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MODIFIED HOMESTEAD METHOD OF AZOLLA CULTIVATION : A NOVEL LOW-COST FARMING METHOD

Bikram Borkotoki[1], Banashree Sarma[2], Kishore K. Sarma[3], Prabal Saikia[4], Arup K. Sarma[5], Ranjita Bejbaruah[6], Nandita Baruah[7], Lakshi K. Nath[8] and Namita Dutta[9]

ABSTRACT

***Azolla* contains ten times more nitrogen (5% N) than farmyard manure (0.5% N); despite the fact, the existing homestead method of *Azolla* cultivation is not popular amongst the farmers of Assam, India mainly because of *Azolla* mortality due to sun scorching and pests' infestation. Moreover, *Azolla* farmers use chemical fertilizers and insecticides that make *Azolla* unfit for organic farming. To address these issues, an experiment was carried out during the year 2016-17 and 2017-18 at the Regional Agricultural Research Station, AAU, North Lakhimpur, Assam, India, in poly pits with two commonly grown *Azolla* species *viz*. *Azolla pinnata* and *Azolla caroliniana* with three levels of nutrient sources *i.e.*, organic, inorganic, and only soil (control) under two conditions *viz*., open and shaded under *Cajanus cajan* plantations along with a net cover. Among the growth conditions, covered and shaded conditions (The modified homestead method) recorded significantly lower Doubling Time (DT), and higher Relative Growth Rate (RGR) compared to the open conditions. Among the sources of the nutrients, chemical fertilizers followed by organic nutrients showed higher RGR and lower DT than that of control. Both the *Azolla* species showed the highest yield, RGR, and lowest DT in pre-monsoon season irrespective of the nutrient sources. Although chemically fertilized modified homestead method was found to be more advantageous for *Azolla* production in terms of economics, conversion of the farmers' practice to organic practice under modified homestead method also gave higher Benefit-Cost ratios. Thus, *Azolla* can easily be promoted for organic farming for compost production or as a biofertilizer under the modified homestead method.**

(Key words : *Azolla*, shade -net, RGR, DT, modified homestead method)

INTRODUCTION

Azolla, a freshwater free-floating aquatic fern (Watanabe and Berja, 1983; Semwal *et al.*, 2016; Potdukhe *et al.,* 2020), has a symbiotic association with the N-fixing algae *Anabaena azollae* (Kitoh and Shiomi, 1991). Besides being extensively used as N bio-fertilizer (Gowda *et al.,* 2004), *Azolla* has also been used as a water purifier (Shiomii and Kitoh, 1987; Bennicellia *et al.,* 2004), animal feed (Cagauan and Pullin, 1991; Anitha *et al.*, 2016, Akhud *et al.,* 2017) and biological herbicide (Biswas *et al.*, 2005; Yadav *et al.*, 2014). It accumulates minerals and nutrients from the water, and soil application supplies these nutrients to plant in available forms (Debusk and Reddy, 1987). Nevertheless, *Azolla* application as a biofertilizer requires a bulk amount of fresh biomass (Lumpkin and Plucknett, 1982). This high rate (0.5-1.0 t ha^{-1}) of application and the highly perishable nature of *Azolla* are the major constraints for its application as a bio-fertilizer. Moreover, *Azolla*, being succulent biomass, attracts insect pests. A broad range of insect fauna is reported to be associated with *Azolla* in different countries (Takara, 1981; Sasmal and Kulshrestha, 1984; Calilung and Lit, 1986; Sands and Kassulke, 1986; Fannah, 1987; Roberts *et al.*, 1998; Hill, 1998). The local farmers of the Northeast region of India are acutely facing two problems that limit *Azolla* cultivation,

1. Jr. Scientist, AICRP for Dryland Agriculture, Biswanath College of Agriculture, AAU, Biswanath Chariali -784176, Assam
2. Res. Associate, Dept. of Environmental Science, Tezpur University, Tezpur-784028, Assam
3. Professor, Dept. of Plant Breeding and Genetics, AAU, Jorhat-785013, Assam
4. Chief Scientist, Regional Agricultural Research Station, AAU, North Lakhimpur-787001, Assam
5. Asstt. Professor, Dept. of Entomology, Biswanath College of Agriculture, AAU, Biswanath Chariali -784176, Assam
6. Jr. Scientist, HRS, Kahikuchi, AAU, Guwahati- 781017, Assam
7. Asstt. Professor, Dept. of Soil Science, Biswanath College of Agriculture, AAU, Biswanath Chariali -784176, Assam
8. Subject Matter Specialist, Krishi Vigyan Kendra, Lakhimpur- AAU, North Lakhimpur- 787032, Assam
9. Subject Matter Specialist, Krishi Vigyan Kendra, Sonitpur, AAU, Napam, Tezpur-784028 Assam

(1) sun scorching of *Azolla* due to lack of shade (Zimmerman, 1985) and (2) mortality of *Azolla* due to eating by the insects (Rice Knowledge Bank, 2020). To overcome the eating of *Azolla* by insects, farmers generally apply Carbofuron 3G in the cultivation pits (Yadav *et al.*, 2014). However, that makes *Azolla* very toxic and cannot be used as animal feed. Also, chemical fertilizers such as Muriate of Potash (MOP) and Single Super Phosphate (SSP) are generally applied in *Azolla* pit as nutrient supplements (Changkakoty, 2001), thus, making it unfit for organic farming. Considering these on-farm difficulties, this paper aims at developing a method that sustainably solves the identified problems associated with Azolla in the agro-ecological conditions of Assam, India, particularly for poor and marginal farmers. To access the suitability of the method, ten days average yield, doubling time, relative growth rate and nutrient content of two commonly cultivated *Azolla* (*Azolla pinnata* and *Azolla caroliniana*) were compared under existing and modified homestead method with the application of both organic and inorganic fertilizers as *Azolla* doubles its biomass in 3-10 days (Pullin and Almazan, 1983).

MATERIALS AND METHODS

The experiment was carried out during 2016-17 and 2017-18 at the Regional Agricultural Research Station, North Lakhimpur, Assam Agricultural University (AAU), India, in poly pits. The *Azolla* species (*Azolla pinnata* and *Azolla caroliniana*) were collected from Assam Agricultural University, Jorhat, and local ponds. They were introduced into the tanks at the rate of 0.3 kg tank$^{-1.}$

Growth conditions

Azolla cultivation, tanks of 1×2×0.2 m were constructed and placed in two environments, namely:

I. Open: Existing homestead method in open space, *i.e., growing of Azolla* in uncovered poly pits

II. Shaded: Modified homestead method, *i.e.*, Construction of frames using locally available bamboos to cover the tanks with nets for preventing litterfall and get rid of *Azolla* eating caterpillars under Arhar (*Cajanus cajan*) shade (planted between the rows of the *Azolla* tanks for providing required shade for the crop). (Plate 1)

During the growth period, the maximum and minimum water temperature (Figure 1) and light intensity (Table 1) were recorded during pre-monsoon (March-May), monsoon (June-September), post-monsoon (October-November) and winter (December-February).

Fertilizers used

Both organic and inorganic fertilizers were used. The inorganic fertilizers used were SSP and MOP. Organic fertilizers included cow dung, P-enriched compost (pH 7.45, Total N 1.4%, Total P 2.89% and Total K 1.93%), banana ash (pH 9.7, Total N 0.02%, Total P 0.2% and Total K 5.8%) and vermiwash (pH 8.16, Total N 2.82%, Total P 7.86% and Total K 7.76%)

Treatment combinations

For the experiment, two factors of treatments were tested; namely, the growth conditions *viz.*, open condition and shaded with Arhar (*Cajanus cajan)* and net cover having three levels of fertilizers in each factor with three replications. The treatment combinations were as followed:

- Open control: Growing Azolla in homestead method after spreading 5 kg fertile soil over the polythene in 10 cm water, *i.e.* homestead method with no fertilizer nutrients
- Shaded control: Growing Azolla in homestead method after spreading 5 kg fertile soil over the polythene in 10 cm water + Arhar shade with net cover, *i.e.* modified homestead method with no fertilizer nutrients
- Open inorganic: Growing Azolla in homestead method with 200 g powdered cow dung + 10 g SSP + 10 g MOP, *i.e.* homestead method with the inorganic source of fertilizer nutrients (existing practice)
- Shaded inorganic: Growing Azolla in homestead method with 200 g powdered cow dung + 10 g SSP + 10 g MOP + Arhar shade with net cover, *i.e.* modified homestead method with fertilizer nutrients.
- Open organic: Growing Azolla in homestead method with 200 g powdered cow dung+ 60 g P-enriched compost + 150 g banana ash + 100 ml concentrated vermiwash, *i.e.* homestead method with an organic source of nutrients.

Shaded organic: Growing Azolla in homestead method with 200 g powdered cow dung + 60 g P-enriched compost + 150 g banana ash+100 ml concentrated vermiwash Arhar shade with net cover, *i.e* modified homestead method with an organic source of nutrients.

Parameters studied:

Observations on *Azolla* growth were taken after the full growth of shaded Arhar plants. For determining biomass productivity, fresh biomass of *Azolla* was harvested after ten days of inoculation, blot dried, and fresh weights were measured (Arora and Singh, 2003). The doubling time (DT) of *Azolla* was calculated as follows (Subudhi and Watanabe, 1981).

$$\text{Doubling time} = \frac{\text{Experimental time}}{r}$$

Where r= log (W_1/W_0)/0.301, W_1= Weight of *Azolla* after t days, W_0= Weight of initial inoculums, 0.301= constant factor

The relative growth rate (RGR) was calculated as follows (Arora and Singh, 2003):

$$\text{RGR} = \frac{0.693}{\text{Doubling time}}$$

The total nutrient content (N, P, and K) of the *Azolla* species were estimated by following the method by Jackson (1973). The crude protein was calculated from total N by multiplying with the factor 6.25 (Ezeagu *et al.,* 2002).

The benefit: cost ratio was computed by dividing the gross income by gross cost over the year.

Pest count

Caterpillars were counted twice a week on the *Azolla* layer in the entire water surface of the unit and its number was converted to sq ft^{-1} (*i.e.* No. of caterpillar observed in the entire water surface of the *Azolla* unit $^{-1}$ area of the water surface in sq. ft.). Snails were also collected twice a week from the water surface as well as from inside the tank; however, its number was converted to sq ft^{-1} basis (*i.e.* No. of snails observed in entire *Azolla* unit^{-1} area of the water surface in sq. ft.) as *Azolla* is floating over the surface. Species variation among caterpillars, if any, was ignored as well for the snails.

Statistical analysis

The mean of all the replications was computed. A factorial, completely randomized design was employed to test the significance of the proposed method concerning the traditional *Azolla* cultivation method.

RESULTS AND DISCUSSION

Ten days average yield of the tested *Azolla spp.* showed the highest value during the pre-monsoon season, and *Azolla caroliniana* showed higher growth than *Azolla pinnata* in all the seasons (Figure 2). Among the fertilizer treatments, inorganic fertilizers recorded higher growth followed by organic and control, while shaded conditions yielded the highest *Azolla* yield than open conditions. (Table 2).

The lowest doubling time was observed during the pre-monsoon season, while winter showed the highest (Figure 3). Among the growth conditions, the shaded condition recorded a significantly lower doubling time compared to the open condition.

Azolla caroliniana recorded a higher RGR compared to *Azolla pinnata* (Figure 4). The highest RGR was noted in the pre-monsoon season and under shaded conditions irrespective of the applied fertilizer. Among the fertilizer treatments, inorganic followed by organic treatments showed higher RGR than that of control plots.

Table three (3) describes the nutrient composition of both the *Azolla* species measured at the end of the experimental period. *Azolla caroliniana* showed a higher concentration of N, P, and K content compared to *Azolla pinnata.* Chemical treatments, irrespective of the shaded or open condition, showed the highest nutrient content. Nevertheless, shaded or open conditions did not have any significant effect on the nutrient content of both the tested *Azolla* species.

The highest caterpillar and snail infestation was observed in the monsoon season and the lowest was observed in winter (Table 4 and 5). Shaded treatments (Arahar shead+ net cover) significantly decreased pest infestation. In open- organic condition, pest infestation was significantly less in organic treatments at all the seasons compared to the rest. In shaded conditions, though it was supposed to be completely free from insects, very few insects could manage to find their room inside the nets. But, unlike open conditions, no such significant differences amongst the treatments have been observed. Conversely, shaded treatments (Arahar shead+ net cover) completely checked the sail infestation in all the seasons.

The benefit:cost ratio for the best *Azolla* species, i.e., *Azolla caroliniana,* was studied under all the treatment combinations to study the economics (Table 6). The economic study was carried out for two years, and projected data was computed for the next three years. It was observed that shaded conditions yielded more biomass than open conditions, and the application of inorganic fertilizers showed higher economic benefits than that of the organic treatment. The modified homestead method was also tested in the farmers' field of Lakhimpur and Sonitpur district of Assam, India in comparison to the farmers practice with the satisfactory outcome (Plate 2).

The study of the RGR indicated that shaded conditions yielded more Azolla biomass than open conditions. This could be attributed to the fact that *Azolla*, being a shade-loving plant, needs only 25-50% of full sun for normal growth (Liu *et al.,* 2008). The shade net under Arhar plantations makes the environment conducive for *Azolla* growth by cutting down around 40% of the light falling on the pit (Table 1). The reduction in the doubling time also could be attributed to the reduced intensity of light. Moreover, the increased ten days average yield indicated higher growth of *Azolla* under the modified method. This was due to its protective cultivation under shade nets; thus, it was not easily assessable to its insect pests (Plate 1). The shaded inorganic condition also yielded more *Azolla* biomass than open conditions in On-Farm Trails (OFTs) conducted at farmers' field of Sonitpur and Lakhimpur districts of Assam (Plate 2).

The application of inorganic fertilizers resulted in higher growth of *Azolla* than control, and organically fertilized plots. This could be attributed to the readily available nutrients, particularly P and K supplied by the inorganic fertilizers (Cohn and Renlund, 1953; Changkakoty, 2001). Therefore, inorganically fertilized treatments had resulted in a higher amount of total N, P, and K content than organic plots making it suitable for use as bio-fertilizer in fields. However, organic treatments significantly reduced the pest infestation of Azolla might be due to the pest repellent property of vermiwash.

Among the two studied *Azolla* species, *Azolla pinnata* showed lesser growth and nutrient content compared to *Azolla caroliniana* (Manna and Singh, 1990). Therefore, the economic feasibility of only *Azolla caroliniana* was only studied. The benefit-cost ratio indicated that the application of inorganic fertilizers had a better economic profit than organic, which is attributed to the higher cost of organic fertilizers than inorganic fertilizers. Also, the shaded condition gave higher economic benefits than the open condition because of the dual benefit of integrated farming of Arhar and *Azolla*. In all cases, projected B: C dropped in the 4th year due to the estimated repairing of bamboo frames and possible replacement of plastic sheets, if needed.

The overall study concludes that compared to the framers' practice of homestead method of Azolla cultivation in open condition, modified homestead method with arhar shed and net cover with inorganic fertilizers give higher yield and better nutrient content along with higher economic benefits of Azolla cultivation. Hence, the recommended fertilizer practice with this modified shed type is more advantageous for *Azolla* production. Although chemically fertilized modified homestead method was found to be more advantageous for *Azolla* production in terms of economics, conversion of the farmers' practice to organic practice under modified homestead method also gave higher Benefit:Cost ratios (B: C ratios >5 in 2nd, 3rd, and 5th year). Thus, *Azolla* can easily be promoted for organic farming for compost production or as a biofertilizer under the modified homestead method. Furthermore, *Azolla* grown in modified homestead method was free from insecticides unlike openly cultivated *Azolla* and, therefore, might also be promoted as animal/ poultry feed. Additional income might be generated from Arhar plantations in the modified homestead method.

Table 1. Average light intensity (µmole $m^{-2} s^{-1}$) in sunny days (Reading time 1 pm)

	Pre-monsoon	Monsoon	Post-monsoon	Winter
Shaded	1535.75	1655.51	1210.08	992.84
Open	2172.62	2307.6	1698.38	1390.51
Reduction in light transmission under shade (%)	41.47	39.39	40.35	40.05

Table 2. Interaction effect of shade and nutrients on *Azolla* production

Treatments	Pre-monsoon (Mar-May)		Monsoon (Jun-Sept)		Post-monsoon (Oct-Nov)		Winter (Dec-Feb)	
	Azolla pinnata	***Azolla caroliniana***	***Azolla pinnata***	***Azolla caroliniana***	***Azolla pinnata***	***Azolla caroliniana***	***Azolla pinnata***	***Azolla caroliniana***
	10 days average yield in g							
OC	734.69	1017.98	419.63	581.44	530.76	735.40	381.72	528.91
OO	940.53	1766.94	537.21	1009.23	679.46	1276.47	488.67	918.05
OI	962.95	1993.16	550.01	1138.44	695.65	1439.903	500.32	1035.59
SC	770.36	1087.27	440.01	621.02	556.52	785.46	400.26	564.91
SO	962.95	1855.59	550.01	1059.87	695.65	1340.52	500.32	964.11
SI	996.58	2043.09	569.22	1166.96	719.95	1475.97	517.79	1061.53
SE(m)±	2.44	9.93	1.39	5.67	1.76	7.17	1.27	5.16
CD (0.05)	7.60	30.93	4.34	17.68	5.49	22.35	3.94	16.08

OC= Open Control, OO= Open Organic, OI= Open Inorganic, SC= Shaded Control, SO=Shaded Organic, SI= Shaded Inorganic

Table 3. Composition of major nutrients in *Azolla* with different nutrient compositions

Treatments	N		P		K	
	%					
	Azolla caroliniana	***Azolla pinnata***	***Azolla caroliniana***	***Azolla pinnata***	***Azolla caroliniana***	***Azolla pinnata***
OC	3.923	3.233	0.306	0.213	2.803	2.073
SC	3.936	3.200	0.303	0.218	3.013	2.106
OI	5.193	4.156	0.523	0.483	4.230	3.260
SI	5.146	4.100	0.518	0.496	4.233	3.196
OO	4.700	3.803	0.393	0.344	3.473	2.526
SO	4.686	3.830	0.404	0.346	3.490	2.530
SE(m)±	0.016	0.024	0.004	0.005	0.096	0.017
CD (0.05)	0.051	0.075	0.012	0.016	0.298	0.053

OC= Open Control, SC= Shaded Control, OI= Open Inorganic, SI= Shaded Inorganic, OO= Open Organic, SO= Shaded Organic

Table 4. Seasonal infestation of caterpillar (no. of caterpillar sq ft^{-1} of water surface)

Treatments	Pre-monsoon (Mar-May)		Monsoon (Jun-Sept)		Post-monsoon (Oct-Nov)		Winter (Dec-Feb)	
	Azolla pinnata	*Azolla caroliniana*	*Azolla pinnata*	*Azolla caroliniana*	*Azolla pinnata*	*Azolla caroliniana*	*Azolla pinnata*	*Azolla caroliniana*
O C	11.33	10.67	14.67	15.33	12.33	11.33	7.33	9.33
O O	9.88	9.33	10.67	12.67	9.33	9.67	8.00	8.33
O I	11.00	11.67	12.33	14.33	11.33	12.33	9.33	9.31
S C	2.00	1.33	1.67	0.67	1.33	1.00	0.67	1.00
S O	0.67	2.67	1.33	0.67	0.33	0.67	0.33	0.33
S I	1.33	2.67	1.33	1.67	1.00	2.00	0.67	0.67
SE (m)±	0.36	0.67	0.53	0.33	0.51	0.59	0.41	0.30
CD (0.05)	1.12	2.08	1.64	1.04	1.59	1.85	1.27	0.95

OC= Open Control, OO= Open Organic, OI= Open Inorganic, SC= Shaded Control, SO=Shaded Organic, SI= Shaded Inorganic

Table 5. Seasonal infestation of snail (no of snail sq ft^{-1} of water surface)

Treatments	Pre-monsoon (Mar-May)		Monsoon (Jun-Sept)		Post-monsoon (Oct-Nov)		Winter (Dec-Feb)	
	Azolla pinnata	*Azolla caroliniana*	*Azolla pinnata*	*Azolla caroliniana*	*Azolla pinnata*	*Azolla caroliniana*	*Azolla pinnata*	*Azolla caroliniana*
O C	19.00	19.67	24.67	25.33	19.67	17.00	13.33	12.67
O O	15.67	17.00	21.33	20.33	17.67	15.67	12.00	10.67
O I	17.33	18.33	23.00	22.33	19.33	17.67	12.78	12.33
S C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
S I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SE(m)±	0.30	0.19	0.30	0.47	0.23	0.19	0.21	0.23
CD (0.05)	0.95	0.60	0.95	1.47	0.73	0.60	0.66	0.73

OC= Open Control, OO= Open Organic, OI= Open Inorganic, SC= Shaded Control, SO=Shaded Organic, SI= Shaded Inorganic

Table 6. Benefit:Cost ratio for *Azolla caroliniana*

	Growing Conditions			
	Inorganic		Organic	
Year	Shaded	Open	Shaded	Open
1st	1.03	1.43	0.91	1.24
2nd	6.67	2.45	5.86	2.13
3rd	6.67	2.45	5.86	2.13
4th*	2.34	2.45	2.08	2.13
5th*	6.67	2.45	5.86	2.13

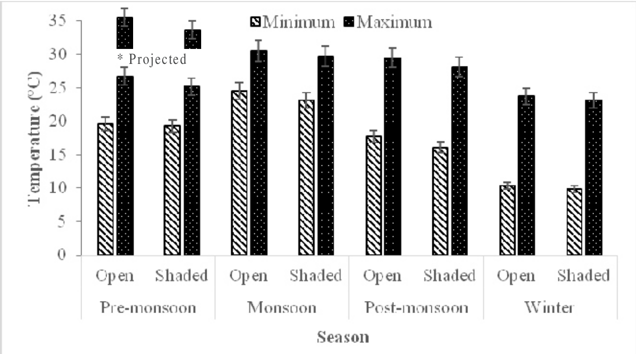

Fig.1. Average maximum and minimum the temperature during the experimental period

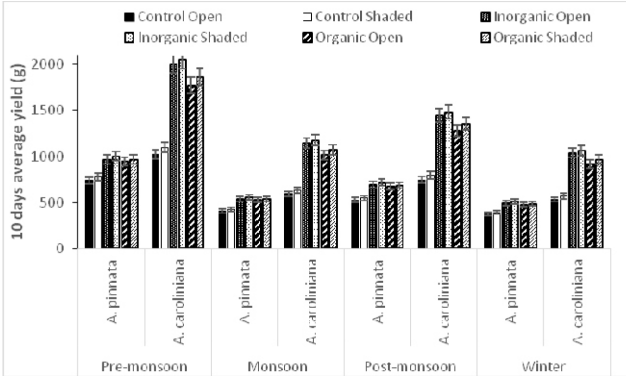

Fig. 2. Ten day's average yield of *A. pinnata* and *A. carolinia* in various seasons

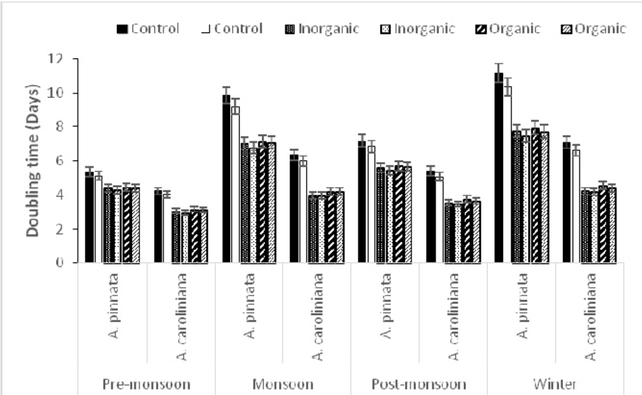

Fig. 3. Doubling time of *A. pinnata* and *A. caroliniana* in various seasons

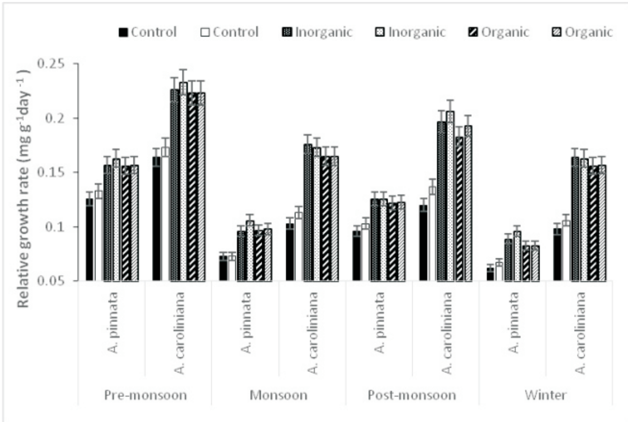

Fig. 4. Relative growth of *A. pinnata* and *A caroliniana* in various different seasons

Plate.1 Azolla grown in modified homestead method at RARS, AAU, North Lakhimpur

Plate 2. Performance of modified homestead method (left) over existing method (right) at farmers' filed of Lakhimpur district

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