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ADAPTATION OF SOME AZOLLA GENOTYPES TO THE AEGEAN ECOLOGICAL CONDITIONS IN WESTERN PART OF TURKEY

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ABSTRACT

The objective of this study was to determine the adaptation of some azolla genotypes to Aegean ecological conditions in the western part of Turkey. A research was carried out in the Research Field of the Aegean University, Faculty of agriculture, Izmir-Menemen during 2002-2003 and 2003-2004. Thirteen genotypes belong to the Species, *A. caroliniana, A. microphylaa, A. filicloides* and *A. pinnata var. Pinnata,* obtained from IRRI and two azolla species, *A. Filicloides and A.mexicana,* adapted to Aegean conditions were used in the experiment. The results of the study showed that the genotypes FI-1040 and MI-4030 could be adaptable to the Aegean ecological conditions. Their fresh weight increased 222.4 % and 221.8 % m^{-2} and they had dry weight values 67.8 g m^{-2} and 8.2 g m^{-2}, respectively. The fresh weight values of these genotypes were approximately 230 ton/ha, whereas, the annual dry matter production reached to 16.0 ton/ha.

Key Words: Azolla specie, fresh weight, dry weight

INTRODUCTION

Azolla (*Azolla anabaena*) is known as an aquatic fern which lives on the water surface of rice fields, small ponds and rivers. Azolla covers the water surface quickly and is situated harmoniously under the canopy of rice plants without affecting its growth. Generally azolla reproduces asexually by splitting and often sexually. The size of the fern varies between 1-5 cm and there are lops observed on its leaves. The blue-green algae *Anabaena azollae* lives on the leaves of azolla and a symbiotic association is characterized in terms of nitrogen fixation. *Anabaena azollae* is stated as able to fix 3-5 kg N per day under favorable conditions. Taking advantages of the nitrogen fixing blue-green algae, Azolla can double its weight within 3-5 days (Ashton, 1971; Talley et al., 1977; Venture and Watanabe, 1990).

As a result of its nitrogen fixation ability and high nitrogen content, azolla has been used as a green manure and resource of organic matter for the wetland rice in northern Vietnam and central China for centuries. About 70 % of N content of azolla is mineralized to NH_4+H after 20 days from symbiosis (Venture et al., 1990). On the other hand, it can be also converted into compost to be used for dry land crops and vegetables. At present, azolla is used in more than a million hectares of rice lands in China. Azolla usage in rice production is also increasing in Philippines. It is estimated that 44 % of rice lands will be fertilized with azolla in near future. Azolla has high protein content, its protein content approximately 2-37 % on dry matter base and it has also been used for animal feeding such as pigs, ducks, and fishes (Hove, 1989; Watanabe et al., 1977; Thomas et al., 1982).

Azolla is known as sensitive to desiccation and the optimum growth temperature is noted as 25°C, however the aquatic fern can tolerate low temperatures up to -5°C (Watanabe et al., 1977). Seven different azolla species are known and four of them are originated from U.S.A. The results of the researches showed that Asia and Ocean originated *A. pinnate* increased 20 % of rice yield when it was used as green manure. On the other hand, the U.S.A. originated species *A. carolina*, *A. filiculoides* and *A. Mexicana* adapted to the temperate ecological conditions increased paddy yield between 23% and 67% (Hove, 1989; Watanabe et al., 1977; Thomas et al., 1982). The advantage of the azolla genotypes are fast growth ability, higher nutrient content and organic matter values and they can be adapted to the temperate ecological conditions. These advantages make azolla a promising green manure for Mediterranean conditions. Also, it is known that *A. filiculoides* is naturally grown in rice production areas of Trakya region in Turkey (Aysel and Gevrek, 2003).

This research aims to evaluate the adaptation and some characteristics of 15 different azolla genotypes, which belong to five different species (*A. caroliniana*, *A. microphylla*, *A. filiculoides*, *A. pinnata var*. *Pinnata*, *A mexicana*) in Aegean ecological conditions in western part of Turkey.

MATERIALS AND METHOD

The study was carried out at Menemen Location (Aegean Region, Western Turkey) during the years 2002-2004.

The azolla material used was 15 different azolla strains were used in the experiment. Thirteen of them were obtained from IRRI (The International Rice Research Institute) and a species from the rice production areas of Turkey. One of them was *azolla mexicana* which adapted to the Aegean conditions (Gevrek et al., 2004), therefore this genotype was used as control in this study. However only five of them could adapt to the ecological conditions of Izmir and survive, thus five different azolla genotypes belonging to four different species (*A. caroliniana*, *A. microphylaa*, *A. filicloides* and *A. pinnata var. pinnata*) created the plant material of the study (Table 1).

Table 1. Information related to azolla genetic material used in the study (Watanabe, et al., 1992, Aysel and Gevrek, 2003)

Variety No.	Species	Code	Characteristics
1	*A. filiculoides*	FI-1040	Highly reproductive by spores
2	*A. caroliniana*	CA-3510	Highly reproductive by spores
3	*A. microphylla*	MI-4030	Nitrogen rate on dry matter is % 4. Highly productive
4	*A. filiculoides*	AF	Adapted to the ecological conditions of Trakya.
5	*A. mexicana*	ME-2026	Highly reproductive by spores and high vegetative growth capacity

Table 2. Average temperatures (° C) and relative humidity (%) values in Izmir in 2002, 2003and 2004.

Years	Average monthly air temperatures (^oC)											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
2002							28,8	28,0	22,4	17,7	13,1	7,9
2003	11,1	4,9	8,6	12,7	21,3	27,2	28,6	28,5	22,5	19,7	13,1	9,5
2004	7,1	8,2	12,2	15,7	20,3	26,5						
Mean	9.1	6.6	10.4	14.2	20.8	26.9	28.7	28.3	22.5	18.7	13.1	8.7
Years	Average relative humidity (%)											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
2002							47,1	47,8	58,7	60,5	65,1	59,5
2003	62,4	60,1	52,1	61,0	52,5	37,5	37,3	38,2	46,9	51,8	62,3	63,6
2004	65,6	55,9	49,2	50,0	48,4	45,1						
Mean	64.0	58.0	50.7	55.5	50.4	41.3	42.2	43	52.8	56.2	63.7	61.6

The experiment was arranged in a 5 x 12 factorial design (genotypes x months) and was repeated for two years. Table 2 shows the average air temperatures and relative humidity of Menemen location.

Fresh azolla plants were inoculated at a rate of 300 g m^{-2} into ponds of 4m x 4m x 4m (16 m^2). Inoculation dates of different genotypes are shown on table 3. The pods were constantly stagnant with a water level of 20 cm. To promote the vegetative growth of azolla plants and nitrogen fixation of Anabaena algae, 0.20 g m^2 of P_2O_5 was applied to the ponds as triple super phosphate (Hove 1989; Khan 1987). The soil texture of the study fields was determined as silty loam.

Fresh azolla plants were collected by hand 14 days after inoculation and fresh weight (g m^{-2}), increasing rate of fresh weight (%) and dry matter (g m^{-2}) were determined.

All data were analyzed by using standard ANOVA techniques of computer program. The means were compared by using the LSD test described by Steel and Torrie (1980).

RESULTS AND DISCUSSION

The differences among the genotypes for fresh weight values were found significant. The average fresh weight of the genotypes was 817.0 g m^{-2} and the highest fresh weight value was obtained from the line MI-4030 (980.0 g m^{-2}) as seen on table 4. The difference between months was found also significant. The highest fresh weight value was recorded in the month March (1045.0 g m^{-2}).

Azolla plant can show high performance between the temperatures 10 and 30°C however, the optimum temperatures for vegetative growth are 20 and 22°C. If the temperatures are below 10°C or over 30°C, the yield decreases. Relative humidity of the air also affects vegetative growth of the plant (Ashton, 1971; Wilbur and Watanabe, 1980). Azolla can grow well under the conditions of 50-60% relative humidity. It is also known that the half of the sunshine duration is enough for vegetative growth of azolla (Hove, 1989). The highest fresh weight values (1045.0 g m^{-2}) were observed in the month March (Table 4) when the mean temperature was 10.4 and the relative humidity was 50.7 % as seen in Table 3.

Table 3. Inoculation dates of the genotypes (2002-3 and 2003-4)

	Months											
Years	1	2	3	4	5	6	7	8	9	10	11	12
2002							08	05	02	07	04	09
2003	06	03	03	07	05	02	07	04	08	06	03	01
2004	05	09	08	05	03	07						

In July, when the mean temperature was high and relative humidity was low, the lowest fresh weight values (576.0 g m^{-2}) were obtained. The results of the study were supported by the findings of some researchers that the fresh weight yield was highly correlated with temperature and relative humidity

Table 4. Fresh weight values (g m^{-2}) of genotypes grown at Menemen location (2002-2004)

	Fresh weight (g m^{-2})					
Months	Genotypes					
	FI-1040	CA-3510	MI-4030	A.F.	ME-2026	Mean
I	1330.0	769.0	1112.0	838.0	694.0	949.0
II	1502.0	719.0	1155.0	843. 0	735.0	990.0
III	1264.0	685.0	1225.0	878.0	1175.0	1045.0
IV	1197.0	648.0	865.0	815.0	779.0	868.0
V	973.0	490.0	768.0	651.0	752.0	719.0
VI	563.0	480.0	783.0	585.0	603.0	602.0
VII	558.0	460.0	724.0	553.0	589.0	576.0
VIII	583.0	590.0	850.0	572.0	889.0	696.0
IX	621.0	665.0	952.0	534.0	979.0	750.0
X	813.0	669.0	1105.0	668.0	1149.0	880.0
XI	1025.0	657.0	1046.0	693.0	916.0	867.0
XII	1191.0	481.0	1178.0	805.0	678.0	866.0
Mean	968.0	609.0	980.0	702.0	828.0	817.0
Annual mean yield	23.232	14.616	23.520	16.848	19.872	19.608
LSD $_{0.05}$	40.296					
Genotype	1502.050**					
Month	527.063**					
Genotype x month	118.550**					

(Ashton, 1971; Wilbur and Watanabe 1980; Hove 1989). In the first five months of the study the genotype FI-1040 and in the second five months the genotypes MI-4030 and ME-2026 were superior for fresh weight whereas, in the last two months of the year the genotypes FI-1040 and MI-4030 showed higher performance. The different characteristics of the genotypes seem to be the reason of the variable yields during the year.

The differences among the genotypes and the months were found to be statistically significant for fresh weight increasing rate. The mean value for all genotypes was 172.0 %, and the highest fresh weight increasing rate was observed for the genotype MI-4030 (224.0 %). When the months are considered, it was seen that the highest values belong to the month March (248.6 %) (Table 5).

Table 5. Fresh weight increasing rates (%) of genotypes grown at Menemen location (2002-2004)

	Fresh Weight increasing rate (%)					
Months	Genotypes					
	FI-1040	CA-3510	MI-4030	AF.	ME-2026	Mean
I	343.8	156.4	270.6	179.4	131.4	215.0
II	400.4	139.9	258.2	181.1	145.2	210.0
III	321.4	128.9	308.3	192.7	291.9	248.6
IV	2991.1	116.1	188.6	171.9	159.6	187.1
V	212.6	63.6	156.2	95.0	150.9	140.1
VI	87.5	60.0	161.0	84.3	101.0	100.9
VII	87.0	53.3	141.4	90.9	96.6	92.5
VIII	94.3	96.7	183.3	78.3	196.5	132.3
IX	106.9	121.7	217.4	122.8	226.5	150.1
X	171.0	123.2	268.4	131.2	238.8	184.8
XI	241.7	90.1	249.0	168.3	205.0	189.1
XII	297.0	119.0	292.9	179.4	126.2	194.9
Mean	221.8	105.7	224.0	134.4	172.3	172.0
LSD $_{0.05}$	17.936					
Genotype	817.215**					
Month	294.644**					
Genotype x month	61.490**					

It is seen on table 5 that the fresh weight rate was recorded as lower in July, when the mean temperature was highest and the relative humidity was lowest. It is remarkable that the fresh weight rate increases with increasing relative humidity. However the genotype ME-2026 has lower fresh weight rate values than the genotypes FI-1040 and AF. in months January, February, March and April, in August, September and October higher fresh weight rates were obtained with this genotype.

The differences among the genotypes and months were found to be statistically significant for dry weight rate. The mean value was 11.3 % (Table 6). The highest dry matter value was obtained with the genotype CA-3510 (16.7 %) and the highest values of dry matter rate (18.4 %) were obtained in the month July (Table 6). With decreasing relative humidity, a decrease in dry weight was also observed during the months (Table 3). In July, the lowest dry matter rate was obtained with the genotype MI-4030 (10.8 g m^{-2}), the highest (30.3 g m^{-2}) with the genotype CA-3510 and a variation among the genotypes was also observed.

The amount of dry matter production for per m^2 was found to be significant for the genotypes and not significant

Table 6. Dry weight rates (%) of genotypes grown at Menemen location (2002-2004)

Dry weight rate (%)						
Months	Genotypes					
	FI-1040	CA-3510	MI-4030	AF.	ME-2026	Mean
I	4.4	11.0	5.6	8.5	11.4	8.2
II	3.7	11.3	5.3	8.5	10.3	7.8
III	4.6	11.7	4.8	7.8	5.1	6.8
IV	5.0	13.2	8.0	8.8	9.4	8.9
V	7.0	25.1	9.6	13.1	9.9	12.9
VI	17.6	25.8	9.3	15.8	14.8	16.6
VII	17.4	30.3	10.8	18.1	15.5	18.4
VIII	14.6	16.2	8.4	17.2	7.7	12.8
IX	13.1	12.4	6.9	19.4	6.6	11.6
X	5.0	12.3	5.6	12.4	5.3	8.8
XI	6.2	17.0	6.0	11.4	7.4	8.7
XII	8.8	12.8	5.1	9.0 C	12.3	9.6
Mean	9.0	16.7	8.5	12.5	9.6	11.3
$LSD_{0.05}$	1.309					
Genotype	817.215 **					
Month	294.644**					
Genotype x month	61.490**					

Table 7. Dry weight values (g m^{-2}) of genotypes grown at Menemen location (2002-2004)

Dry weight (g m^{-2})						
Months	Genotypes					
	FI-1040	CA-3510	MI-4030	AF.	ME-2026	Mean
I	78.7	36.8	69.8	44.1	50.0	55.9
II	85.8	41.7	64.8	43.3	48.6	56.8
III	69.1	40.6	80.1	47.5	63.2	60.2
IV	75.2	37.5	59.6	50.3	52.5	55.0
V	67.9	31.3	59.5	41.8	51.1	50.3
VI	52.9	28.7	70.7	41.1	44.7	47.6
VII	56.6	32.4	59.8	39.6	45.7	46.8
VIII	62.2	38.3	64.9	38.6	56.8	52.1
IX	59.0	38.3	72.9	40.6	64.0	54.9
X	67.7	39.5	70.1	44.6	59.6	56.3
XI	69.9	36.1	66.5	42.3	53.5	53.6
XII	68.2	30.1	79.3	45.4	46.2	53.8
Mean	67.8	35.9	68.2	43.4	53.1	53.6
Annual mean yield	1627.2	816.6	1636.8	1041.6	1274.4	1286.4
$LSD_{0.05}$	5.179					
Genotype	60.142**					
Month	1.801 ns					
Genotype x month	0.821 ns					

for months and months x genotype interaction (Table 7). The dry matter value for per m^2 was noted as 53.6 g in average and the highest values were obtained with the genotypes MI-4030 (68.2 g m^{-2}) and FI-1040 (67.8 g m^{-2}), respectively. The mean dry matter value was between 46.8 and 60.2 g m^{-2} whereas, the lowest production value belongs to the month July (Table 7). The highest value (60.2 g m^{-2}) was obtained in March and February (56.8 g m^{-2}), respectively, and October (56.3 g m^{-2}) followed them. The genotypes FI-1040 and MI-4030 showed higher performance than the genotype ME-2026 between January and June. On the other hand, the genotype MI-4030 produced in September, October, and December higher dry matter was obtained from the genotype MI-4030.

Fresh weight amounts in table 5 and dry matter values in table 7 are noted for 14 days and if the values are multiplied by two, yield for one month can be obtained. If the results are examined it is seen that annual production of MI-4030 brings the fresh weight yield of 235.2 t/ha and the genotype FI-1040 has the annual mean yield 232.3 t/ha. We propose the genotypes MI-4030 and FI-1040 are introduced for azolla production instead of the genotype ME-2026 (198.7 t/ha).

CONCLUSION

Fresh weight, fresh weight rate, dry matter production rate and dry matter amount of five different azolla genotypes were investigated for two years in this experiment. The genotypes, MI-4030 shows a better performance than the genotype ME-2026 can be reported as adapted to the Aegean ecological conditions in the western part of Turkey. It could be proposed that both genotypes can be utilized for azolla production during 12 months of year.

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