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Integrated Effect of Azolla in Combination with Nitrogenous Fertilizer on Chemical Properties of Soil and Yield of Rice Grown under SRI

Abdul Mateen Baktash, Naveen Datt and Shabnam[1*]

CSK Himachal Pradesh Agriculture University, Palampur-176 062, India
[1]Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan-173 230, India
[*]E-mail: mehtashabnam05@gmail.com

***Abstract*:** The study was conducted to assess the effect of azolla application in combination with nitrogen fertilizer on yield of rice and chemical properties of soil under system of rice intensification (SRI)at CSKHPKV, Palampur during *kharif,* in the year2016.Azollafirst produced and then collected. The collected azollawas evaluated for nitrogen (%), nitrogen fixation, carbon and nitrogen ratio (C: N), protein content, phosphorous, potassium, secondary elements (S, Ca and Mg) and micronutrient cations (Fe, Mn, Zn and Cu). Azollawas applied along with graded doses of inorganic N fertilizer. Maximum paddy grain yield of 5.13 t ha^{-1} was observed with application of125 kg N ha^{-1} + 8 tonnes of azolla followed by 100 kg N ha^{-1}+ 8 tonnes of azolla. However, lowest rice grain yield (0.83 t ha^{-1}) was in control with no application of azolla and fertilizer N. The highest straw yield was observed with 125 kg N ha^{-1} + 8 tonnes of azolla. The increase in pH (5.57) was also observed with combined application of azollaand fertilizer nitrogen. Organic carbon, CEC as well as available N, P and K were higher in 125 kg N ha^{-1} + 8 t azolla.

Keywords: Azolla, N fertilizer, SRI, paddy, Yield, Soil chemical properties

The primordial shift has taken place in agriculture research and food production. In the past, the principal driving force was to increase the yield potential of food crops and to maximize the productivity and now the drive is focusing on increasing the productivity along with sustainability. For farming systems to remain productive and to be sustainable in long-term it will be necessary to replenish the reserves of nutrients which are removed or lost from the soil. Rice (*Oryza sativa*) is the staple food for more than half of the world's population. About 90 per cent of total rice is grown and consumed in Asia. In India rice is cultivated on an area of 43.79 million hectare with the total production of 112.91 million tonnes with the average productivity of 25.8 q ha^{-1} (Anonymous 2019). Rice is also one of the main food crops grown during the *kharif* season in the state of Himachal Pradesh; where it occupies an area of 71.61 thousand hectares with a total production of 132.49 thousand tonnes and productivity of 1736 kg ha^{-1} (Anonymous 20118). At the current rate of population growth, India has to produce about 130 million tonnes of rice by 2025 to feed the growing population (Anonymous 2012). Meeting the targeted demand of food grains is a challenging task for the policy makers, researchers and all other stakeholders. The problem is still confounded as the targeted increase has to be met in the background of declining resource base (land, water, soil productivity, labour etc.) and increasing environmental and soil health concerns. To safeguard and sustain the food security in India, it is therefore, imperative to explore and evaluate such technologies which may increase the productivity of rice under situations of dwindling resource base particularly when there is little scope of horizontal or lateral expansion. Thus, the increase in production has to be vertical and should come from the same cultivated land by way of increased crop productivity. The System of Rice Intensification (SRI) is a method of rice cultivation developed in an unconventional way now known and being practiced in more than 40 countries. In agricultural systems N has been applied in the form of N-fertilizer, or be derived from atmospheric nitrogen through biological N_2 fixation (BNF). Although, BNF has long been a component of many farming systems throughout the world, its importance as a primary source of nitrogen for agriculture has diminished in recent decades as increasing amounts of nitrogen fertilizers are being used for the production of food and cash crops. However, international emphasis on environmentally sustainable development with the use of renewable resources is likely to focus attention on the potential role of BNF in supplying N for agriculture. Azolla is a free floating water fern which fixes atmospheric nitrogen in association with the cyanobacteria *Anabaena azollae*. The heterocyst of symbiont anabaena is a site of nitrogen fixation. Nitrogen fixation associated with high growth rate can enables azolla to accumulate more than 10 kg N $ha^{-1}day^{-1}$ under optimal growth conditions. In general, a single crop of azolla is known to provide 20-40 kg ha^{-1} N and also increases the availability of both macro and micro nutrients, but this is insufficient to meet the total nitrogen requirement of the target crop. Therefore, the use of azolla in combination with chemical nitrogen fertilizers affords a feasible alternative practice.

In addition to the use of azolla as nitrogen source for rice crop can be used for reclaiming saline soils, reducing evapotranspiration and to control weed infestations in rice crops. It can also be used to purify waste water as it can accumulate P and some heavy metals from water. However, there are some constraints on the production and use of azolla, like the availability and control of water supplies, P limitations in soils, predators of azolla, light intensity, photoperiod, salinity and its temperature sensitivity. Azolla is capable of tolerating a wide range of temperature from 5-45°C, so high-temperature-tolerant azolla species, *azolla microphylla*, can be used in tropical countries to overcome the problem of its sensitivity to high temperatures. This species can survive at temperatures of up to 38±1ºC and can fix nitrogen. Sufficient work has been done on the exploitation of azolla as a biofertilizer in rice in other states of country, however limited systematic studies so far has been conducted in Himachal Pradesh about the usefulness of azolla in rice production (Thakur 2013). Keeping this in view the present study has been done to evaluate the integrated effect of azolla application along with graded doses of inorganic N on rice yield and soil properties.

MATERIAL AND METHODS

Location and climate: The present study was conducted at CSK Himachal Pradesh Agriculture University, Palampur of Himachal Pradesh in the North-Western Himalayas. The experimental farm is situated at 32°6' N latitude and 76°03' E longitude at an altitude of about 1290 meters above mean sea level. The climate of the study area is characterized as wet temperate with mild summers (March–June) and cool winters. The average annual rainfall of the area ranges from 2500 to 3000 mm. In general, a major portion of the rainfall (about 80%) was received during monsoon period from June to September. The weekly maximum and minimum temperature ranged from 23.9 to 30.6 °C and 14.0 to 20.6°C, respectively. The mean relative humidity ranged from 55.6 to 98.3% and total of 2500 mm rainfall were received during the crop season. Soil of the study area was silt loam in texture and was classified as "*Typic Hapludalf*" as per the Taxonomic System of Soil Classification. At the initiation of the experiment the pH of the soil was 5.5. The contents of organic carbon, available nitrogen (N), phosphorus (P) and K were 8.7 g kg, 377.0 kg ha^{-1}, 17.8 kg ha^{-1} and 159 kg ha^{-1}, respectively (Table 1). The 12 treatments which includes azolla application along with fertilizer N (Table 3). The experiment was conducted in randomized block design (RBD) with three replications and the plot size was 10 m^2 (5 m X 2 m).

Nutrient management: Paddy (HPR-2143) was taken as the test crop and was fertilized with different grades of nitrogen fertilizers along with azolla. Azolla has been grown in nursery into three trenches of size 2 x 2 x 0.2 m and leveled uniformly. Water was maintained at a depth of 10 cm. Cattle dung (112.5 g) mixed with water (225 ml) was sprinkled. Azolla inoculum @ 100 g was introduced in each trench. Superphosphate @ 10g was applied in three splits at an interval of 4-days as top dressing. Azolla is a fast growing aquatic fern and doubles in 2 to 3.5 days. After fifteen days azolla was harvested and from one harvest 1.9 kg fresh azolla m^{-2} was obtained. The azolla produced was then collected, which was ready for application in fields. The collected azolla was evaluated for nitrogen (%), N fixation, carbon and nitrogen (C: N) ratio, protein content, phosphorous, potassium, secondary elements (S, Ca and Mg) and micronutrient cations (Fe, Mn, Zn and Cu). The manurial content of the azolla have been given under (Table 2).

Sampling and analysis: Soil samples from a depth of 0-0.15 m from each plot were collected after the harvest of crop and then were air dried and finely grounded to pass through 2 mm sieve and subsequently stored in polythene bags for further analysis. The processed soil samples were analyzed for pH, organic matter, cation exchange capacity, available N, P and K, microbial biomass carbon, urease activity and phytase enzyme following glass electrode method given by Jackson

Table 1. Soil properties before sowing of *kharif*, rice (2016)

Soil property	Value
Water holding capacity (%)	49.38
Bulk density (mg m^{-3})	1.46
Water stable aggregates (<0.1mm)	1.49
Permanent wilting point (%)	16.10
Field capacity (%)	25.81
pH (1: 2.5, soil : water)	5.50
Organic carbon (g kg^{-1})	8.70
Nitrogen (kg ha^{-1})	377.0
Phosphorus (kg ha^{-1})	17.8
Potassium (kg ha^{-1})	159.0
CEC [cmol (p+) kg^{-1}]	8.50
Microbial biomass carbon (µg g^{-1})	113.4
Urease activity (µg g-1 min^{-1})	4.1
Phytase activity (µg inorganic P solid g^{-1} ha^{-1})	0.32

Nursery of paddy (HPR-2143) was raised and further transplanted on 25th June, 2016 at a spacing of 25 cm X 15 cm

(1967) rapid titration method (Walkley and Black, 1934), alkaline permanganate method (Subbia and Asija, 1956), ammonium molybdate blue colour method (Olsen et al 1954), 1N neutral ammonium acetate method (Jackson 1973), ammonium acetate method (Black 1965), fumigation extraction method (Vance et al 1987), urea hydrolysis method (Tabatabai 1972) and Ames (1966) respectively.

RESULTS AND DISCUSSION

Integrated effect of azolla and N fertilizer on productivity of paddy: The maximum paddy grain yield (5.13 t ha^{-1}) was with application of 125 kg N ha^{-1} + 8 tonnes of azolla followed by 100 kg N ha^{-1} + 8 tonnes of azolla (5.10 t ha^{-1}) and 50 kg N ha^{-1} + 8 tonnes of azolla (5.00 t ha^{-1}). An increase of 0.59 per cent was observed with application of 100 kg N ha^{-1} + 8 tonnes of azolla over 125 kg N ha^{-1} + 8 tonnes of azolla (Table 3). The grain yield obtained in all the treatments was significantly higher than the control. However, minimum grain yield i.e. 0.83 t ha^{-1} was observed in control with no application of azolla and N fertilizer. The maximum straw yield of 7.55 t ha^{-1} was in 125 kg N ha^{-1} + 8 tonnes of azolla followed by 100 kg N ha^{-1} + 8 tonnes of azolla, 50 kg N ha^{-1} + 8 tonnes of azolla and 50 kg N ha^{-1} + 8 tonnes of azolla. The increase of 0.80 per cent was observed in 125 kg N ha^{-1} + 8 tonnes of azolla over 100 kg N ha^{-1} + 8 tonnes of azolla. There is an increase of 17.95 per cent in straw yield in 100 kg N ha^{-1} + 8 tonnes azolla over 100 kg N ha^{-1} + 4 tonnes of azolla. Similarly, 100 kg N ha^{-1} + 4 tonnes of azolla produced 21.18 per cent increased straw over 100 kg N ha^{-1}. The straw yield obtained from all the treatments was significantly higher than control. Kumar and Shahi (2016) also reported similar findings on yield of rice with integrated application of azolla and inorganic N fertilizer. The increase in grain and straw yield in all the treatments over control might be due to the continuous addition of N through the application of azolla and inorganic fertilizers, which had significantly increased the biological yield of paddy. Inorganic treatments alone produced higher yield as compared to organic alone because of inability of organic sources to release N at the time of higher requirements by the crop (Castro et al 2003).

Integrated effects of azolla and N fertilizers on soil properties: The pH of the soil samples varied between 5.51 and 5.71 (Table 4). There was an increase in pH of soil after the application of azolla. As azolla is a green manure, rise in pH may be resulted due to the decomposition of azolla that might have reduced Fe and Mn oxides causing the soil pH to rise and secondly mineralization of organic anions to CO_2 and H_2O, thereby removing H^+ ions. Similar results were reported by Singh et al (2006). Similarly, highest organic carbons were r in treatments where, azolla was added and were slightly higher than sole application of inorganic fertilizer. The lowest organic carbon was in control. The organic carbon content in soil is due to successive azolla cropping with rice plants. It has been observed that azolla completely decomposed within 30 days. Azolla biomass may persist in soils for a longer period, and possibly results in an increase in the organic matter content of soil at a faster rate. This is in agreement with (Cisse and Vlek 2003). The cation exchange capacity also increased with the azolla addition and varied in between 8.50 cmol (p+) kg^{-1} to 8.73 cmol (p+) kg^{-1}. The

Table 2. Manurial content of azolla

Parameters	Mean value
Moisture (%)	81.54
C (%)	35
N (%)	4.10
P (%)	1.11
K (%)	4.50
Ca (%)	0.20
Mg (%)	0.21
S (%)	0.49
Zn (mg kg^{-1})	38
Mn (mg kg^{-1})	39
Fe (mg kg^{-1})	7.62
Cu (mg kg^{-1})	16
C:N ratio	9.56
Protein content (%)	25.62
N fixation (n moles $C_2H_4 g^{-1}$ Dwt min^{-1})	13.94

Table 3. Effect of integrated application of azolla and inorganic N fertilizer on grain and straw yield of rice

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
Control	0.83	1.05
50 kg N ha^{-1}	2.33	2.99
100 kg N ha^{-1}	4.03	5.24
125 kg N ha^{-1}	4.47	5.90
4 tonnes of azollaalone	2.67	3.57
50 kg N ha^{-1}+ 4 tonnes of azolla	3.67	4.99
100 kg N ha^{-1}+ 4 tonnes of azolla	4.60	6.35
125 kg N ha^{-1}+ 4 tonnes of azolla	4.87	6.81
8 tonnes of azolla alone	3.80	5.40
50 kg N ha^{-1}+ 8 tonnes of azolla	5.00	7.20
100 kg N ha^{-1} + 8 tonnes of azolla	5.10	7.49
125 kg N ha^{-1} + 8 tonnes of azolla	5.13	7.55
CD (P= 0.05)	0.70	0.97

Table 4. Effect of integrated application of azolla and inorganic fertilizer on soil chemical properties

Treatments	pH	Organic carbon (g kg^{-1})	CEC [cmol (p+) kg^{-1}]	Available N (kg ha^{-1})	Available P (kg ha^{-1})	AvailableK (kg ha^{-1})
Control	5.61	8.70	8.50	365.0	15.50	146.7
50 kg N ha^{-1}	5.61	8.80	8.60	387.3	17.87	162.3
100 kg N ha^{-1}	5.61	8.80	8.60	390.5	18.50	165.4
125 kg N ha^{-1}	5.61	8.80	8.70	395.7	18.70	166.2
4 tonnes of azollaalone	5.63	8.90	8.65	382.0	18.20	162.3
50 kg N ha^{-1} + 4 tonnes of azolla	5.71	8.90	8.70	387.8	18.30	163.4
100 kg N ha^{-1} + 4 tonnes of azolla	5.64	8.90	8.72	395.6	18.50	164.6
125 kg N ha^{-1} + 4 tonnes of azolla	5.51	8.90	8.72	398.4	18.70	167.4
8 tonnes of azolla alone	5.71	8.90	8.69	392.7	18.40	163.7
50 kg N ha^{-1}+ 8 tonnes of azolla	5.65	8.90	8.70	395.9	18.60	165.2
100 kg N ha^{-1} + 8 tonnes of azolla	5.53	8.90	8.71	399.2	18.80	167.8
125 kg N ha^{-1} + 8 tonnes of azolla	5.54	8.90	8.73	402.8	18.87	169.4
CD (P= 0.05)	NS	NS	0.12	13.26	1.61	6.58

highest was in 125 kg N ha^{-1} + 8 tonnes of azolla*,* whereas lowest was recorded in control. This might be due to the continuous release of cations with the decomposition of organic matter which would have increased the CEC of soil (Thakur 2013). Available nitrogen was found significantly higher in the treatment 125 kg N ha^{-1} + 8 tonnes of azolla over all the treatments. The lowest available N content was in control. These results indicate that higher dose of inorganic N along with azolla had increased the nitrogen content of soil. Increase in available N with azolla plus inorganic N application can be explained on the basis of nitrogen mineralized during the decomposition of azolla (Sudadi and Sumarno 2014). The release of nitrogen from azolla species was faster than from sesbania as the C: N of azolla is quite low in comparison to sesbania. Singh et al (2005) also reported the similar results. Available phosphorus and potassium did differ significantly among all the treatments. Numerically higher value was recorded in the treatment 125 kg N ha^{-1} + 8 tonnes of azolla, which was significantly higher than control, 50 kg N ha^{-1} and 4 tonnes of azolla alone, whereas it was significantly at par with the rest of the treatments. Lowest available K was recorded in control. Singh et al (2006) also reported that application of azolla in combination with urea showed higher available K in soil. Increase in available potassium over control with the addition of azolla might be due to reduction in potassium fixation and release of potassium due to interaction of organic matter with clay, besides the direct addition to the soil pool (Urkurkar et al 2010).

CONCLUSIONS

The highest grain and straw yield under paddy was with 125 kg N ha^{-1} + 8 tonnes of azolla followed by 100 kg N ha^{-1} along with 8 tonnes of azolla the treatment. Similarly, rise in pH over initial pH was observed in almost all the treatments with integrated application of inorganic fertilizers along with azolla. Similarly, other chemical properties of soil have also showed an increase over initial values, where integrated application of inorganic fertilizer and azolla has been done.

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