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Impact of climate on biomass production of *Azolla* in Bihar

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ABSTRACT

Widely cultivated in the Asian regions, *Azolla* is either incorporated into the soil before rice transplanting or grown as a dual crop along with rice. To examine the feasibility of its use in flooded rice fields, the study was conducted during 2011-13 with 9 different species/strains of *Azolla* at BAU Sabour, to study the growth-development dynamics and the resistance/tolerance to extreme temperature which generally occurs in the area. *Azolla* biomass increased during February- April but suddenly decreased during May-June and again increased during July-September thereafter, biomass decreased during October-January. The correlation coefficient between biomass growth rate of strains *A. faliculoides*, *A. microphylla* and *BAUAS-1* of *Azolla* and maximum temperature was found significantly positive. Significant positive correlation between biomass production of species *A. faliculoides* and strain *BAUAS-1* with minimum temperature was found 0.70 and 0.62 respectively, which indicates that increase in minimum temperature up to limit, may increase the growth rate in these strain/spp. There was significant negative correlation (0.70, 0.63 and 0.68) between biomass production rate and relative humidity measured at morning, in the species/strain *A. rubra, BAUAS-1, BAUAS-2* respectively. Biomass production rate of azolla species *A. pinnata* showed significant negative correlation with relative humidity at evening. Significant positive correlation between biomass production and rainfall during the growth period in species *A. faliculoides* was found, which indicates rainfall or sufficient water increases the growth in *Azolla*.

Key words: *Azolla*; biomass production; temperature; rainfall; relative humidity; interactions

The aquatic pteridophyte, *Azolla* is an excellent biofertilizer and green manure having global distribution. Ability of *Azolla-Anabaena* system to fix atmospheric nitrogen at faster rates makes it an outstanding agronomic choice for the cultivation of rice under tropical conditions. Very low water depths might slow down the growth and hence reduce its biomass production (Biswas *et al.,* 2005). Temperature is one of the most important factors determining growth rates of free floating macrophytes in the field (Van Der Heide *et al.,* 2006). A very high (above 30°C) or very low temperature (below -4°C) play an inhibitory role in the growth of *Azolla* (Fernandez-Zamudio *et al.,* 2010). The optimum temperature range for *Azolla* growth has been shown to be between 18 and 28°C (e.g. Tuan and Thuyet, 1979). Different *Azolla* species, strains or varieties have different temperature sensitivities (Uheda *et al.,* 1999). At relative humidity of less than 60%, *Azolla* becomes dry and fragile (Bocchi and Malgioglio, 2010). Sadeghi *et al.,* (2013) demonstrated that when the air humidity exceeds 80%, the prevalence of *Azolla* would be low. Mean relative humidity for allowing *Azolla* growth was estimated at 55-83% (Lumpkin and Bartholomew, 1986) and it was in the range of 65-75% based on the study of Biswas *et al.,* (2005) in Indian condition. However, according to the latter authors, for optimum *Azolla* growth and biomass production, high temperature, high humidity and low water depth may not be good conditions in particular during the dry season. When the weather is completely dry, the fern dies (Biswas *et al.,* 2005). Therefore, *Azolla* needs enough humidity in order to have successful growth and multiplication. The length of the growing season and day length are other climatic factors which regulate production of aquatic plants. Biomass production and growth of *Azolla* are also dependent on the specific growing season. Agriculture can play a significant role in the reduction of greenhouse gases, particularly for CO_2 if the rice farmers can increase the soil stable organic matter and treat agricultural soils as powerful carbon sinks. In order to make use of the *Azolla* fern as a practicable Biofertilizer in rice fields in India , research is required for identifying fern strains with good resistance to high summer temperature and to alternating day/night temperatures before the rice sowing period, and to be able to produce the needed

Table 1: Mean temperatures, relative humidity and rainfall during the experimental period (pooled data of 2011-12 & 2012-13)

Time period	Maximum temperature (°C)	Minimum temperature (°C)	Morning relative humidity (%)	Evening relative humidity(%)	Rainfall (mm)
February	25.8	9.9	82.2	42.2	1.4
March	31.5	14.5	71.1	37.2	20.1
April	34.6	20.7	70.2	44.4	45.5
May	35.9	23.4	73.5	51.0	60.5
June	34.8	24.8	81.5	62.7	182.5
July	32.2	25.1	88.5	77.0	219.5
August	31.3	25.5	89.8	78.5	299.5
September	30.9	24.9	89.9	79.7	127.7
October	31.3	20.9	88.5	66.7	41.1
November	27.3	13.9	90.1	56.0	7.4
December	21.1	9.4	95.2	69.1	0
January	20.6	7.2	90.9	61.4	8.9

quantities to be incorporated in the soil. Therefore, the study was carried out aimed at comparing different *Azolla* strains, analysing the growth rate of their biomass before the sowing of rice to evaluate it as rice Biofertilizer

MATERIALS AND METHODS

The experiment was carried out to evaluate 9 species/ strains through growth analysis at Bihar Agricultural University, Sabour. Tanks were arranged in three replicates per species/strain and set in a completely randomized block design. 30 g of *Azolla* were introduced into each tank and the fresh weight was measured at interval of 30 days in the months of February to March during 2011-12 and 2012-13. Before weighing, the *Azolla* was dried with blotting paper. During the entire period, the water lost through evapo-transpiration was replenished every day with water and the nutrient content in the solution was continuously controlled and maintained at a constant level. Observations of morphological variation were carried out to associate the relevant data to the increase of biomass.

RESULTS AND DISCUSSION

Biomass production

Increase in the growth rate measurements are important in the estimation of the amount of *Azolla* required to inoculate rice paddies and to provide a sufficient nitrogen contribution (25–30 kg ha^{-1}). The calculation of growth rate allowed us to determine the amount of inoculums required to allow complete coverage of flooded paddies by the time of rice sowing. *Azolla* biomass increased during February- April but suddenly decreased during May-June and again increased during July-September thereafter biomass decreased during October-January (Table 2). The decrease of the biomass during May-June may be due to high temperature and less rainfall during period. Increase in the biomass of *Azolla* during July-August may be due to more rainfall and less evaporation of the water which may have provided sufficient moisture for growth. The decrease of biomass production during October-January may be due to very low temperature and less sunshine hours during the period. Insufficient rainfall during the period may have reduced the growth of biomass.

Correlation between biomass growth rate Azolla and weather parameters

Temperature and biomass increase were significantly correlated for some strains whereas the correlation index for some strains were lower and not significant. The correlation coefficient between biomass growth rate of strains *A. faliculoides*, *A. microphylla* and *BAUAS-1* of *Azolla* and maximum temperature was found significantly positive 0.58, 0.65 and 0.83 respectively. In the *BAUAS-1*, it was highly significant which indicates that if maximum temperature increase in growing period, the growth of the biomass production may also increase up to certain limit. In rest of the species, there was no significant correlation though it is

Table 2: Variation in biomass production of different strains/species of *Azolla* (g kg^{-1} day^{-1}) (pooled data of 2011-12 & 2012-13)

Different strains of Azolla spp.	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan
A. Caroliniana	278.6	309.7	293.0	124.1	125.7	236.4	250.9	304.0	298.4	315.2	160.3	172.9
A. Faliculoides	211.0	249.3	217.6	184.5	224.3	248.6	272.1	319.2	220.2	168.5	130.6	145.1
A. maxicana	170.1	274.6	245.4	123.2	145.7	211.9	252.6	235.6	192.6	202.8	149.5	144.4
A. microphylla	320.8	390.1	356.5	244.0	286.4	303.6	313.7	316.7	314.7	299.6	156.4	154.6
A. pinnata	137.4	59.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
A. rubra	305.7	343.5	260.1	250.7	186.2	214.3	238.9	249.7	202.5	168.8	148.9	134.2
BAUAS-1	342.2	341.4	357.1	366.6	322.0	274.1	301.5	355.6	356.5	254.8	168.3	136.7
BAUAS-2	282.5	278.9	327.9	308.5	137.2	174.4	243.4	256.7	247.9	193.3	169.9	147.5
BAUAS-3	267.0	348.9	295.5	144.9	157.6	209.9	277.8	269.1	159.5	182.1	140.9	136.1

Table 3: Correlation between biomass growth rate and different weather parameters in *Azolla* (pooled data of 2011-12 & 2012-13)

Different strains/spp. of Azolla	Maximum temperature	Minimum temperature	Morning relative humidity	Evening relative humidity	Rainfall
A. Caroliniana	0.054	-0.009	-0.060	-0.143	-0.124
A. Faliculoides	0.580*	0.704*	-0.152	0.301	0.624*
A. maxicana	0.290	0.279	-0.212	-0.004	0.284
A. microphylla	0.651*	0.445	-0.551	-0.310	0.217
A. pinnata	-0.190	-0.434	-0.274	-0.583*	-0.333
A. rubra	0.472	0.554	-0.701*	-0.523	0.016
BAUAS-1	0.828**	0.624*	-0.634*	-0.269	0.189
BAUAS-2	0.465	0.195	-0.677*	-0.496	-0.175
BAUAS-3	0.297	0.149	-0.474	-0.313	0.154

*Significant at 0.05 level of significance ** Significant at 0.01 level of significance

positive, except *A. pinnata*. It was found significant positive correlation between growth rate of biomass production of species *A. faliculoides* and stain *BAUAS-1* with minimum temperature, 0.70 and 0.62 respectively which indicates that increase in minimum temperature may increase the growth rate of biomass production of these strain/spp. There was significant negative correlation (0.70, 0.63 and 0.68) between biomass production rate and relative humidity measured at morning in the species/strain *A. rubra, BAUAS-1, BAUAS-2* respectively. Biomass production rate of *Azolla* species *A. pinnata* showed significant negative correlation with relative humidity. In other species/strains, negative correlation with evening relative humidity, though statistically non-significant. When the relative humidity increased more than 75 % in most of the months in the morning, the *Azolla* biomass growth showed negative correlation with the relative humidity. High humidity increased more diseases and insect pest attack on *Azolla* beyond the maximum limit of relative humidity, which may have reduced biomass growth during high humidity period. It was found significant positive correlation between biomass production rate and rainfall during the growth period in species *A. faliculoides* which means that increase in rainfall water may increase the growth of the biomass of this species.

CONCLUSION

Biomass of the *Azolla* increased in the month of July and August and reduced during May-June and October-January. The correlation coefficient between biomass growth rate of strains *A. faliculoides*, *A. microphylla* and *BAUAS-*

1 of *Azolla* and maximum temperature was found significantly positive. Significant positive correlation between biomass production of species *A. faliculoides* and strain *BAUAS-1* with minimum temperature was found respectively which indicates that increase in minimum temperature up to limit may increase the growth rate in these strain/spp.

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