Effect of Green and Dry Azolla on wheat yield and yield components

Tesfaye Feyisa1, Tadele Amare1 and Yihenew G.Selassie[2]
1, Adet Agricultural Research Center, P.O.Box, 08 Bahir Dar. Tel: 0583380234.
E-mail tesfaberhan98@yahoo.com
2, Amhara Regional Agricultural Research Institute (ARARI), P.O.Box 527 Tel: 0582206400

Abstract

The experiment was conducted at Adet on station during 2006 and 2007 on red soil in a randomized complete block design with three replications with the objective of studying the effect of green and dry Azolla on yield and yield components of wheat and generate information on use of green and dry azolla as N source for crops other than rice. Azolla multiplied in two concrete tanks of a size 10 x 5 m^2 was harvested, dried and stored during the off season (winter). Green azolla at a rate of 10 t ha^{-1} and dry azolla at a rate of 2.5 t ha^{-1} were incorporated to the respective plots ten days before sowing. Significant differences ($P<0.05$) were recorded for plant height, grain yield and straw yield. green azolla + 92 kg N ha^{-1} recorded maximum grain yield (4.6 t ha^{-1}) followed by 92 kg N ha^{-1} alone (4.3 t ha^{-1}) and dry azolla + 92 kg N ha^{-1}(4 t ha^{-1}). Green azolla and dry azolla alone increased grain yield by 25% (385 kg) and 31% (478 kg) respectively over the control equivalently with 23 kg N ha^{-1} (30.7%(470 kg)). Hence, Azolla can be used as N source for wheat. However, since wheat is produced on larger plot of land and need large amount of N, it may not be possible to satisfy its N requirement from green azolla and dry azolla for large amount of green and dry azolla is needed per hectare. Therefore, green and dry azolla can be used for high value crops (vegetables and fruit) that can be grown on small plots of land.

Keywords: Green Azolla, dry azolla, inoculation, N source

Introduction

Nitrogen fertilizers supplement the natural soil nutrient supply to satisfy the demand of the crops to compensate for N lost by removal of plant products, N leaching and gaseous N loss and maintain productive soil conditions for agriculture (Tabachow *et al*., 2001). Chemical synthesis of N-fertilizer by industry means is energy intensive and costly (Singh, 1998). However, the same process is also carried out enzymatically by cyanobacteria (blue green-algae) and certain species of bacteria (Singh, 1998). Most of the cyanobacteria exist under free living conditions but some of them are found in symbiotic association with lower plants like water fern azolla (Giller, 2001, Suba Rao, 1999).

The aquatic fern azolla together with blue green algae (*anabaena azollae*) provides a symbiotic association that can fix agrnomically significant amounts of nitrogen (Giller, 2001). With repeated harvesting, annual N production rate by azolla can be as high as 500 kg-1200 kg N ha^{-1} with daily production rate of 0.4-3.6 kg N ha^{-1} per day (average 2 kg N ha^{-1} per day) (Kikuchi *et al*., 1982). It can be grown as green manure and incorporated into the soil during land preparation or as green manure and transported to the field where crop (usually rice) is produced or as intercrop with the crop (rice) (Singh, 1998).

Azolla provides N to the crop after its decomposition. Unincorporated azolla decomposed slowly as compared to incorporated azolla which took 8-10 days to decompose and release 67 % of its N within 35 days (Singh *et al*., 1991). The N from azolla is released slowly in comparison to fertilizer N and its availability to the first rice crop is about 70 % of ammonium sulphate N (Saha *et al*., 1982).

Azolla makes the soil fertile by increasing the contents of organic carbon, N, P, and K (Singh and Singh, 1987). It also increases availability of micronutrients like Fe, and Mn in soil as a result of its incorporation. In addition, azolla reduces bulk density and soil resistance and increases aggregate stability and available moisture content (improve soil physical and chemical property).

Azolla is converted into compost to be used as fertilizer for dry land crops and vegetables (Singh, 1998). Experimental results have shown that 10 tones of azolla green manure can increase a rice yield by 470 kg ha^{-1} (Rains and Talley 1978) in FAO 1982). Tesfaye *et al*., 2007 also reported that azolla incorporated once to a soil can increase rice by 15-19% (721 kg – 911 kg ha^{-1}).

Loss of azolla N according to Watanabe *et al*. (1989), was found to be small (0-11%) in comparison with the loss from an equivalent amount of urea fertilizer (30%) which was probably due to direct volatilization of ammonia to the atmosphere. When azolla was incorporated into the soil, the overall fertilizer loss was reduced by 35-55% (Kumarasinghe and Eskew, 1993).

Soils of Ethiopian highlands are inherently poor in available plant nutrients and organic matter (Tekalign *et al*., 1988). Murphy (1963) reported that the major part of Ethiopian soils is deficient in nitrogen and phosphorus. However, the use of fertilizer N in different agricultural systems by Ethiopian farmers is limited by low percapita income, poor credit facilities, poor current commodity value, and absence of effective infrastructures for fertilizer production and distribution. In addition, the cereal dominated cropping systems, aimed at meeting the farmers' subsistence requirements, coupled with low usage of chemical fertilizers have led to the widespread depletion of soil nitrogen in the cereal crops growing areas of Ethiopia. Moreover, the heavy rains during the early part of the main cropping season (June-August) cause substantial soil nutrient losses due to intensive leaching and erosion (Amsal and Tanner, 2001).

Therefore, since azolla is easy to manage, cheap nitrogen source and its mat is harvested every 2-3 weeks, composted and stored during the dry season, it is high time to evaluate and generate information on its effect on crop yield other than rice and its N contribution efficiency. Therefore, the present work was proposed to study the effect of azolla green manure and dry compost on yield and yield components of wheat and to generate information on use of azolla as green manure and dry compost for wheat.

Materials and Methods

The experiment was conducted at Adet Agricultural Research Center on station on Nitosol in a Completely Randomized Block Design (RCBD) with three replications. Two ponds of 10 m x 5 m size were constructed with concrete tank in the center, filled with loam soil (forest soil) at the rate of 5 kg per m^2 (250 kg loam soil per pond) and filled with tape water at a depth of 10 cm and left over night to let the suspended materials settle. Next day, the suspended materials were removed and fresh *Azolla filiculoides* was inoculated to the tanks at a rate of 3 kg per tank (Fig. 1a). The water level was maintained to a depth of $\geq$ 5cm every day. 725 gm TSP (333.5 gm P_2O_5) was applied to each tank initially and when deficiency symptom was observed. The azolla mat was harvested every two weeks, weighed, dried and stored to be used for the experiment during the dry season (Fig. 1c). Ten days before sowing 3 kg (2.5 t ha^{-1}) of dry azolla and 12 kg (10 t ha^{-1}) of green azolla (Fig.1b) was weighed and applied to the respective plots (12 m^2) and incorporated to the soil. After 10 days of incorporation wheat was sown at a seed rate of 150 kg per ha^{-1} with a spacing of 20 cm between rows and 1 m space between plots and blocks with the following treatment arrangement. Phosphorus was applied at a rate of 46 kg P_2O_5 ha^{-1} to each plot uniformly during planting. Similarly, half of the N was applied during planting and half at tillering.

Figure 1. Azolla pond (a), harvested green azolla (b), and dry azolla (c)

Treatments

1. Control
2. 23 kg N ha^{-1}
3. 46 kg N ha^{-1}
4. 69 kg N ha^{-1}

5. 92 kg N ha^{-1})
6. Dry azolla
7. Dry azolla + 23 kg N ha^{-1}
8. Dry azolla + 46 kg N ha^{-1}
9. Dry azolla + 69 kg N ha^{-1}
10. Dry azolla + 92 kg N ha^{-1}
11. Green azolla
12. Green azolla + 23 kg N ha^{-1}
13. Green azolla + 46 kg N ha^{-1}
14. Green azolla + 69 kg N ha^{-1}
15. Green azolla + 92 kg N ha^{-1}

Data collection

Five representative plants were randomly selected from each plot and plant height was measured using a meter scale and the average was recorded. Among 15 rows of wheat per plot, 13 central rows were harvested from each plot and grains and straws were separated and straw and grain yield per plot were measured. 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 ha^{-1}.

Data Analysis

The data collected for all relevant characters were subjected to analysis of variance appropriate to factorial experiment CRBD (Gomez and Gomez, 1984). Significant differences between and/or among treatments were calculated using the Least Significant Difference (LSD) MSTATC Computer software.

Result and Discussion

Significant difference in mean plant height was observed among treatments combined over years (Table 1). The maximum mean plant height was recorded due to 92 kg N ha^{-1} + dry azolla followed by 92 kg N ha^{-1} alone, green azolla + 92 kg N ha^{-1}. During 2006, there was no significant difference in plant height due to dry or green azolla alone compared to the control whereas significant difference in plant height was recorded due to green azolla alone over the control during 2007. Green azolla alone increased plant height equally with 69 kg N ha^{-1} alone in both years whereas dry azolla increased plant height equally with 46 kg N ha^{-1}alone during 2006 and with 23 kg N ha^{-1} alone during 2007. In general, combined over years there was no difference in plant height due to green or dry azolla alone, the difference was due to the N fertilizer applied from urea (Table 1).

Table 2 showed that there was significant difference ($P<0.05$) in grain yield among the treatments. The combined analysis showed that green azolla + 92 kg N ha^{-1} gave the maximum grain yield (4.6 t ha^{-1}) followed by 92 kg N ha^{-1} alone (4.3 t ha^{-1}) and dry azolla

+ 92 kg N ha^{-1}(4 t ha^{-1}). Dry and green azolla equivalently increased grain yield with 23 kg N ha^{-1}. Dry and green azolla with 46 kg N ha^{-1} increased grain yield equally with 69 kg N ha^{-1} alone. Dry azolla and green azolla alone increased grain yield by 31% (478 kg) and 25% (385 kg) over the control respectively.

Table1. Effect of Azolla dry compost and green manure on plant height of wheat during 2006 and 2007

Treatment	*Mean plant height (cm)*		
	2006	2007	Combined
Control	67.67	61.00	64.33
23 kg N ha^{-1}	72.53	69.13	70.83
46 kg N ha^{-1}	73.20	75.87	74.53
69 kg N ha^{-1}	79.07	78.87	78.97
92 kg N ha^{-1}	80.20	83.20	81.70
Dry azolla	71.33	68.80	70.07
Dry azolla + 23 kg N ha^{-1}	75.07	78.13	76.60
Dry azolla + 46 kg N ha^{-1}	78.73	80.93	79.83
Dry azolla + 69 kg N ha^{-1}	81.60	78.27	79.93
Dry azolla + 92 kg N ha^{-1}	81.40	85.87	83.63
Green azolla	72.00	71.67	71.83
Green azolla + 23 kg N ha^{-1}	74.00	73.53	73.77
Green azolla + 46 kg N ha^{-1}	76.07	74.60	75.33
Green azolla + 69 kg N ha^{-1}	77.60	81.67	79.63
Green azolla + 92 kg N ha^{-1}	79.47	82.73	81.10
LSD (0.05)	7.703	7.899	7.630
C.V (%)	6.06	6.19	6.19

Table2. Effect of Azolla dry compost and green manure on grain yield of wheat during 2006 and 2007

Treatment	*Mean grain yield kg ha^{-1}*		
	2006	2007	Combined
Control	1645	1420	1533
23 kg N ha^{-1}	2251	1555	1903
46 kg N ha^{-1}	3193	2425	2809
69 kg N ha^{-1}	3675	3123	3399
92 kg N ha^{-1}	4699	3813	4256
Dry azolla	1884	2138	2011
Dry azolla + 23 kg N ha^{-1}	2330	2504	2417
Dry azolla + 46 kg N ha^{-1}	3335	3377	3356
Dry azolla + 69 kg N ha^{-1}	3759	3726	3743
Dry azolla + 92 kg N ha^{-1}	3944	4074	4009
Green azolla	1803	2034	1918
Green azolla + 23 kg N ha^{-1}	2421	2318	2370
Green azolla + 46 kg N ha^{-1}	3768	3354	3561
Green azolla + 69 kg N ha^{-1}	4245	3577	3911
Green azolla + 92 kg N ha^{-1}	4825	4345	4585
LSD (0.05)	134.9	280.3	215.1
C.V (%)	2.53	5.74	4.31

Table3. Effect of Azolla dry compost and green manure on straw yield of wheat during 2006 and 2007

Treatment	*Mean straw yield kg ha^{-1}*		
	2006	2007	Combined
Control	2553	2006	2280
23 kg N ha^{-1}	3153	2241	2697
46 kg N ha^{-1}	4251	3126	3688
69 kg N ha^{-1}	4651	3719	4185
92 kg N ha^{-1}	5709	4426	5068
Dry azolla	2879	2686	2783
Dry azolla + 23 kg N ha^{-1}	3440	3238	3339
Dry azolla + 46 kg N ha^{-1}	4485	3974	4229
Dry azolla + 69 kg N ha^{-1}	4880	4413	4647
Dry azolla + 92 kg N ha^{-1}	5025	4890	4957
Green azolla	2692	2422	2557
Green azolla + 23 kg N ha^{-1}	3388	2847	3118
Green azolla + 46 kg N ha^{-1}	4309	3876	4093
Green azolla + 69 kg N ha^{-1}	5231	3997	4614
Green azolla + 92 kg N ha^{-1}	5805	5052	5428
LSD (0.05)	359.9	394.0	369.0
C.V (%)	5.17	6.68	5.87

Table4. Effect of Azolla dry compost and green manure on dry biomass yield of wheat during 2006 and 2007

Treatment	*Mean dry biomass kg ha^{-1}*		
	2006	2007	Combined
Control	4208	3426	3817
23 kg N ha^{-1}	5403	3796	4599
46 kg N ha^{-1}	7445	5550	6497
69 kg N ha^{-1}	8325	6842	7583
92 kg N ha^{-1}	10410	8240	9324
A. f. dry compost	4792	4824	4808
A. f. dry compost + 23 kg N ha^{-1}	5770	5742	5756
A. f. dry compost + 46 kg N ha^{-1}	7849	7351	7600
A. f. dry compost + 69 kg N ha^{-1}	8639	7856	8247
A. f. dry compost + 92 kg N ha^{-1}	8969	8964	8967
Green azolla	4505	4455	4480
Green azolla + 23 kg N ha^{-1}	5810	5870	5840
Green azolla + 46 kg N ha^{-1}	8078	7230	7654
Green azolla + 69 kg N ha^{-1}	9476	7574	8525
Green azolla + 92 kg N ha^{-1}	10630	9432	10030
LSD (0.05)	411.6	1002.0	749.0
C.V (%)	3.35	9.25	6.62

There was significant difference ($P<0.05$) among most treatments in straw yield. Maximum straw yield was recorded by green azolla + 92 kg N ha^{-1} (5.43 t) followed by 92 kg N ha^{-1} alone (5.07 t) and dry azolla + 92 kg N ha^{-1} (4.96 t) (Table 3). The straw yield recorded by dry azolla and green azolla alone was comparably equal with the straw yield recorded by 23 kg N ha^{-1}. However, there was no significant difference ($P<0.05$) in straw yield between green azolla and the control. Dry azolla and green azolla with different N rates increased straw yield significantly.

There is significant difference ($P<0.05$) among most treatments in dry biomass yield. Maximum dry biomass yield was recorded by green azolla + 92 kg N ha^{-1} (10.03 t) followed by 92 kg N ha^{-1} alone (9.32 t) and dry azolla + 92 kg N ha^{-1} (8.97 t) (Table 4). The dry biomass yield recorded by dry azolla and green azolla alone was comparably equal with the dry biomass yield recorded by 23 kg N ha^{-1}. However, there was no significant difference ($P<0.05$) in dry biomass yield between green azolla and the control. Dry azolla and green azolla with different N rates increased dry biomass yield significantly over the control and 23 kg N ha^{-1}.

In general, results due to inoculation of dry and green azolla to wheat showed significant difference for most parameters over the control. Green azolla and dry azolla alone have equivalently affected most parameters with 23 kg N ha^{-1} 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 also a recycling source of P, S and other nutrients and hence increases grain yield and other yield parameters (Main, 1991; Singh and Singh, 1987 and Singh et al;. 1981). Talley *et al*;. 1977 also reported that rice yield was increased by 112% (1470) kg over the control by incorporating *A. filiculoides* once and by 216% (2700 kg ha^{-1}) by incorporating once and then growing Azolla as a dual crop with rice. In addition, Lumpkin and Plunknet, 1980, reported that rice yield was increased by 18.6% due to azolla. Tesfaye *et al,*. 2006 also reported that incorporation of azolla alone once to a rice field has increased rice yield by 15% -19% at Fogera plain. Therefore, the yield increment for wheat due to dry azolla and green azolla alone (31% & 25% respectively) is in line with the above findings.

Conclusion and Recommendation

From the results it could be concluded that green and dry azolla can be used as N source for wheat. Dry azolla and green azolla alone at a rate of 2.5 t ha^{-1} and 10 t ha^{-1} respectively increased grain yield and other yield components of wheat equivalently with 23 kg N ha^{-1}. However, wheat is produced on a large plot of land and requires large amount of N fertilizer and the amount of azolla needed to provide the required amount of N would be very high and needs large amount of green and dry azolla. Hence, larger ponds, sufficient irrigation water and high labor are needed to produce the required amount of green and dry azolla. The land to be allotted to larger pond construction could also compete for land. Therefore, azolla should be used as a biofertilizer for high valued crops (such as vegetables and fruit trees) that can be grown on small plots of land.

References

Amsal, T. and D. G. Tanner. 2001. Effects of fertilizer application on N and P uptake, recovery and use efficiency of bread wheat grown on two soil types in central Ethiopia. Eth. J. Nat. Res. 3 : 219-244.

FAO (Food and Agricultural Organization). 1982. Application of nitrogen fixing systems in soil improvement and management. Rome. Italy. 150p.

Gezahegn Ayele and Tekalign Mamo. 1995. Determinants of demand for fertilizer in a vertisol Cropping system in Ethiopia. Tropical Agriculture (Trinidad) 72: 165-169

Giller, K.E. 2001. Nitrogen fixation in Tropical cropping systems. Second edition. pp 128-138

Kikuchi, M., Watanabe, I. and L.D., Haws. 1984. Economic Evaluation of azolla use in rice production. In: organic matter and rice, pp 569-592. IRRI. Los Banos, Philippines.

Kumarasinghe, K.S. and D.L. Eskew. 1993. Isotopic studies of azolla and nitrogen fertilization of rice. Kluwer Academic Publishers, Dordercht. 145p.

Murphy, H. F. 1963. Fertility and other data on some Ethiopian soils. *Cited by* B. Taye. 1998. Soil Fertility Research in Ethiopia. Paper presented at the Soil Fertility Management Workshop. April 21-22, 1998. Addis Ababa, Ethiopia.

Saha, K.C., Panigraphi, B.C. and P.K., Singh. 1982. Blue green algae, azolla additions on the nitrogen and phosphorus availability and redox potential of a flooded soil. Soil Biol and Biochem 14: 23-26

Singh, A.L. and P.K., Singh. 1987. Influence of azolla management on the growth, yield of rice and soil fertility. I Azolla growth, N_2 fixation and growth and yield of rice. Plant and Soil: 102: 41-47

Singh, P.K., Singh, D.P., Manna, A.B., Singh, R.P. and R.N., Bisoyi. 1991. Performance of *Azolla caroliniana* in Indian rice fields. In: Biological nitrogen fixation associated with rice production (eds.) S.K. Data and C., Slogger pp 95-107

Singh, P.K. 1998. Water fern Azolla: a proven biofertilizer for wet land rice. In: Soil and plant- microbe interaction in relation to integrated nutrient management. Summer school handbook. B.D. Kaushik (course director) June 17-July 8 1998. New Delhi. pp 64 - 75

Subba Rao, N.S. 1999. Soil microbiology. 4th edition pp 160-165

Tobachew, R.M., Pierce, J. and D.D., Richter. 2001. Biochemical models relating soil nitrogen losses to plant available N. Environmental engineering science 18: 81-89

Tekalign, M., I. Haque and C. S. Kamara. 1988. Phosphorus status of some Ethiopian highland Vertisols, pp. 232-252. *In* S. C. Jutzi ed. Management of Vertisols in sub-Saharan Africa. Proc. Conference Held at the International Livestock Center for Africa. 31 Aug. - 4 Sep., 1987. Addis Ababa, Ethiopia

Watanabe, I., Ventura, W., Mascarina, G., and D.L., Eskew. 1989. Fate of azolla species and urea nitrogen applied to wetland rice (*Oryza sativa* L.) Biol. Fertil. soils 8: 102-110