SEASONAL TEMPERATURE EFFECT ON THE BIOMASS PRODUCTIVITY OF FODDER *AZOLLA*

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ABSTRACT: *Understanding the habitat requirements of Azolla is very helpful for managing this aquatic fern throughout the year as a fodder substitute. Azolla withstands a wide range of temperature depending upon its species and strain. Its response on summer seasonal temperature is not well understood. Hence, an experiment was conducted at the Experimental Farm, Department of Agronomy, Annamalai University, Annamalainagar, Tamilnadu during hot weather period (Zaid season) of 2016, to study the effect of summer seasonal temperature on the green and dry biomass productivity of Azolla in coastal northern Tamilnadu. The green and dry biomass production was observed from 6th to 13th standard weeks. The results revealed that the maximum air temperature between 31.37 and 33.74°C, minimum temperature between 22.81 and 23.34°C and water temperature between 32.6 and 34.4 °C were found to enhanced the biomass productivity of Azolla, while air temperature above 35.2°C perished the Azolla colonies.*

Key Words: *Azolla pinnata, air and water temperature, dry biomass, green fodder yield*

1. INTRODUCTION

The free floating freshwater fern *Azolla* (Azollaceae) became progressively more popular as animal feedstock because of its capability to grow on artificial water pools, fast growth in nitrogen deficient habitats and production of enormous green and dry fodder with high nutrient content (Mathur *et al*., 2013; Chatterjee *et al*., 2013; Cherryl *et al*., 2014; Anitha *et al*., 2016; Meena *et al*., 2017; Shukla *et al*., 2018; Rex Immanuel *et al*., 2019). *Azolla* possesses the ability to utilize the atmospheric N_2 for their biomass production due to a symbiotic association with the blue-green algae *Anabaena azollae* (Kannaiyan, 2002). Depending on conditions, *Azolla* doubles its biomass within 3-10 days and reaches an appropriate fresh weight of 8-10 tonnes ha^{-1}. A maximum of 37.8 tonnes ha^{-1} fresh weight (2.78 tonnes ha^{-1} dry weight) has been reported for *A. pinnata* R.Br. in Indian condition (Pullin and Almazan, 1983).

Azolla grows in full to partial shade (100-50 per cent sunlight) with growth decreasing quickly under heavy shade (Ferentinos *et al*., 2002). The biomass production greatly decreases at a light intensity lower than 1500 lux (Liu *et al*., 2008). The most favourable relative humidity for *Azolla* growth is between 85-90 per cent. Rate of plant growth and biomass production is dependent upon the temperature adjacent to the plant and each species has a specific temperature range represented by a minimum, maximum, and optimum. Extreme weather events occurring during the summer period would have the most dramatic impact on plant productivity. Short term duration of a few days with temperature increases of over 2-5 °C above the normal temperatures affect the *Azolla* growth and productivity.

Under optimal conditions *Azolla* species had a rapid vegetative multiplication with biomass doubling time of two to five days (Sadeghi *et al*., 2013). The mean air temperature ranging from 30 – 35°C which varies according to species and growth conditions (Uheda *et al*., 1999).There have been some studies about the differences in temperature responses of *Azolla* species and their eco-physiological strains indicated that a very high (above 30°C) or very low temperature (below -4°C) could play an inhibitory role in the growth of *Azolla* (Fernandez-Zamudio *et al*., 2010; Liu *et al*., 2008; Sadeghi *et al*., 2012). *Azolla* growing water temperature reached up to 41°C, which was 6°C above air temperature (Krock *et al*., 1988). At higher temperatures (38±1°C/25±1°C) *Azolla* consistently showed a superior growth rate (Kannaiyan and Somporn, 1989). Accordingly, the information about the effects of seasonal temperature during hot weather period on the green and dry biomass production of *Azolla* is necessary for its year round cultivation and management in artificial water bodies.

2. MATERIALS AND METHODS

The Experimental Farm is situated at 11°24' N latitude and 79°44' E longitude and at an altitude of +5.79 m above MSL (mean sea level) and 10 km away from the Bay of Bengal. The weather at experimental

site was moderately warm with hot summer months. The mean annual rainfall of the experimental farm was 1,500 mm distributed over 60 rainy days. The potential evapotranspiration varies from 1,700 to 1,900 mm resulting in an annual water deficit of 200 – 400 mm year^{-1}. The maximum temperature ranged from 28.0 to 39.0° C with a mean of 33.0° C while the minimum temperature varied from 18.5 to 27.5° C with a mean of 23.0° C. The mean highest and lowest relative humidity was 96 (September – January) and 76 per cent (February - August), respectively. The experiment was conducted during hot weather period (*Zaid* season), particularly the setup was accomplished between 6th and 13th standard weeks of 2016. The observations on weather parameters during crop season revealed that, maximum temperature ranged from 31.25°C to 35.20°C with a mean of 33.20°C. The minimum temperature varied from 21.10°C to 24.40°C with a mean of 22.60°C. The relative humidity was fluctuated from 85.71 to 90.00 per cent with a mean of 87.73 per cent. There was no rainfall event occurred during the period of experimentation.

Table 1 Weather prevailed during the growth period

Months	Standard week	Mean temperature (°C)		RH (%)	Evap-oration (mm)	HBSS (hrs)	Rain-fall (mm)	Number of rainy days
		Max.	Min.					
Tray-culture Experiment								
Feb 08 – 14	6	31.25	21.10	88.00	3.2	9.25	000.0	-
15 – 21	7	31.37	22.81	86.86	3.4	9.39	000.0	-
22 - 28	8	33.27	22.60	88.71	3.5	9.97	000.0	-
Feb 29 - March 06	9	32.60	23.07	90.00	3.1	7.74	000.0	-
07 – 13	10	33.39	23.34	88.57	3.7	8.84	000.0	-
14 – 20	11	33.74	23.11	88.00	3.6	8.74	000.0	-
March 21 – 27	12	35.20	23.40	86.00	3.8	8.30	000.0	-
March 28 – April 03	13	34.80	24.40	85.71	3.7	8.72	000.0	-

Deep bore well was the source of water for growing of *Azolla* (pH 7.8, EC 1125 µScm^{-1} and SAR 2.07). Trays were used to cultivate *Azolla* with five replications and the gross dimension of the individual tray was 0.3 x 0.2 m (0.06 m^2). The fresh *Azolla pinnata* was collected from the rice paddy of Annamalai University Experimental Farm and further cultured in artificial water bodies in plastic trays under homogenous conditions. Before the beginning of experiment, samples were washed thoroughly with tap water and rinsed with distilled water. Organic cultivation was practiced. As the *Azolla* plant is a N_2 fixer, it has a competitive advantage over other floating plants for its production in water without added nitrogen fertilizer. Enriched Farm Yard Manure (EFYM) (Phosphorus as rock phosphate at the rate of 2 per cent was thoroughly mixed and incubated for three weeks) at the rate of 0.8 per cent (W/V) was added in *Azolla* pool whenever required (Rex Immanuel *et al*. 2019). First crop was harvested on 7th day after inoculation and the subsequent harvesting was done at weekly interval. The plants were harvested at the specific period and the moisture was removed from the surface with blotting paper. The fresh and dry weights were determined and recorded. The observations recorded on the various parameters were computed with the help of MS Office Excel Worksheet.

3. RESULTS AND DISCUSSION

The effect of maximum temperature on the green and dry fodder productivity of *Azolla* are furnished in Fig 1 and 2. From 7th to 11th standard week (Feb 15th to 20th March) the temperature fluctuated from 31.37 to 33.74 ^{o}C. This temperature was helpful for increasing the production of green and dry fodder. Thereafter the rapid increase in maximum temperature from 33.74 to 35.20 ^{o}C affected the growth and reduced the green and dry fodder yield.

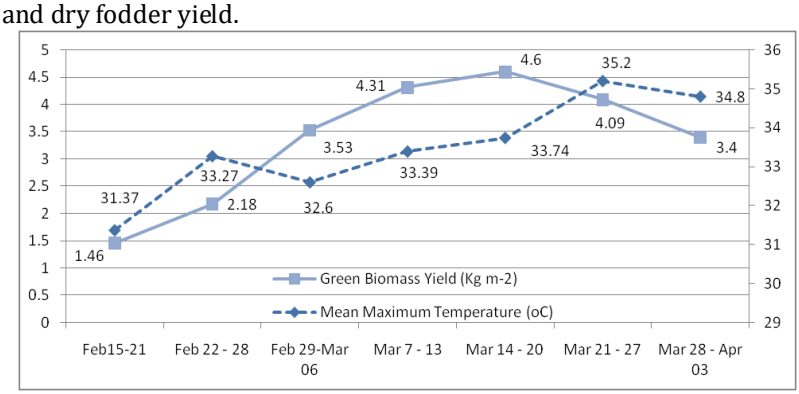

Fig.1 Effect of maximum temperature on the green biomass yield

The effect of minimum temperature on the green and dry biomass yield of fodder *Azolla* are exhibited in Fig 3 and 4. The optimum mean minimum temperature of 22.60 to 23.34 °C was recorded. This temperature was useful for the maximum growth and production of green and dry fodder. Thereafter the quick increase in average minimum temperature from 23.11 to 24.40°C retarded the growth and declained the green and dry fodder yield.

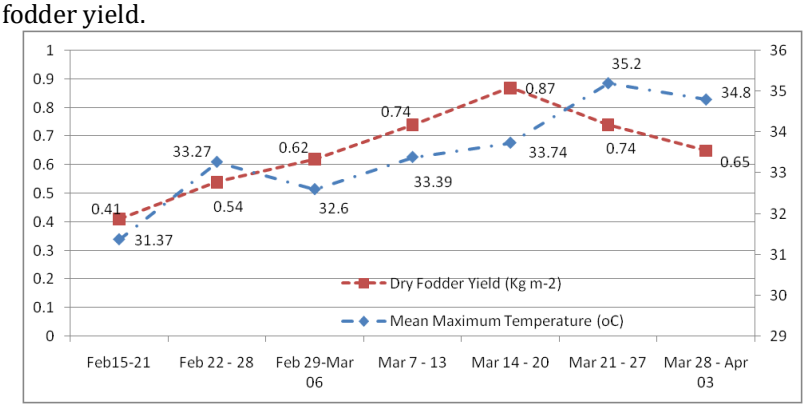

Fig.2 Effect of maximum temperature on the dry biomass yield of fodder *Azolla*

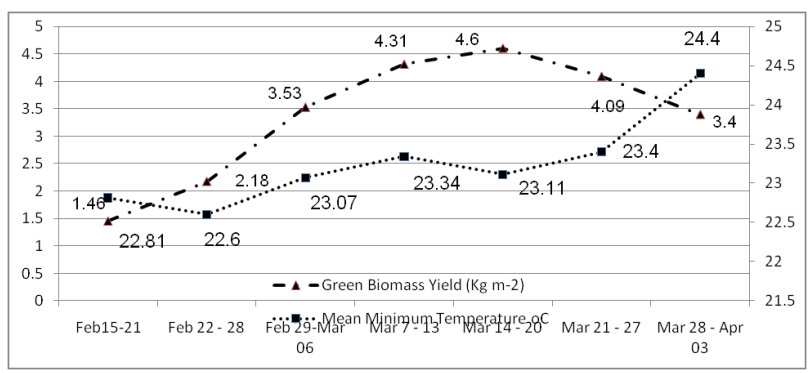

Fig.3 Effect of minimum temperature on the green biomass yield of fodder *Azolla*

Green and dry fodder productivity of *Azolla* shot up when seasonal weather factors such as optimum air temperature, water temperature, humidity and day length were good (Plate 1). This weather experienced between 6th and 11th standard week with the mean of 32.60 °C (maximum temperature), 22.67 °C (minimum temperature), 88.36 (humidity %), 3.4 (evaporation mm) and 8.99 (hours of bright sunshine) (Table 1). Biomass production of *Azolla* was also dependent on the specific growing season. The changes in temperature conditions over different weeks have an important effect on *Azolla* growth and biomass production. For most *A. pinnata* strains, the maximum weekly relative growth rate was higher at 33°C with 1.9 doubling days and gave a maximum biomass after 13–23 days, while some strains grew up to 30 days, resulting in higher biomass production (Watanabe and Berja, 1983). Low production occurs during winter, while highest production was obtained in summer and monsoon having high temperature of more than 30° C was reported by Speelman *et al*. (2009) and Aziz (2012).

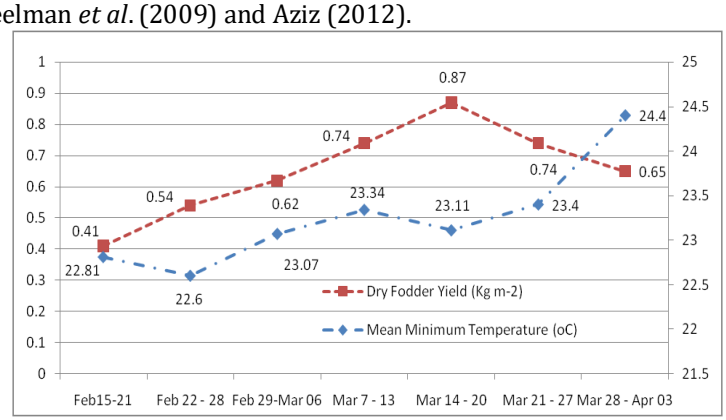

Fig.4 Effect of minimum temperature on the dry biomass yield of fodder *Azolla*

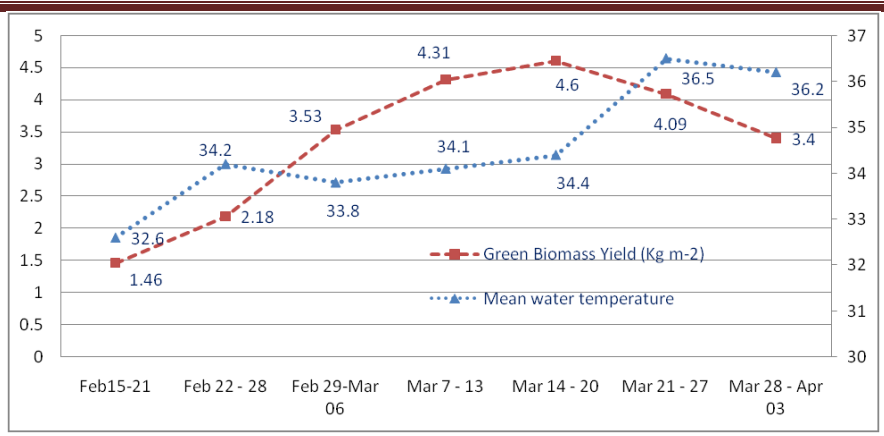

Fig. 5 Effect of water temperature (12 noon) on the green biomass yield of fodder *Azolla*

The water temperature (12 noon) was also fluctuating widely over the course of every day. It varied between 32.6 and 36.2 ^{o}C (Fig 5). The maximum production was recorded between the temperature of 32.6 and 34.4^{o}C. *Azolla* strains have been found to grow at temperatures of 40° C or higher and it was not a problem in *Azolla* production if supply of sufficient nutrient is maintained (Cary and Weerts, 1992). It was also reported that, the temperature of *Azolla* growing water pools temporarily exceeds 40^{o}C in the noon in summer, particularly in ponds or pools that are small and shallow (Uheda *et al*. 1999). However, in the present study the *Azolla* becomes visible dead after experiencing the very high sudden maximum air and water temperature of above 35.2 and 36.5^{o}C, respectively (Plate 2).

4. CONCLUSION

Temperature plays a vital role in the production of fodder *Azolla*. As a result of this study, it is proved that during summer season, cultivation of *Azolla* in artificial pools gave a good green and dry biomass yield up to the maximum air temperature of 33.74°C, minimum temperature of 22.81 °C and water temperature of 34.4 °C.

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REFERENCES

1. Anitha, K.C., Rajeshwari, Y.B., Prasanna, S.B and Shilpa Shree, J. 2016. Nutritive evaluation of Azolla as livestock feed. Journal of Experimental Biology and Agricultural Sciences. 4(6): 670-674. DOI: http://dx.doi.org/10.18006/2016.4(Issue6).670.674
2. Aziz, A. 2012. New method of large-scale production of Azolla pinnata var. pinnata R. Brown: A multipurpose crop. International Journal of Applied Agricultural Research 7(1): 1-9
3. Cary, P. R. and Weerts, P. G. J. 1992. Growth and nutrient composition of Azolla pinnata R. Brown and A. filiculoides Lam. as affected by water temperature, nitrogen and phosphorus supply, light intensity and pH. Aquatic Botany. 43: 163-180.
4. Chatterjee, A., Sharma, P., Ghosh, M.K., Mandal and M. P.K. Roy. 2013. Utilisation of Azolla microphylla as feed supplement for crossbred cattle. International Journal of Agriculture and Food Science Technology. 4: 207-214
5. Cherry, D.M., Prasad, R.M.V., Rao, J.S., Jayalaxmi, P and Kumar, D.S. 2014. A study on the nutritive value of Azolla pinnata. Livestock Research International 2: 13-15.
6. Ferentinos, L., Smith, J and Valenzuela, H. 2002. Azolla: Green manure crop. In: Sustainable Agriculture in Hawaii. University of Hawaii, Manoa, USA
7. Fernandez-Zamudio, R., García-Murilloa, P and Cirujano, S. 2010. Germination characteristics and sporeling success of A. filiculoides Lam., an aquatic invasive fern, in a Mediterranean temporary wetland. Aquatic Botany. 93, 89-92.
8. Kannaiyan, S and Somporn, C. 1989. Effect of high temperature on growth, nitrogen fixation, and chlorophyll content of five species of Azolla Anabaena symbiosis. Biology and Fertility of Soils 7 (2): 168-172. https://doi.org/10.1007/BF00292577
9. Kannaiyan, S. 2002. Biotechnology of Biofertilizer. Kluwer Academic Publishers, ISBN: 978-1-4020-0219-9, India.
10. Krock, T., Alkamper, J and Watanabe, I. 1988. Temperature regime of Azolla under Rice. Journal of Agronomy and Crop Science. 161(5): 316-321. https://doi.org/10.1111/j.1439-037X.1988.tb00675.x

11. Liu, X., Min, C., Xia-Shi, L. and Chungchu, L. 2008. Research on some functions of Azolla in CELSS system, Acta Astronautica, 63(7):1061-1066 doi: 10.1016/j.actaastro.2008.03.001
12. Mathur, G. N., Sharma, R and Choudhary, P. C. 2013. Use of Azolla (Azolla pinnata) as cattle feed Supplement. Journal of Krishi Vigyan, 2(1): 73-75
13. Meena, G.S., B.L. Dhaka, B. Singh, R.K. Meena and Meena, K.C. 2017. Effect of Azolla as Feed supplement on milk yield in buffaloes. International Journal of Current Microbiology and Applied Sciences. 6(12): 3490-3494 https://doi.org/10.20546/ijcmas. 2017.612.406
14. Pullin, R. S. V. and Almazan, G. 1983. Azolla as a fish food. ICLARM Newsletter, 6 (1): 6 -7.
15. Rex Immanuel, R., Thiruppathi, M., Sudhagar Rao, G.B., Vigil Anbiah, S and Chitharanjan, S. 2019. Agronomic effectiveness of enriched farm yard manure (EFYM) on biomass productivity of fodder Azolla. International Journal of Research and Analytical Reviews. 6(1):464-472. http://doi.one/10.1729/Journal.19319
16. Sadeghi, R., Zarkami, R., Sabetraftar, K and Van Damme, P. 2013. A review of some ecological factors affecting the growth of Azolla spp. Caspian Journal of Environmental Sciences. 11(1): 65-76
17. Sadeghi, R., Zarkami, R., Sabetraftar, K. and Van Damme, P. 2012. Use of support vector machines (SVMs) to predict distribution of an invasive water fern Azolla filiculoides (Lam.) in Anzali wetland, southern Caspian Sea, Iran. Ecological Modelling. 244: 117–126.
18. Shukla, M. A., Bhattacharyya, P. K., Shukla, D., Roy, B. Yadav and Sirohi, R. 2018. Effect of Azolla feeding on the growth, feed conversion ratio, blood biochemical attributes and immune competence traits of growing turkeys. Vetirnary World. 11(4): 459–463. doi: 10.14202/vetworld.2018.459-463
19. Speelman, E.N., Van Kempen, M.L., Barke, J., Brinkhuis, H., Reichart, G.J., Smolders, A.J.P., Roelofs, J.G.M., Sangiorgi, F., De Leeuw, J.W., Lotter, A.F. and Sinninghe Damste, J.S. 2009. The Eocene Arctic Azolla bloom: environmental conditions, productivity and carbon drawdown. Geobiology. 7: 155–170.
20. Uheda E., S. Kitoh and N. Shiomi, 1999. Response of six Azolla species to transient high-temperature stress. Aquatic Botany 64: 87-92
21. Watanabe, I and Berja, N. S. 1983. The growth of four species of Azolla as affected by temperature. Aquatic Botany. 15(2): 175-185. https://doi.org/10.1016/0304-3770(83)90027-X

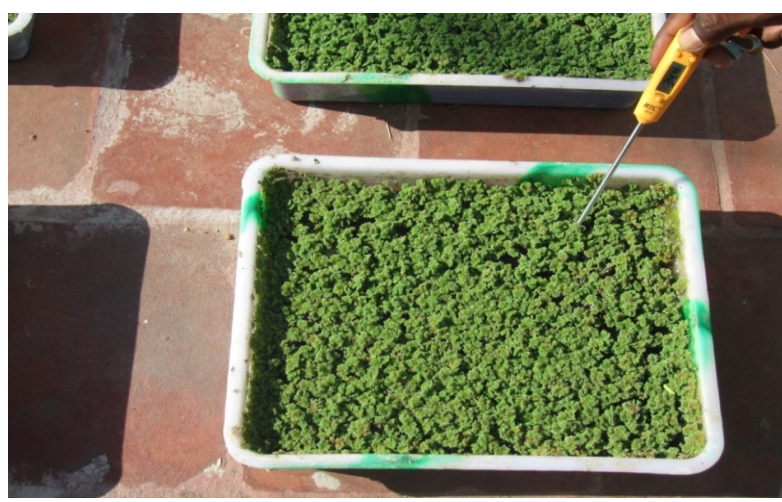

Plate 1 Good *Azolla* growth under optimum temperatures

Plate 2 Dead *Azolla* due to sudden increase in air and water temperature