Soil Fertility Management

Symbiotic Blue Green Algae (Azolla): A Potential Biofertilizer for Low Land Rice Production at Fogera Plain

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Abstract

Two Azolla strains (*Azolla filiculoides* and *Azolla microphylla*) were introduced from India in 2004. They were maintained and multiplied in plastic containers at Adet in a green house and inoculated to concrete tanks for adaptability test. Both strains were well adapted to Adet condition and produced 42 - 56.4 tons with an average of 48 tons and 30 - 45 tons with an average of 40 tons fresh biomass per hectare during summer respectively. Biomass production was reduced during autumn and winter due to temperature fluctuation. Field experiment was conducted at Fogera plain, where low land rice is widely produced, during 2005 and 2006 in a randomized complete block design in three replications to assess the adaptability of the strains and generate information on their nitrogen contribution efficiency. 54.4 t ha^{-1} of Azolla fresh biomass was harvested at Fogera. Maximum plant height, number of tillers, straw yield and grain yield of rice was recorded by 64 kg N + 20 kg P ha^{-1}followed by *Azolla filiculoides* + 20 kg P ha^{-1}, 32 kg N + 10 kg P ha^{-1}. Inoculation of *Azolla filiculoides* and *Azolla microphylla* incorporated once to soil has increased rice yield by 911 kg ha^{-1} (19%) and 721 kg ha^{-1} (15%) over the control respectively. However, there was temperature fluctuation and colonization of azolla roots by algae. Multiplication and maintenance of azolla needs special attention. It also needs continuous watering to a depth of 5 -10 cm and P fertilizer, thus, irrigation facility and alternate P sources are vital. Azolla produce high biomass and easy to manage and establish and should be used as biofertilizer for rice and its effect on high value and perennial crops shall be studied.

Key words: Azolla, biofertilizer, fresh biomass, nitrogen, rice, symbiotic

Introduction

Nitrogen is the key element required for growth and productivity of plants. It is abundant in atmosphere (80%) but can not be utilized by plants as such and has to be converted to nitrate or ammonium form either by chemical or biological process (Singh, 1998; Banu, 2003). Chemical synthesis of nitrogen by industrial means is energy intensive and costly. However, the same process can also be carried out enzymatically by cyanobacteria and certain species of bacteria. Most of the cyanobacteria exist under free living conditions but some are found in symbiotic association with lower plants like water fern Azolla (Singh, 1998).

Azolla partners blue green algae inside its lobes and is capable of harvesting atmospheric nitrogen. Due to this invisible partnership, the fern multiplies very fast. The symbiotic association of the algae aid in the creation of a huge amount of biomass on the surface of the water. In Azolla-anabaena symbiosis, the fern is a macro symbiont which gives protective environment and nutrients to blue green algae (the micro symbiont) which in turn gives nitrogen and other growth hormones to the fern for its growth and multiplication. Both partners harvest solar energy via photosynthesis and the total nitrogen requirement can be supplied by the assimilation of N fixed by anabaena. Each leaf of Azolla has the potential of harboring 75,000 anabaena cells containing 3 to 3.5% nitrogen (www. ineedcoffee.com/06/azolla/). The beauty of this fern is that it is quite hardy and during favorable environmental conditions multiplies in geometric proportions. The algal symbiont is closely associated with all stages of the fern's development and resides in the cavities formed in the dorsal lobe of the fern. Rapid multiplication of the fern takes place in summer months. Azolla lives on water surface of rice fields harmoniously under the canopy of rice plants without affecting its growth (Gevrek, 1999), on small ponds, canals, and rivers (Dhar *et al*., 2003; Ferentinos, 2002). Generally, it multiplies vegetatively and often sexually. Its size is 1- 5 cm. Azolla has high protein content of approximately 23-37 % (dry biomass). Hence, it can also be used as, feed supplement with other low protein rations, feed for fish, pigs, ducks, chicken and cattle that like to eat it fresh as well as dried and used in salads and sandwiches, just as alfalfa and bean sprouts are used (Ferentinos et al., 2002; Gevrek, 1999).

Azolla is a world wide in distribution. Seven species are recognized in temperate and tropics viz. *Azolla filiculoides*, *A. rubra, A. caroliniana, A. mexicana, A. microphylla, A. pinnata* and *A. nilotica* (Dhar *et al.*, 2003). All these species has anabaena as symbiont in leaves (Singh, 1998).

The high nitrogen fixing ability, rapid growth, high biomass accumulation and N content determines the potential of Azolla as fertilizer for increasing rice yield under low cost rice production technology. Biological nitrogen fixation through *Azolla anabaena* complex is considered a potential biological system for increasing rice yield at comparatively low cost (Singh, 1998). Becking, (1979) showed that doubling time of population of Azolla varies between 2 to 10 days for most species. Maximum biomass production according to Kikuchi *et al*, (1984) was ranged from 0.4 to 5.2 t dry matter ha^{-1} and averaged 2.1 t dry matter ha^{-1} N content ranged from 40-146 kg ha^{-1} with an average of 70 kg N ha^{-1}.

Azolla derives more than 80 % of its N from Nitrogen fixation in the field (Giller, 2001). Annual N production rates by Azolla can be as high as 500 kg N ha^{-1} (for *A. pinnata*) to 1200 kg N ha^{-1} (for *A. filiculoides*) with average of 1000 kg N ha^{-1} yr^{-1} with daily production rates of 0.4 – 3.6 kg ha^{-1} day^{-1} with average of 2 kg N ha^{-1} day^{-1} (Kikuchi et al., 1984). Azolla grown as an intercrop with rice can accumulate 40-170 kg N ha^{-1} (average 70 kg N ha^{-1}) (Kikuchi *et al*., 1984). Singh, (1978) in Gevrek, (1999) reported that mineral nutrient composition inside the plant body on *A. pinnata* was Nitrogen, 4-5 %; Phosphorus, 0.5-0.9%; Potassium, 2-4.5 %; Calcium, 0.4-4 %; Magnesium, 0.5-0.65 %; Iron, 0.06-0.26 %; Manganese, 0.11-0.16 % and crude protein 24-30 5 on dry matter basis. Gevrek and Yagmur (1997), also recorded the chemical composition of *A. mexicana* as N, 3.92 %; P, 0.52 %; K, 1.25 %; Ca, 4.3 %; Mg, 1.10 %; Na, 1.08 5; Zn, 0.1 %; Mn, 0.3 % and etc on dry matter basis. This indicated that Azolla has higher rate of nitrogen than compost (0.5 – 0.9 % N) and animal manure.

Losses of Azolla N were found to be small (0-11%) in comparison to the loss from an equivalent amount of urea fertilizer (30 %) which was probably due to direct volatilization of ammonia to the atmosphere (Watanabe *et al*., 1989). Giller (2001), observed that the pH of the flood water was reduced by 2 pH units due to the presence of mat of Azolla on its surface and resulted in reduction in N losses by ammonia volatilization and increased the recovery of fertilizer N applied as urea up to 60 %. When Azolla was incorporated into the soil, overall fertilizer losses were reduced by 35-55 % (Kumarasighe and Eskew, 1993). Biological N_2 fixation through *Azolla anabaena* complex is considered a potential biological system for increasing rice yield at comparatively low cost (Singh, 1998; Khan, 1988 and Main, 1993). Recently, Azolla has been used as biofertilizer in many countries in the world viz. China, Vietnam, India, North America, Thailand, Philippines, Korea, Srilanka, Bangladesh, Nepal, West Africa and etc (Dhar *et al*., 2003; Khan, 1988). Some of these countries use Azolla as one of the substitutes to commercial fertilizer. A report made by Gevrek, (1999) revealed that Azolla is used in more than a million hectares of rice land in China and in more than 400,000 hectares in Vietnam.

Low land rice is recently introduced to Ethiopia and has got special attention at Fogera plain and well adopted by farmers. According to Fogera Office of Rural and Agricultural Development, its area coverage has increased from 80 to 6400 hectares within less than a decade (1996-2004) with yield of less than 3.5 t ha^{-1}. However, Its productivity declines from time to time due to continuous cereal cultivation and nutrient depletion and failurity by most farmers to use chemical fertilizer due to rise in cost (Gezahegn and Tekalign, 1995). When in excess, azolla is converted into compost to be used as fertilizer for dry land crops and vegetables (Singh, 1998). Rice yield was increased by 1,470 kg (112%) over the control when one layer of 60 kg N $ha^{-1}$of *A. filiculoides* was incorporated into the paddy soil and further increased by 2700 kg ha^{-1} (216%) by incorporating one layer and then growing Azolla as dual crop with rice (Talley *et al*,. 1977). Since Azolla is a low cost nitrogen source, ecologically friendly, easy for management and used as nitrogen fertilizer source in different countries in the world, introduction and use of this cheap and ecologically friendly N source to our system is vital to increase rice yield and hence, this work was initiated with the objective of introducing Azolla strains and generating information on their N contribution to the newly introduced low land rice at Fogera plain

Materials and Methods

The experiment was done in two phases:

Phase I

Two Azolla strains namely, *Azolla filiculoides* and *Azolla microphylla* were introduced from India in 2004 and stayed at Addis Ababa in National Soils Research Center green house in a nutrient media and were brought to Adet Agricultural Research Center to maintain and test their adaptability. Labeled plastic containers were filled with 5 kg of forest soil and tape water was added at a depth of 10 cm and left over night to let the suspended materials settle. To maintain the mother culture, fresh and healthy Azolla fronds were inoculated to the containers and water was maintained to $\geq$ 5 cm depth every day. A pinch of TSP was added initially and when the deficiency symptom was seen to each container. There was no insect problem in the plastic containers. Both strains were multiplied very well and covered the surface of the containers in the green house within three weeks.

After enough biomass of both strains was attained, two concrete tanks of a dimension 4mx1.5mx0.45m were constructed and filled with forest soil at a rate of 5 kg m^{-2} (i.e. 30 kg of forest soil per tank) and filled with tape water at a depth of 10 cm and left over night to let the suspended materials settle. Next day fresh *Azolla filiculoides* was added to one tank and *Azolla microphylla* to the other tank at a rate of 1kg per tank. The water level was kept to a depth of $\geq$ 5cm every day. 87 gm TSP (40 gm P_2O_5) was applied to each tank initially and when deficiency symptom was observed.

The adaptability of the strains to the new environment was studied based on the biomass produced, pheneotypical appearance at different weather conditions, occurrence of disease and insect pests. Two additional concrete tanks of a size 5x10 m^2 were constructed for multiplication of Azolla for field experiment (to produce enough biomass) following the same procedure, forest soil (250 kg was added to each tank) the strains were inoculated and water was maintained to 5-10 cm depth every day. Two third of the Azolla mat was collected every two weeks from each container and tank leaving one third for further multiplication and the collected mat was weighed sun dried and stored.

Phase II

The field experiment was conducted at Fogera plain where paddy rice is produced widely practiced during 2005 and 2006 in a randomly completed block design with three replications. The experimental site of size 13m x 34m was selected each year and prepared as per the farmers practice and divided to replications and experimental plots of 2m x 3m. The distance between plots and blocks was 2m each. The plots were leveled and rows at a spacing of 20cm were prepared and fertilizer was applied to rows of respective plots evenly at a rate of 64 kg N ha^{-1}+20 kg P ha^{-1}, 32 kg N ha^{-1}+ 10 kg P ha^{-1}, 20 kg P $ha^{-1}$and 10 kg P ha^{-1} then mixed with the soil and rice variety x-jigna was sown at a rate of 80 kg ha^{-1} in rows with 20 cm spacing between rows. N was applied in split i.e. half of N and all P were applied initially and the split was applied at flowering during Azolla incorporation. N and P sources were urea and TSP respectively. After sowing, ridges were made for each plot to collect water which could float the Azolla strains and then the strains were inoculated to their respective plots at a rate of 1kg fresh biomass after the field was flooded with water. The strains were incorporated to the soil in a plot by draining the water after producing enough biomass (forming thick mat).

Treatments:

1. Control
2. 64 kg N ha^{-1}+20 kg P ha^{-1}
3. 32 kg N ha^{-1}+ 10 kg P ha^{-1}
4. *Azolla filiculoides* + 20 kg P ha^{-1}
5. *Azolla microphylla* + 20 kg P ha^{-1}
6. *Azolla filiculoides* + 10 kg P ha^{-1}
7. *Azolla microphylla* +10 kg P ha^{-1}
8. *Azolla filiculoides*
9. *Azolla microphylla*

Agronomic data

Five representative plants were randomly selected from each plot and number of tillers were counted and the average was recorded. Similarly, average plant height was measured for five randomly selected plants per plot using a meter scale. Fresh biomass of Azolla in kg per m^{-2} was measured by a spring balance taking a mat from 1m x 1m area using a quadrant and the average was recorded. The measured fresh biomass of Azolla was sun dried and the equivalent dry weight was recorded.

Among 10 rows of rice per plot, 8 central rows were harvested from each plot and grains and straws were separated to measure straw and grain yield per plot. The grain yield was recorded after adjusting the moisture to 12.5% and expressed as kg per hectare. The straws separated from grains from each plots were sun dried and weighed to determine the straw yield in kg plot^{-1}.

Result and Discussion

Both strains were well adapted to Adet in a green house and out door concrete tanks. The strains started multiplying within two days and covered the whole surface of the containers forming a thick mat within three weeks after inoculation (Fig 1). The starter inocula were very small in amount and hence the multiplied strains were inoculated to other containers to achieve enough biomass for further activities (Fig 2a).

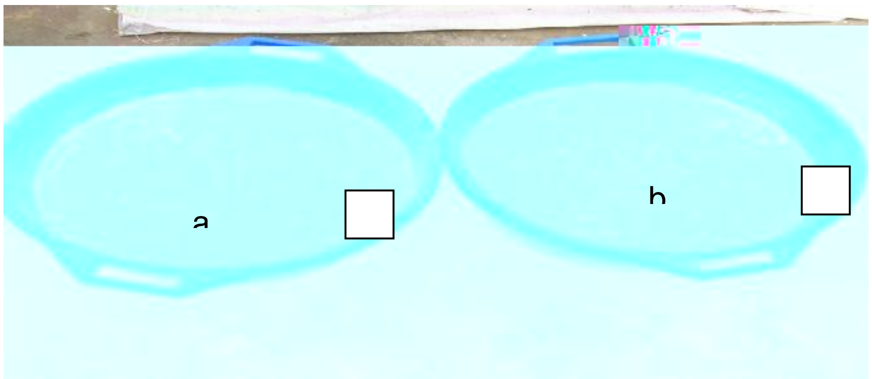

Figure 1. Mother culture of *A. filiculoides (a)* and *A. microphylla (b)* in a green house at Adet

After enough biomass was achieved from the plastic containers, both strains were inoculated to the out door concrete tanks at a rate of 1 kg fresh biomass per tank (Fig 2b). The strains started multiplying and covered the surface of the tanks after three weeks. After first harvest, the strains covered the surface of the tanks forming thick mat every two weeks (Fig 2c). The fern is light green in color until the micro symbiont (*anabaena azollae*) makes association with and turned deep green after association. The blue green algae formed series of oval rings on the dorsal lobe of each leave of the fern under microscope as reported by Anand and Geeta (www.ineedcoffee.com/06/azolla/). They observed that each leave of azolla has the potential of harboring 75,000 anabaena cells and has high nitrogen fixing capacity. Both strains were performed well, deep green in color and formed thick mat from June to September (Fig 2).

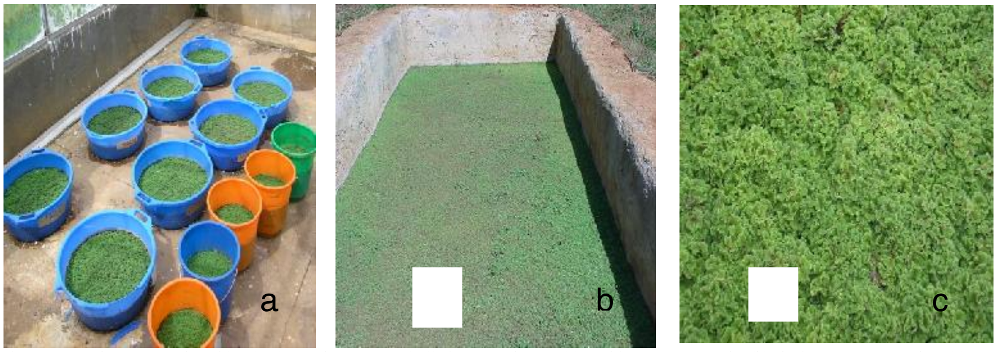

Figure 2. Performance of *A. filiculoides* and *A. microphylla* in green house (a) and in concrete tanks (b) during June – October (c) thick mat of azolla

A. filiculoides tolerated relatively low temperature and performed better from October to January and poorly performed from Feb to April. Whereas *A. microphylla* tolerated relatively high temperature and performed better from February to April and poorly performed from October to January. This result is in agreement with FAO (1982) report. The biomass produced by both strains during these seasons is indicated in Table 1. Both strains turned brown (Fig 3a) when exposed to high temperature or low temperature and/or during maturity (Fig.3b) and green to slightly brown otherwise. Pinkish color was developed during the occurrence of P deficiency and can be corrected by applying P from P source such as TSP. However, both strains may poorly perform if the temperature too cold or too hot. Therefore, partial shade is needed for their better performance.

Figure 3. Azolla turned brown during temperature fluctuation (a) and during maturity (b)

Growth of algae was a common problem for both strains particularly during October to April and seriously affected the *A. microphylla* strain and than *A. filiculoides*. It greatly hindered growth and multiplication of the strains at Adet during these months. The reason was due to addition of excess P to the tanks to recover the strains from damage due to temperature fluctuation for similar symptom was observed and this caused the growth of algae in excess and failure to remove from the tanks by hand. Therefore, lesson was learned in such a way that excess P should not be applied and even be applied in split to avoid algal growth and maintain the strains.

Table 1 Average fresh biomass produced by azolla strains during different seasons

S.N	Season	Fresh biomass in t ha^{-1}		Remark
		A. filiculoides(A.f)	*A. microphylla (A.m)*	
1	May - Sept	48	40	Maximum biomass of 56.4 t and 45 t ha^{-1} was harvested from *A.f* and *A.m* respectively
2	Oct - January	30	11	Though *A.f* performed well it turned cloudy pinkish during severe temperature drop and do not perform as good as from May to Sept
3	Feb - April	14	32	Though *A.m* performed well it turned brown during severe temperature raise and do not perform as good as from May to Sept

From the field experiment conducted at Fogera, it was observed that both strains were well adapted, multiplied and covered the plots within two weeks. The fern formed a thick mat (Fig. 4) and produced 54.4 t fresh biomass ha^{-1} within 40 days after inoculation. Literature revealed that the fresh biomass produced by Azolla ranges from 10-20 t ha^{-1}(Singh, 1998). There was no insect and disease problem for both strains at all locations. The fresh biomass produced indicates that Azolla can adapt and perform well in Ethiopia and hence may serve as source of nitrogen and other macro and micro nutrients for rice and high value crops.

a

Figure 4. Thick mat of Azolla produced in a plot (a) and in a space between blocks (b) at Fogera plain

Significant difference in mean plant height was observed among treatments (Table 2). The maximum mean plant height was recorded due to full recommended NP (64 kg N ha^{-1}+ 20 kg P ha^{-1}) followed by *A. filiculoides* + 20 kg P ha^{-1}, *A. filiculoides* + 10 kg P ha^{-1}, *A. filiculoides* alone and *A. microphylla* + 20 kg P ha-^{1}. Whereas the least was recorded by the control followed by *A. microphylla* + 10 kg P ha^{-1}. The result revealed that *Azolla filiculoides* alone increased plant height as equivalent as *A. filiculoides* with full recommended P. In addition, both strains significantly increased plant height than the control (Table 2).

Table 2. Effect of Azolla on plant height at Fogera during 2005 and 2006

Treatment	***Mean plant height (cm)***		
	2005	2006	Combined
Control	95.30	95.00	95.15 d
64 kg N + 20 kg P ha^{-1}	107.27	102.20	104.70 a
32 kg N + 10 kg P ha^{-1}	99.50	98.83	99.17 c
Azolla filiculoides + 20 kg P ha^{-1}	103.70	100.70	102.20 b
Azolla microphylla + 20 kg P ha^{-1}	101.53	97.30	99.42 c
Azolla filiculoides + 10 kg P ha^{-1}	101.90	96.30	99.10 c
Azolla microphylla + 10 kg P ha^{-1}	99.53	93.03	96.28 d
Azolla filiculoides	101.63	100.70	101.20 b
Azolla microphylla^{-1}	100.47	96.93	98.70 c
LSD (0.05)	1.76	1.693	1.661
C.V (%)	1.01	1	1

Significant difference in number of tillers was observed among some treatments (Table 3). Maximum number of tillers was recorded by full recommended NP followed by half recommended NP (32 kg N ha^{-1} + 10 kg P ha^{-1}), *A. filiculoides* alone, *A. microphylla* alone and *A. filiculoides* + 20 kg P ha^{-1}. Both strains significantly ($P<0.05$) increased number of tillers over the control.

Table 3. Effect of Azolla on number of tillers of rice at Fogera during 2005 and 2006

Treatment	***Mean number of tillers per plant***		
	2005	2006	Combined
Control	9.67	8.33	9.00 c
64 kg N + 20 kg P ha^{-1}	15.00	13.00	14.00 a
32 kg N + 10 kg P ha^{-1}	12.00	11.33	11.67 b
Azolla filiculoides + 20 kg P ha^{-1}	11.00	10.00	10.33 bc
Azolla microphylla + 20 kg P ha^{-1}	10.67	9.33	10.17 bc
Azolla filiculoides + 10 kg P ha^{-1}	11.00	8.67	9.67 c
Azolla microphylla + 10 kg P ha^{-1}	10.67	9.00	10.00 bc
Azolla filiculoides	11.67	9.67	10.50 bc
Azolla microphylla^{-1}	11.33	9.00	10.33 bc
LSD (0.05)	2.550	1.252	1.928
C.V (%)	12.86	7.37	10.91

Maximum straw yield was recorded due to recommended NP followed by half recommended NP combined over years whereas straw yield due to the other treatments have no significant difference($P<0.05$) than the control (Table 4). However, *A. microphylla* + 20 kg P ha^{-1} and *A. filiculoides* + 20 kg P ha^{-1}as well as *A. microphylla* + 10 kg P ha^{-1}, *A. filiculoides* + 10 kg P $ha^{-1}$and *A. filiculoides* alone affected straw yield as equally as half recommended NP but not significantly different from the control and *A. microphylla* alone.

Table 4. Effect of Azolla on straw yield of rice at Fogera during 2005 and 2006

Treatment	***Mean straw yield (kg per ha)***		
	2005	2006	Combined
Control	7417 c	7359 g	7388 c
64 kg N + 20 kg P ha^{-1}	10132 a	9035 a	9584 a
32 kg N + 10 kg P ha^{-1}	8931 ab	8357 b	8644 ab
Azolla filiculoides + 20 kg P ha^{-1}	8396 bc	8063 c	8230 bc
Azolla microphylla + 20 kg P ha^{-1}	8757 abc	7799 de	8278 bc
Azolla filiculoides + 10 kg P ha^{-1}	8354 bc	7674 e	8014 bc
Azolla microphylla + 10 kg P ha^{-1}	8688 bc	7514 f	8101 bc
Azolla filiculoides	7444 c	7924 cd	7684 bc
Azolla microphylla^{-1}	7708 bc	7480 fg	7594 c
LSD (0.05)	1430	148.1	1017
C.V (%)	10.2	1.13	7.48

Table 5 shows that there was significant difference in grain yield among the treatments. The combined analysis showed that recommended NP fertilizer gave the maximum grain yield of 6.2 t ha^{-1} followed by half recommended NP fertilizer and *A. filiculoides* + 20 kg P ha^{-1} with grain yield of 5.9 and 5.8 t ha^{-1} respectively. All treatments have significant difference in grain yield over the control. *A. filiculoides* + 20 kg P ha^{-1} equivalently increased grain yield with half recommended NP followed by *A. filiculoides* alone. *A. filiculoides* alone has recorded significantly different ($P<0.05$) grain yield over *A. microphylla* alone. However, *A. microphylla* with and without P has recorded significant grain yield increment over the control. *A. filiculoides* and *A. microphylla* without P incorporated once to the soil has increased rice yield by 911 kg ha^{-1} (19%) and 721 kg ha^{-1} (15%) over the control respectively.

Table 5. Effect of Azolla on grain yield of rice at Fogera during 2005 and 2006

Treatment	**Mean grain yield (kg ha^{-1})**		
	2005	2006	Combined
Control	4812 e	4932 f	4872 f
64 kg N + 20 kg P ha^{-1}	6167 a	6219 a	6193 a
32 kg N + 10 kg P ha^{-1}	6041 b	5826 b	5934 b
Azolla filiculoides + 20 kg P ha^{-1}	5937 bc	5758 b	5848 bc
Azolla microphylla + 20 kg P ha^{-1}	5791 d	5603 cd	5697 de
Azolla filiculoides + 10 kg P ha^{-1}	5812 d	5555 de	5683 de
Azolla microphylla + 10 kg P ha^{-1}	5749 d	5473 e	5611 e
Azolla filiculoides	5840 cd	5726 bc	5783 cd
Azolla microphylla^{-1}	5729 d	5458 e	5593 e
LSD (0.05)	117.1	125	121.1
C.V (%)	1.22	1.28	1.28

In general, results due to inoculation of *A. filiculoides and A. microphylla* with and with out P has significant difference for most parameters over the control. *A. filiculoides* with 20 kg P ha^{-1} have equivalently affected most parameters with half recommended NP. *A. filiculoides* alone and *A. filiculoides* with 20 kg P ha^{-1} have equivalently affected grain yield of rice combined over years.

Azolla is rich in major nutrients such as N, P, K and S and micro nutrients such as Fe, Zn and others. It is a recycling source of P, S and other nutrients to rice and hence the increase in grain yield and other yield parameters may be due to this fact (Main, 1991; Singh and Singh, 1987 and Singh et al;. 1981). Talley *et al*;. 1977 reported that rice yield was increased by 112% (1470) kg over the control by incorporating *A. filiculoides* once (at the rate of 60 kg ha^{-1}) and by 216% (2700 kg ha^{-1}) by incorporating once and then growing Azolla as a dual crop with rice. In addition, scientists in China also reported rice yield increases due to azolla ranging from 0.4-158% with an average of 18.6% (Lumpkin and Plunknet, 1980). Therefore, the result achieved at Fogera plain (15-19%) is in line with these findings.

Conclusion

Azolla should be used as a biofertilizer for rice production in Ethiopia since:

- ✓ it has high nitrogen fixing capacity,
- ✓ produce high biomass,
- ✓ easy to manage and establish,
- ✓ increase the availability of macro and micronutrients (it scavenge K and recycles P and S),
- ✓ improves soil physical and chemical properties and fertilizer use efficiency,
- ✓ increase crop yield 15-19% (by one incorporation) in Ethiopia,
- ✓ release plant growth hormones and vitamins and does not attract rice pests

However, it:

- ✓ requires nursery for multiplication
- ✓ occupy land for production
- ✓ requires continuous watering and high labor for incorporation and watering
- ✓ needs irrigation facility
- ✓ needs rice crop to be sown in rows

- ✓ may be difficult to establish during dry season due to temperature fluctuation
- ✓ may be attacked by algae
- ✓ requires high P fertilizer for multiplication
- ✓ may be a weed in irrigation channels

Recommendation

- Multiplication tanks should be constructed at Fogera and other potential areas to multiply and scaling up azolla
- Its effect on high valued crops (vegetables and fruit crops) should be studied
- Control mechanism for algae should be studied
- Its effects on water bodies (when entered rivers and lakes) should be evaluated
- Cheap P sources should be investigated
- Rice should be planted in rows by transplantation

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