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Temporal soil fertility with organic nitrogen sources in acidic soil of Meghalaya

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Rice (*Oryza sativa* L.) constitutes staple food for a large part of world's human population, especially in Asia. It is the agricultural commodity with the third highest worldwide production of 769.6 mt in 2017 with about 90% contribution from Asia. China was the leading global producer of rice with 212.7 mt followed by India (168.5 mt) in 2017 (FAOSTAT 2017), whereas in Meghalaya it is limited to 3.0 lakh tonnes (GoM 2016). The energy crisis and high fertilizer costs have already created considerable concern, and the use of organic materials as sources of plant nutrients has been viewed important option.

The use efficiency of N from fertilizer sources in lowland rice is low (30–50%), because of its losses from soils through various chemical and biochemical processes. It has, therefore, become necessary to look for alternative renewable resources to meet at least a part of the N-demand of rice crops. N-fixing BGA and *Azolla* have been shown to be the most important in maintaining and improving the productivity of rice fields. *Azolla* is a free-floating water fern that floats in the water and fixes atmospheric N because of its association with the N fixing cyanobacterium *Anabaena* (Singh *et al.* 2018).

An *Azolla-Anabaena* system is ideal for the cultivation of rice under tropical conditions because of its ability to fix atmospheric N and capacity to multiply at faster rates (Asghar *et al.* 2018). An investigation was carried out at CAU, Umiam, Ri-Bhoi district of Meghalaya during *kharif* 2017 to study the temporal soil fertility build-up with N application through urea and *Azolla* under lowland rice cultivation in acidic soil. The experimental soil was having *p*H 5.1, SOC 1.75%, available N, P and K as 288.6, 17.2 and 201.5 kg/ha, respectively. The field trial was laid out in RBD with six treatments and four replications, viz. control (T_1), *Azolla* incorporation on fresh weight basis @16000 kg/ha (T_2), 30 kg N/ha through urea (T_3), 60 kg N/ha through urea (T_4), 30 kg N/ha through urea + *Azolla* incorporation @16000 kg/ha (T_5) and 60 kg N/ha through urea with *Azolla* incorporation @16000 kg/ha (T_6). The N, P and K content in *Azolla* on dry weight basis was 4.2, 0.6 and 1.9%, respectively.

The soil samples from each plot were collected by core sampling at 30, 60, 90 days after transplanting and at maturity of rice crop and analysed for available N P, K and organic C by standard methods. The results revealed a decreasing trend of available N with advancement of crop age (Table 1). The combined application of *Azolla* and urea in T_5 and T_6 exhibited significant effect on available N in the soil at 90 DAT and at maturity. The T_6 treated plot had significantly greater available N at 30 DAT and at maturity i.e. 319.37 kg/ha and 290 kg/ha followed by T_5 treated plot in comparison to control and other treatments plots. The T_5 and T_6 treatments registered 20.6 and 27.2% higher available N than the control in soil samples collected at maturity. Available N varied from 227.5 kg/ha under control (T_1) in the soil samples collected at maturity to 319.4 kg/ha under T_6 at 30 DAT. Available N in T_6 was significantly higher over T_4; T_5 showed superiority over T_3 with advancement in crop age. Also T_2 was significantly better than T_1. The values of available nitrogen obtained in T_5 at all the crop age(s) i.e. 30, 60, 90 DAT and at maturity were statistically at par with the available nitrogen values of T_4, whereas available nitrogen estimated in T_3 was statistically at par with T_2 at all the crop age(s). At 30 DAT available N was more in T_2 (299.6 kg/ha) as compared to T_4 (299.8 kg/ha). But at 60 and 90 DAT, available N was lower in T_2 than in T_4, however the trend reversed at maturity (T_2>T_4). The higher availability of N with combined use of N sources of *Azolla* and urea might be due to the enhanced microbial activities and higher rate of mineralization of soil organic N with advancement of crop age whereas, the higher soil available N in organic treatments might be due to a higher N fixation by micro-organisms that led to better soil condition and also due to the nutrient release pattern from *Azolla*. The higher soil available N in T_4 as compared to T_2 and T_1 might be due to faster mineralization. The lower content in control plots is a result of mining of available N with continuous cropping without fertilization during the crop period. These results are in line with the findings of Asghar *et al.* (2018) who also observed that available N content

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Table 1 Temporal availability of soil N, P and K (kg/ha) with nitrogen application through urea and *Azolla* under low land rice cultivation in acidic soil

Treatment	30 DAT			60 DAT			90 DAT			At maturity		
	N	P	K	N	P	K	N	P	K	N	P	K
T_1	279.95	15.15	193.04	252.45	15.01	181.95	235.95	14.97	179.95	227.45	14.91	160.95
T_2	299.56	21.98	202.41	281.06	20.23	190.91	270.56	19.23	188.16	266.56	18.76	177.66
T_3	292.88	15.99	195.63	280.37	15.80	187.88	265.87	15.67	181.58	256.87	15.45	167.63
T_4	299.84	16.15	198.84	282.09	16.05	189.84	276.59	15.98	185.09	263.59	15.92	173.59
T_5	312.38	23.94	206.99	295.49	21.49	197.49	288.99	20.86	192.99	274.74	19.74	181.59
T_6	319.37	24.13	217.32	311.48	23.35	210.82	302.48	22.08	201.82	289.98	20.63	192.32
SE(m)±	13.97	0.91	9.39	13.88	1.12	8.99	12.36	0.93	8.48	11.98	0.88	8.19
CD (P=0.05)	NS	2.73	NS	NS	3.36	NS	37.23	2.79	NS	36.08	2.65	NS

in soil increased with the use of recommended dose of N fertilizer in combination with organic manures.

The combined application of *Azolla* and urea exhibited a significant effect on available P in the soil. The T_6 treated plot had significantly greater available P (24.13 P_2O_5 kg/ha and 20.63 P_2O_5 kg/ha) at 30 DAT. The T_5 and T_6 treatments registered 24 and 29.4% higher available P than the control at maturity stage. Available P varied from 14.91 P_2O_5 kg/ha under control (T_1) in the soil samples collected at maturity to 24.13 P_2O_5 kg/ha under T_6 at 30 DAT (Table 1). Further, it was also observed that available P in T_6 was significantly higher over T_4, whereas T_5 was better than T_3 along the crop growth period. Also, T_2 showed significant increase in available P over T_1.

The higher soil available P in combined treatments might be due to higher content of organic C and thus help converting the immobilized P into labile or inorganic P. The increase of available P could also be explained by better soil condition and subsequently lesser P fixation. Incorporation of *Azolla* in combination with urea recorded higher content of P in soil may be attributed to higher addition of organic matter which helped in releasing the higher amounts of P from the soil. Organic manure enhanced the labile P in the soil through complexation of cations like Ca^{+2} and Mg^{+2} when it is applied in combination with urea. Generally, addition of organic manures with chemical fertilizers had beneficial effect in increasing the phosphate availability (Bhuvaneshwari and Singh 2015).

The soil available K content was not affected by treatments significantly (Table 1). However, T_6 treated plot had highest available K at 30 DAT and in the soil samples collected at maturity stage of the crop followed by T_5 treated plot. The T_5 and T_6 treatments registered 12.8 and 19.5% higher available K than the control at the maturity stage soil. The enhanced K availability could be attributed to the combined source of nutrients which activated the soil biologically, thereby increased the mineralization of organic K from manures (Singh *et al.* 2005). The beneficial effect of organic manure on available K may also be ascribed to the reduction of K fixation and release of K due to the integration of organic matter with clay, besides the direct K addition to the soil K pool (Urkurkar *et al.* 2010).

The combined application of *Azolla* with urea significantly increased the soil organic C as compared to urea alone at maturity (Table 2). The highest (2.22%) value was observed in T_6 followed by 2.14% in T_5 at 30 DAT whereas the lowest (1.55%) was observed in T_1 (Control) at maturity. The T_5 and T_6 treatments registered 29.7 and 35.5% higher soil organic C than the control in the maturity soil samples. The significant increase in soil organic C with the combined application of *Azolla* along with urea in comparison to urea alone may be attributed to the inclusion of fresh *Azolla* biomass in large quantity (16000 kg/ha) which added humus to the soil and thus mass per unit volume decreased, resulting in increased organic C content (Bhuvaneshwari and Singh 2015). In combination treatments, urea enhanced root growth leading to accumulation of more organic residues in the soil. The increase in organic C content in the *Azolla* combination is also attributed to the direct incorporation of *Azolla* into the soil. The subsequent decomposition of *Azolla* over time might have resulted in the enhanced organic C content in the soil. Addition of organic nutrient source might have created environment conducive for formation of humic acid and stimulated the activity of soil micro-organism, resulting increased organic C content of the soil (Srilatha *et al.* 2013).

Table 2 Temporal availability of SOC (%) with nitrogen application through urea and Azolla under low land rice cultivation in acidic soil

Treatment	30 DAT	60 DAT	90 DAT	At maturity
T_1	1.64	1.61	1.58	1.55
T_2	2.05	2.02	1.95	1.93
T_3	1.68	1.64	1.61	1.58
T_4	1.71	1.68	1.65	1.60
T_5	2.14	2.09	2.05	2.01
T_6	2.22	2.18	2.12	2.10
SE(m)±	0.17	0.15	0.16	0.12
CD (P=0.05)	NS	0.44	NS	0.37

The investigation demonstrated that application of 60 kg N/ha through urea with *Azolla* incorporation @16000 kg/ha (T_6) was found most effective in maintaining a steady pool of soil available N, P, K and organic C and also improving the temporal soil nutrient availability as compared to sole application of organic manure or chemical fertilizers. Therefore, this may be applied in Meghalaya and other similar regions for getting optimum production of rice in acidic soils.

SUMMARY

A field experiment was conducted at CAU, Umiam, Meghalaya during *kharif* 2017 to investigate the effect of nitrogen application through urea and *Azolla* on temporal soil fertility build-up under low land rice cultivation at 30, 60, 90 days after transplanting (DAT) and at maturity in acidic soil. The experiment consists of six treatments with and without *Azolla* incorporation laid out in RBD with four replications. The application of 60 kg N/ha through urea along with *Azolla* incorporation @16000 kg/ha (T_6) recorded highest available N (289.98 kg/ha) after harvest which was significantly superior over control (227.45 kg/ha) with 9.1% increase. Similarly, this treatment recorded highest available P, K and OC i.e. 20.6, 192.3, 2.1 kg/ha after harvest followed by T_5 and T_2. Further, it was also observed that available P, K and OC in T_6 were statistically significant over T_4 whereas T_5 was significant over T_3 with respect to advancement in crop age.

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