Original Research Article

Soil Fertility as influenced by incorporation of K enriched azolla

Abstract

Use of chemical fertilizer injudiciously without organic manure has created many soil health problems. Therefore, alternate sources of N has to be evolved to supply crop demanded N with less or no environmental pollution. Biological Nitrogen Fixation (BNF) is a major source of fixed N for plant life and to sustain production and productivity of agricultural crops. All other biofertilizers simply solubilize or mobilize the nutrients that are already present in soils. Whereas the *Azolla* is unique in the sense that it acts as host to the N-fixing cyanobacteria after which it is used virtually as a green manure. An incubation experiment was conducted by growing *Azollae filiculoides* with 2 agriculturally important potassic fertilizers (Potassium Chloride, Potassium shulphate) as main plot in seven concentrations (0, 5, 10, 20, 30, 40 and 50 ppm of K) as sub-plots laid down in split plot design replicated thrice. The collected azolla was incorporated with soil @ 10 t / ha and maintained at two moisture condition such as 60 and 100 percent and assessed soil fertility by estimating various available plant nutrients and organic carbon status. Soil fertility is influenced by the humic substances formed during the decomposition of Azolla. The mean organic carbon content of soil was 0.657 and 0.525 % by K enriched azolla at 60 and 100 % moisture contents respectively. Application of 10 tons/ha of manure were able to increase soil organic C by 24.4% compared to control (Syamsiyah *et al*. 2015). The available N content ranged from 216.2 to 327.3 and 191.1 to 285.3 kg / ha from 0 to 40 ppm of K concentration at 60 and 100 % moisture respectively because the Azolla has a high N content and released into the soil after decomposition. Azolla also contributes to the supply of Phosphorus, Potassium, Sulfur, Zinc, Iron and Molybdenum in sufficient amounts in addition to other micronutrients besides addition of Nitrogen. Among the various concentration, 40

and 50 ppm K were significantly maintained higher and equal soil available P status of 75.17 and 77.33 kg / ha respectively. The fertilizer, K_2SO_4 with 30, 40 and 50 ppm at 60 % moisture content and 40 and 50 ppm of K_2SO_4 and 40 ppm of KCl produced statistically higher and equal available K in azolla incorporated soil maintained at 100 % moisture. The soil biological health, mineralization and consequent increase in nutrient status by the application of K enriched Azolla was more under 60 % soil moisture content than fully saturated soil.

Introduction

Intensive crop production is the demand of time to feed the vast growing population in India. This has created a pressure to use more chemical fertilizer. Use of chemical fertilizer injudiciously without organic manure has created many soil health problems like low fertilizer use efficiency, poor soil physical condition, reduced water holding capacity, degraded rhizospharic properties, and low fertility (Awodun, 2008). Rice crops remove around 16-17 kg N for the production of each ton of paddy cultivation (Sahrawat, 2000). Most of the rice soils of the world are deficient in N, so, fertilizer N applications are required to meet its N demand. Generally, urea is applied as the N source for rice production. But the efficiency of added urea-N is very low, due to denitrification, NH_3 volatilization and leaching (De Datta and Buresh. 1989). Therefore, alternate sources of N has to be evolved to supply crop demanded N with less or no environmental pollution. The demand of fertilizers and manures is increasing at the present days scenarios to maximize the crop production. Biological Nitrogen Fixation (BNF) is a major source of fixed N for plant life and to sustain production and productivity of agricultural crops. Estimate of global terrestrial showed that the BNF ranged from 100 to 290 million tonnes of N / year. Of this, 40–48 million tonnes is estimated to be biologically fixed in agricultural crops and fields. BNF is one of the natural sources of nitrogen for rice and *Azolla*-cyanobacteria biomass has been identified as potential source of nitrogen. The integrated nutrient management is to maintain or adjust plant nutrient supply to achieve a given level of crop production by optimizing the benefits from all possible sources of plant nutrients (Subba Rao, 2005). Organic manures are considered to play a significant role in nutrient contribution. The use of organic fertilizer is a way to improve soil fertility. Azolla can be used as organic fertilizer (Syamsiyah *et al*., 2015). Subedi and Shrestha (2015) explained that Azolla does not only increase the productivity of rice but also improve the long-term soil fertility. All other biofertilizers simply solubilize or mobilize the nutrients that are already present in soils. Whereas the *Azolla* is unique in the sense that it acts as host to the N-fixing cyanobacteria after which it is used virtually as a green manure. In the process, it adds not only the biologically fixed N but also the other nutrients absorbed from the soil and present in its biomass. Against the total anticipated biofertilizers demand of 1 million tonne in the country, the current supply position is very low (<10 000 tonnes). The present investigation studied soil fertility improvement by azolla grown under varied K fertilizer commonly used in agriculture.

Materials and Methods

An incubation experiment was conducted by growing *Azollae filiculoides* with 2 agriculturally important potassic fertilizers (Potassium Chloride, Potassium shulphate) as main plot in seven concentrations (0, 5, 10, 20, 30, 40 and 50 ppm of K) as sub-plots laid down in split plot design replicated thrice. One gram of Azolla fern was grown in a tray with a dimension of 23 x 15x 6 cm^3 filled with 1.5 litres of potassic solutions and the fern was collected on 7th, 15th, 30th , 60th , 90th and 120th day after incubation / culturing, rinsed with distilled water and analysed for various biometric and biochemical parameters. The collected azolla was incorporated with soil @ 10 t / ha and maintained at two moisture condition such as 60 and 100 percent. The azolla incorporated soil was collected after 30 days of incubation, processed and analyzed for various available plant nutrients and organic carbon status. Organic carbon present in soil is oxidised by chromic acid ($K_2Cr_2O_7$) in the presence of conc. H_2SO_4. Potassium dichromate on reaction with H_2SO_4 provides nascent oxygen which combines with carbon and forms CO_2. The excess chromic acid left unused by the organic matter is determined by back titration with 0.5 N ferrous sulphate or ferrous ammonium sulphate using diphenylamine indicator (Walkley and Black, 1934). Available nitrogen in soil is estimated by alkaline permanganate method (Subbiah and Asija, 1956). Available phosphorus extracted with 0.03 N NH_4F and 0.025 N HCl. The amount of P extracted is treated with ammonium molybdate and antimony potassium tartarate and developed colour with ascorbic acid. The intentensity of blue colour is determined colorimetrically at 660 nm (Bray *et al*., 1945). The soil is leached with neutral normal ammonium acetate and the K^+ ions in the exchange sites are replaced by NH_4^+ ions. The K^+ ions in solution is then determined with the flame photometer (Standford and English (1949).

Results

Organic carbon

The effect of K fertilizer, its concentration and their interaction on the organic carbon content of azolla incorporated soil at 60 % and 100 % moisture content is presented in Table 1 and 2. The concentration of K fertilizer alone influenced the organic carbon content of the azolla incorporated soil incubated at both 60 % and 100 % moisture status. The mean organic carbon content of soil was 0.657 and 0.525 % by K enriched azolla at 60 and 100 % moisture contents respectively. Azolla enriched with 40 ppm K solution recorded significantly superior and higher soil organic carbon content of 0.763 and 0.623 % respectively at 60 and 100 % soil moisture status (Table 1) which was 42 and 56 % more than the control (azolla grown under 0 ppm K). However it was on par with 50 and 30 ppm of K solution in both the moisture maintained soil. The 20 ppm K registered 0.697 and 0,567 % of organic carbon content in soil maintained at 60 and 100 % moisture which were 9 to 10 % less than the highest organic carbon maintained by 40 ppm of K.

Available N

The main effect of azolla grown under K fertilizer and its concentration alone significantly influenced the available N content at both 60 and 100 % moisture status. On an average 291.9 and 256.9 kg / ha of available N was maintained by the incorporation of K enriched azolla in soil maintained at 60 and 100 % moisture respectively (Table 1). Among the K. fertilizer, K_2SO_4 significantly maintained higher available N status of 297.2 and 262.2 kg / ha and it was 4 to 5 % higher than the KCl which registered 286.6 and 251.6 kg / ha of soil available nitrogen content at 60 and 100 % moisture respectively. The available N content ranged from 216.2 to 327.3 and 191.1 to 285.3 kg / ha from 0 to 40 ppm of K concentration at 60 and 100 % moisture respectively. Though the 40 and 50 ppm of K were on par with each other they maintained significantly higher available N status of 327 and 285 kg/ha at 60 and 100 % moisture status respectively and it was 4 percent higher than 30 ppm of K enriched azolla.

Available P

The main and interaction of fertilizer and their concentration significantly influenced the available P status of azolla incorporated soil maintained at 100 % moisture where as the main effect was alone significantly influenced the available P content at 60 % moisture condition. On an average, the K enriched azolla registered 59.63 and 42.13 kg / ha of

Table 1. Soil fertility of K enriched Azolla as influenced by main effect of fertilizer and concentration at 60 and 100 % moisture condition

Soil Fertility Parameters	Organic Carbon (%)		Available N (Kg/ha)		Available P (Kg/ha)		Available K (Kg/ha)	
Moisture	**60 %**	**100 %**	**60 %**	**100 %**	**60 %**	**100 %**	**60 %**	**100 %**
Fertilizer								
F_1 (KCl)	0.644	0.513	286.6^{b}	251.6^{b}	57.54^{b}	40.04^{b}	205.1^{b}	160.9^{b}
F_2 (K_2SO_4)	0.670	0.538	297.2^{a}	262.2^{a}	61.71^{a}	44.21^{a}	215.5^{a}	171.3^{a}
Mean	**0.657**	**0.525**	**291.9**	**256.9**	**59.63**	**42.13**	**210.3**	**166.1**
SEd	0.006	0.006	1.17	1.16	0.85	0.85	1.02	1.02
CD (0.05)	NS	NS	5.02	5.0	3.68	3.68	4.40	4.4
Concentration								
C1 (0 ppm)	0.518^{f}	0.398^{e}	216.2^{g}	191.2^{g}	34.50^{g}	22.50^{f}	157.8^{g}	125.8^{f}
C2 (2 ppm)	0.552^{e}	0.422^{e}	266.8^{f}	236.8^{f}	44.50^{f}	29.50^{e}	172.5^{f}	135.5^{e}
C3 (5 ppm)	0.587^{d}	0.457^{d}	280.0^{e}	250.0^{e}	51.67^{e}	36.67^{d}	190.2^{e}	153.2^{d}
C4 (10 ppm)	0.632^{c}	0.502^{c}	296.2^{d}	259.2^{d}	57.83^{d}	39.83^{c}	204.5^{d}	162.5^{c}
C5 (20 ppm)	0.697^{b}	0.567^{b}	307.5^{c}	270.5^{c}	64.83^{c}	46.83^{b}	219.3^{c}	177.3^{b}
C6 (30 ppm)	0.755^{a}	0.622^{a}	314.0^{b}	277.0^{b}	71.17^{b}	53.17^{a}	238.7^{b}	189.7^{a}
C7 (40 ppm)	0.763^{a}	0.623^{a}	327.3^{a}	285.3^{a}	75.17^{a}	53.17^{a}	250.0^{a}	195.0^{a}
C8 (50 ppm)	0.753^{a}	0.613^{a}	327.2^{a}	285.2^{a}	77.33^{a}	55.33^{a}	249.5^{a}	189.5^{a}
Mean	**0.657**	**0.525**	**291.9**	**256.9**	**59.63**	**42.13**	**210.3**	**166.1**
SEd	0.011	0.013	2.96	3.0	1.08	1.07	2.89	2.89
CD (0.05)	0.023	0.235	6.06	6.1	2.20	2.19	5.93	5.92

Table 2. Soil fertility of K enriched Azolla as influenced by interaction effect between fertilizer Vs concentration at 60 % and 100 % moisture condition

Soil Fertility Parameters	Organic Carbon (%)		Available N (Kg/ha)		Available P (Kg/ha)		Available K (Kg/ha)	
Moisture	**60 %**	**100 %**	**60 %**	**100 %**	**60 %**	**100 %**	**60 %**	**100 %**
F_1C_1	0.510	0.390	214.3	189.3	33.33^{j}	21.33^{j}	156.3^{f}	124.3^{h}
F_1C_2	0.543	0.413	263.7	233.7	44.00^{i}	29.00^{i}	171.3^{e}	134.3^{f}
F_1C_3	0.577	0.447	278.0	248.0	51.67^{h}	36.67^{h}	187.3^{d}	150.3^{e}
F_1C_4	0.617	0.487	287.0	250.0	56.67^{g}	38.67^{gh}	195.3^{d}	153.3^{e}
F_1C_5	0.670	0.540	302.7	265.7	61.00^{f}	43.00^{f}	207.0^{c}	165.0^{d}
F_1C_6	0.727	0.593	307.3	270.3	65.00^{e}	47.00^{e}	226.0^{b}	177.0^{c}
F_1C_7	0.757	0.617	319.7	277.7	73.00^{c}	51.00^{d}	249.3^{a}	194.3^{ab}
F_1C_8	0.753	0.613	320.3	278.3	75.67^{bc}	53.67^{cd}	248.3^{a}	188.3^{b}
F_2C_1	0.527	0.407	218.0	193.0	35.67^{j}	23.67^{j}	159.3^{f}	127.3^{h}
F_2C_2	0.560	0.430	270.0	240.0	45.00^{i}	30.00^{i}	173.7^{e}	136.7^{f}
F_2C_3	0.597	0.467	282.0	252.0	51.67^{h}	36.67^{h}	193.0^{d}	156.0^{e}
F_2C_4	0.647	0.517	305.3	268.3	59.00^{fg}	41.00^{fg}	213.7^{c}	171.7^{cd}
F_2C_5	0.723	0.593	312.3	275.3	68.67^{d}	50.67^{d}	231.7^{b}	189.7^{b}
F_2C_6	0.783	0.650	320.7	283.7	77.33^{ab}	59.33^{a}	251.3^{a}	202.3^{a}
F_2C_7	0.770	0.630	335.0	293.0	77.33^{ab}	55.33^{bc}	250.7^{a}	195.7^{ab}
F_2C_8	0.753	0.613	334.0	292.0	79.00^{a}	57.00^{ab}	250.7^{a}	190.7^{b}
Mean	0.657	0.525	291.9	256.9	59.63	42.13	210.3	166.1
SEd								
F at C	0.016	0.017	4.08	4.09	1.66	1.65	3.96	3.96
C at F	0.016	0.016	4.18	4.19	1.52	1.51	4.09	4.09
CD (0.05)								
F at C	NS	NS	NS	NS	4.39	4.39	8.71	3.9
C at F	NS	NS	NS	NS	3.11	3.11	8.38	4.1

available P at 60 and 100 % soil moisture respectively. Among the fertilizers used, the K_2SO_4 was superior and maintained higher available P content of 61.71 and 44.21 kg / ha in the soil incorporated with K enriched azolla at 60 and 100 % moisture respectively followed by KCl which registered the available P content of 57.54 and 40.04 kg / ha (Table 1). Among the various concentration, 40 and 50 ppm K were significantly maintained higher and equal soil available P status of 75.17 and 77.33 kg / ha respectively which was 8.6 percent more than the 30 ppm K (71.17 kg / ha) at 60 % moisture content. But in 100 % soil moisture condition, 30, 40 and 50 ppm K were significantly maintained higher and on par soil available P status followed by 20 ppm K. The lowest available P of 34.5 and 22.5 kg / ha was registered by soil incorporated with azolla enriched with 0 ppm of K at 60 and 100 % moisture condition. Under the interaction between K fertilizer and its concentration, K_2SO_4 at 50 and 30 ppm were significantly superior in maintaining higher available P status at 100 % moisture content followed by 40 ppm K_2SO_4 and it was on par with 50 ppm of KCl (Table 2). However, the 0 ppm of both the fertilizer produced lowest available P content (21.33 and 23.67 kg / ha) of azolla incorporated soil.

Available K

The available K content of soil incorporated with K enriched Azolla was significantly influenced by the main and interaction effect of K fertilizer and its concentration. Irrespective of the fertilizer and their concentration about 210.3 and 166.1 kg / ha of available K was maintained by the incorporation of K enriched azolla in soil at 60 and 100 % moisture respectively (Table 1). Among the K fertilizer, K_2SO_4 was superior in maintaining available K content (215.5 and 171.3 kg / ha) in azolla incorporated soil which was 5 -7 per cent more than the KCl (205.1 and 160.9 kg / ha). With respect to concentration of K, 40 and 50 ppm of K at 60 % moisture and 30,40 and 50 ppm of K at 100 % moisture registered significantly higher and equal available K in azolla incorporated soil followed by 30 and 20 ppm of K at 60 and 100 % moisture respectively. The azolla grown under 0 ppm of K registered the lowest available K content of 157.8 and 125.8 kg / ha at 60 and 100 % moisture respectively. Under the interaction between K fertilizer and its concentration, K_2SO_4 with 30, 40 and 50 ppm at 60 % moisture content and 40 and 50 ppm of K_2SO_4 and 40 ppm of KCl produced statistically higher and equal available K in azolla incorporated soil maintained at 60 and 100 % moisture respectively (Table 2). The 0 ppm of both the fertilizer registered the lowest available K content (159.3 and 156.3 kg / ha) in soil incorporated with azolla grown under these concentration at both moisture content.

Discussion

Soil fertility is influenced by the humic substances formed during the decomposition of Azolla (Bhardwaj and Gaur 1970). Incorporation of Azolla enhanced the soil nutrients availability by their biological activity. The decomposed organic matter from Azolla biomass plays an active role in the development of microbial population. Similarly, Kannaiyan and Subramani (1992) showed the increased cellulolytic and urea hydrolyzing activities in addition to significant increase in the population of heterotrophic bacteria by the added Azolla. Soil incorporation of Azolla also increased urease and phosphatase activity (Thanikachalam *et al*. 1984). Azolla contains macro, secondary and micronutrients that is important for quality rice production (Kumar and Shahi, 2016). Sutanto (2002) stated that use of 7.5 ton ha^{-1} Azolla to paddy field increased soil organic matter (C-organic) 0.09 times of control (without Azolla). Syamsiyah *et al*. 2015 proved that application of Azolla @ 2 tons/ha could increase the organic matter up to 3.69 % compare to the field without Azolla. The increasing of organic C is caused by the high content of organic C in Azolla. The incorporated Azolla into soil would soon be mineralized. Watanabe *et al*, (1991) stated that 90% of Azolla was decomposed in 4 weeks and releases humic substances in to the soil. The increase in grain yield might be due to build up of soil organic carbon and more nitrogen through the integrated use of NPK and green manuring with Azolla.

Biological Nitrogen Fixation (BNF) is a major source of fixed N for plant life and to sustain production and productivity of agricultural crops. Estimate of global terrestrial showed that the BNF ranged from 100 to 290 million tonnes of N / year. Of this, 40–48 million tonnes is estimated to be biologically fixed in agricultural crops and fields. BNF is one of the natural sources of nitrogen for rice and *Azolla*-cyanobacteria biomass has been identified as potential source of nitrogen. The glutamate synthase enzyme dominated in ammonia assimilation followed by glutamine synthates and glutamate dehydrogenase in Azolla (Fig, 1). The activity of all the three enzymes were more at the 40 ppm of K followed by 30 and 50 ppm of K. Incorporation of 40 ppm K either as KCl and K_2SO_4 incubated azolla enhanced ammonia assimilation and improved soil fertility (Fig. 2) on 30 days which may help to reduce nitrogen demand for rice crop (Muruganayaki, 2017).

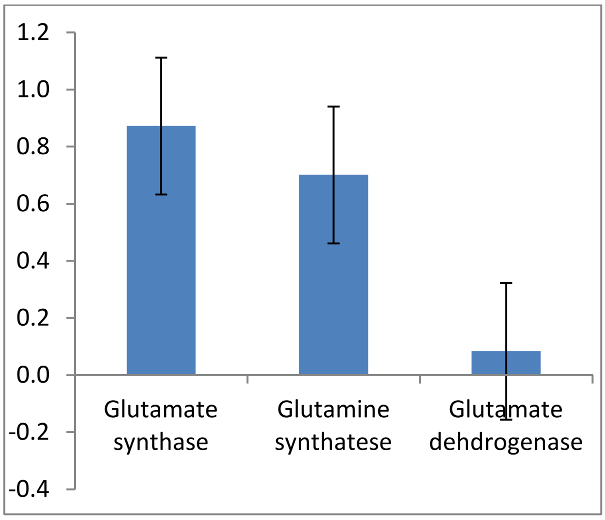

Fig 1. Nitrogen assimilating enzymes as influenced by K fertilizer

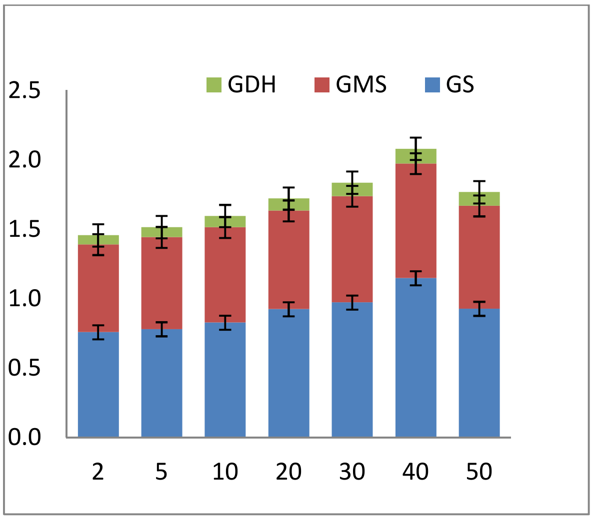

Fig 2. Nitrogen fixing enzyme as influenced by concentration of fertilizers

According to Roy, 1981 incorporation of 6 t of *Azolla*/ha, equivalent to 36 kg of N/ha before planting and incorporation of 1 t/ha *Azolla*, equivalent to 24 kg N/ha after 3-4 days of planting. Fogg *et al*. 1973 have found that *Azolla* and cyanobacteria bio-fertilizer can add as much as 30-120 kg N / ha per crop. Many researchers have considered cyanobacteria as a promising source of nitrogen in tropical rice soils. (Valiente *et al*., 1998) investigated the potential contribution of N_2 fixation by indigenous cyanobacteria to rice soil with increasing amount of fertilizers. Ventura *et al.* (2012) concluded that about 50% of the N in Azolla was mineralized after 2 weeks of incubation with more than 3% N content. Use of azolla as green manuring and as intercrop proved beneficial and significant result over control in respect of P content. The highest available phosphorus (29.6 kg ha^{-1}) was recorded with 100% NPK + green manuring of azolla (Kumar and Shahi, 2016). Azolla also contributes to the supply of Phosphorus, Potassium, Sulfur, Zinc, Iron and Molybdenum in sufficient amounts in addition to other micronutrients besides addition of Nitrogen. Similarly, the soil biological health due to application of Azolla has resulted in improving mineralization and consequent increase in the soil microbial status (Yadav *et al*. 2014).

Conclusion

Soil biological health, mineralization and nutrient status by the application of K enriched Azolla was more under 60 % soil moisture content than fully saturated soil. Further, enrichment of azolla with 40 ppm of K_2SO_4 enhanced nutrient content in azolla and subsequently in soil.

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