
SOD	0.394	-0.548	0.583*	-0.344	0.878**	1

*** Correlation is significant at the 0.05 level (2-tailed).**
****Correlation is significant at the 0.01 level (2-tailed).**

Table 7.2: Table showing correlation matrix amongst leaf water potential, photosynthesis, leaf proline, POD, and SOD of the crops as affected by drought at vegetative stage and application of soil amendments in year 2.

Parameters	Leaf water potential	Photosynthesis	Leaf proline	Leaf Protein	POD	SOD
Leaf water potential	1					
Photosynthesis	-0.051	1				
Leaf proline	-0.373	-0.322	1			
Leaf Protein	0.376	0.033	-.671*	1		
POD	0.388	-0.397	0.574	-0.196	1	
SOD	0.571	-0.330	0.349	-0.192	.830**	1

*** Correlation is significant at the 0.05 level (2-tailed).**
****Correlation is significant at the 0.01 level (2-tailed).**

Table 7.3: Table showing correlation matrix amongst leaf water potential, photosynthesis, leaf proline, POD, and SOD of the crops as affected by drought at reproductive stage and application of soil amendments in year 1.

Parameters	Leaf water potential	Photosynthesis	Leaf proline	Leaf Protein	POD	SOD
Leaf water potential	1					
Photosynthesis	-0.021	1				
Leaf proline	-0.164	-.691*	1			
Leaf Protein	0.042	.793**	-.826**	1		
POD	.638*	-0.112	0.239	-0.327	1	
SOD	.812**	-0.358	0.330	-0.369	.809**	1

*** Correlation is significant at the 0.05 level (2-tailed).**
****Correlation is significant at the 0.01 level (2-tailed).**

Table 7.4: Table showing correlation matrix amongst leaf water potential, photosynthesis, leaf proline, POD, and SOD of the crops as affected by drought at reproductive stage and application of soil amendments in year 2.

Parameters	Leaf water potential	Photosynthesis	Leaf proline	Leaf Protein	POD	SOD
Leaf water potential	1					
Photosynthesis	-0.348	1				
Leaf proline	-0.077	-.608*	1			
Leaf Protein	0.544	0.128	-.739**	1		
POD	0.787**	-0.542	0.388	0.110	1	
SOD	0.732**	-0.677*	0.540	-0.008	0.905**	1

*** Correlation is significant at the 0.05 level (2-tailed).**
****Correlation is significant at the 0.01 level (2-tailed).**

Leaf Protein Content

Exposure to drought at vegetative stage significantly reduced the leaf protein content in both the crops (up to 60%). Under *Vigna radiata* cultivation, amending the soils with biochar enhanced the leaf protein content up to 9%. Under *Lathyrus sativus* cultivation amending the soils with biochar or FYM in the first year resulted in increased leaf protein content (up to 29%) when exposed to drought at vegetative stage. In the second year of cultivation, amending the soil with biochar as the mitigation strategy against drought at vegetative stage led to a decreased leaf protein (13%), whereas, FYM increased the same up to 58%.

Drought at reproductive stage, significantly reduced the leaf protein content in both the crops (up to 20%). In the first year of cultivation, amending the soils with biochar or FYM significantly mitigated the reduced the leaf protein (up to 88% and 64% respectively) under drought at reproductive stage. However, in the second year of cultivation, biochar resulted a decrease in the protein content in both the crops (up to 7%) but FYM enhanced the leaf protein of *Lathyrus sativus* by 4% when exposed to drought at reproductive stage.

Interactive effects

During stress at vegetative stage, in the first year of cultivation, a strong positive correlation between SOD activity with proline content ($R=0.583$, $P\leq0.05$) and peroxidase activity (POD) ($R=0.878$, $P\leq0.01$) was documented. The proline content also had a strong positive correlation with POD (R=0.727, P≤0.01), but its negative correlation with leaf protein was also recorded (R=-0.598, P≤0.05). Moreover, photosynthesis documented a negative correlation with proline content (R=-0.729, P≤0.0) and peroxidase activity (R=-0.583, P≤0.05). In the second year of cultivation, a strong positive correlation of peroxidase and SOD activity (R=0.830, P≤0.01) was recorded, along with a negative correlation between leaf protein and proline content (R=-0.671, P≤0.05).

During stress at reproductive stage, exposure to drought at vegetative stage in both the years of cultivation, a strong correlation of negative leaf water potential with peroxidase activity (up to R=0.787, P≤0.01) and SOD activity (R=0.812, P≤0.01) was documented. Moreover, a negative correlation of leaf proline with protein (R=-0.826, P≤0.01) and photosynthesis (R=-0.691, P≤0.05) along with a strong positive correlation between SOD with POD (up to R=0.905, P≤0.01) was documented. During stress at reproductive stage, a strong positive correlation of photosynthesis with leaf protein (R=0.793, P≤0.01) in the first year of cultivation and a strong negative correlation with SOD (R=-0.677, P≤0.05) in the second year of cultivation was also documented.

List of Publications

Original Articles Published

Mondal, S.C., Sarma, B., Farooq, M., Nath, D.J. and Gogoi, N., 2019. Cadmium bioavailability in acidic soils under bean cultivation: role of soil additives. *International Journal of Environmental Science and Technology*, pp.1-8.

Baruah, N., **Mondal, S. C.**, Farooq, M., and Gogoi, N. (2019). Influence of heavy metals on seed germination and seedling growth of wheat, pea, and tomato. *Water, Air, & Soil pollution*, *230*(12), 1-15.

Sharma, A., Das, S., Bora, A., **Mondal, S. C.**, Gogoi, N., and Dwivedi, S. K. (2021). Phycoremediation of water of Ellenga beel polluted with paper mill effluent using Chlorella ellipsoidea and Desmodesmus opoliensis. *Bioremediation Journal*, 1-11.

Mondal, S. C., Gogoi, N., Nath, D., and Gayan, A. (2022). Soil amendments for improving grain quality of grass pea (Lathyrus sativus L.) under drought. *JSFA Reports*, *2*(1), 27-36.

Mondal, S. C., Sarma, B., Narzari, R., Gogoi, L., Kataki, R., Garg, A., and Gogoi, N. (2022). Role of pyrolysis temperature on application dose of rice straw biochar as soil amendment. *Environmental Sustainability*, *5*(1), 119-128.

Book Chapter published

Gogoi, N., Sarma, B., **Mondal, S. C.**, Kataki, R., and Garg, A. (2019). Use of biochar in sustainable agriculture. In *Innovations in sustainable agriculture* (pp. 501-528). Springer, Cham.

Oral/Poster papers presented in conferences

Poster paper presentation titled "Use of soil amendments to mitigate drought stress in Phaseolus vulgaris L." in International plant physiology virtual symposium (IPPVS 2021) on 'Physiological interventions for climate smart agriculture' Organized by ICAR-Sugarcane breeding Institute (SBI), Coimbatore, Tamil Nadu, India, in collaboration with Indian Society of Plant Physiology (ISPP), New Delhi, India, held during 11-12 March, 2021.

Oral Paper Presentation titled "Use of nature inspired soil amendments to mitigate drought stress in Vigna radiata L. and Lathyrus sativus L." in International Earth Science Conference 2022 'Sustainable development: Challenges and way forward' Organized by Department of Earth Science, University of Science and Technology, Meghalaya, in collaboration with Department of Environmental Science, Tezpur University, Assam, India, held during 18-19 November, 2022.