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Integrated Nutrient Management Boosts Productivity and Help Maintaining Sustained Yield of Upland Paddy under Jhum Cultivation in Hilly Region of Northeast India

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ABSTRACT

Background: Replenishing the lost nutrients through the use of various soil amendments is vital in order to maintain soil fertility for sustained productivity in jhumlnd. Integrated Nutrient Management, can boost the upland rice productivity in jhumland by building up the lost soil nutrients.

Methods: The study was conducted to evaluate the impact of integrated nutrient management on growth and yield of upland paddy (*Oryza sativa* L.) in Lai-Lad, Jirang Block of Ri-Bhoi District, Meghalaya, India; during 2019 and 2020. Randomised block design with 12 treatments was applied for the trial with 3 replications.

Result: Application of 100% recommended doses of fertilizers + fa rmyard manure + *Azospirillum lipoferum* + phosphorus solubilizing bacteria + potassium mobilising bacteria + *Glomus* + zinc solubilizing bacteria (T_{10}) significantly increased plant growth in both years of cultivation. Grain yield, harvest index and benefit cost ratio of upland paddy were at par among the treatments and were higher in 2nd cropping year. Integrated nutrient management could increase the growth characters, maintain sustained yield and economic profitability of upland paddy in hilly terrains of north-east India, under jhum cultivation.

Key words: Economics, Growth characters, Integrated nutrient management, Upland paddy, Yield characters.

INTRODUCTION

Shifting cultivation is the most prevalent form of agriculture in North eastern part of the country, including the state of Meghalaya. Direct-seeded upland paddy forms the major crop in jhum cultivation (Borah *et al*., 2016). However, the production is constrained mainly due to deficiency in soil nutrients and moisture resulting in a poor socio-economic condition of these rainfed farmers. This makes the practice short and when the crop yield begin to decrease due to nutrient loss after cropping phase, the farmers migrate to the new patch of land. Therefore, the system needs a new approach of nutrient management for making it relevant for cultivating crops on a long term basis.

After slashing and burning of vegetation the jhum cultivators grow upland paddy for one year and abandon the land in search of a new area for cultivation, due to perceived decline in productivity because of reduced soil fertility. It is assumed that if the cropping phase in jhum cultivation system is extended even for one more year may reduce deforestation and land degradation in hilly region. However, maintaining the soil fertility by replenishing the lost nutrients through the use of various soil amendments is vital in order to have extended cropping phase with sustained productivity. Use of only conventional fertilizers management practices results in a great harm to rice productivity on sustained basis in rainfed upland ecosystem, but their integrated use may boost production on sustained basis (Dass *et al*., 2009). Thus, it is expected that integrated nutrient management (INM), can enhance the upland rice productivity in jhumland but supportive data on application of INM in upland paddy is meagre. Therefore, the present investigation was conducted to study the INM effect on upland paddy cultivation with an aim to obtain sustainable productivity in crop yield in jhum lands of Meghalaya, India.

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MATERIALS AND METHODS

The study was conducted at Lai-Lad, Jirang Block of Ri-Bhoi District, Meghalaya, India during 2019 and 2020 under the affiliation of Mizoram University, Aizawl, Mizoram. The experimental plot was Sandy Clay-Clayey in texture, lies within 25°56′61″N latitude and 91°45′90.3″ E longitude with an elevation of 226 m msl and a slope of 40°. The average annual temperature and average annual rainfall in Ri-bhoi

District are 21.8°C and 3200 mm, respectively (The District Level Task Force, 2019).

The experiment was laid out in a current year jhum land after slashing and burning the vegetation with randomized block design and having 12 treatment combinations for two consecutive years *i.e.*, T_1 [Control], T_2 [100% recommended doses of fertilizers (RDF)], T_3 [100 % RDF+farm yard manure (FYM)], T_4 [100% RDF+*Azospirillum lipoferum*], T_5 [100% RDF+*Glomus*], T_6 [100% RDF+zinc solubilizing bacteria (ZnSB)], T_7 [100% RDF+phosphorus solubilizing bacteria (PSB)], T_8 [100% RDF+potassium mobilising bacteria (KMB)], T_9 [100% RDF+*Azospirillum lipoferum*+PSB+KMB +*Glomus* +ZnSB] , T_{10} [100 % RDF+FYM+*Azospirillum lipoferum*+PSB+KMB+*Glomus*+ZnSB], T_{11} [*Azospirillum lipoferum*+PSB+KMB+*Glomus*+ZnSB] and T_{12} [FYM+ *Azospirillum lipoferum*+PSB+KMB+*Glomus*+ZnSB]. The quantity of bio-fertilizers incorporated were *Azospirillum lipoferum* (2.5 kg ha^{-1}), PSB (2.5 kg ha^{-1}), KMB (2.5 kg ha^{-1}), *Glomus* (18.75 kg ha^{-1}) and ZnSB (2.5 kg ha^{-1}) and FYM is 15 tonnes ha^{-1}.

Each experimental unit consisted of size plot 4 m^2 (2 m × 2 m). Rice cultivar (Mynnar var) @ 50 kg ha^{-1}, were broadcasted in each plot. Fertilizers were applied basally at the time of sowing the seeds.

Growth characters such as, plant height of five randomly selected tagged plants from each replicated plot was measured in cm from the base of the plant to the tip of the upper most latest leaf for calculating average plant height and number of tillers $hill^{-1}$ at different growth stages was recorded from the tagged plants in each plot following Kumar *et al*. (2018). Number of panicles $tiller^{-1}$ and panicle length were recorded and the total filled grains $panicle^{-1}$ was recorded at harvesting stage. 1000 bold grains were counted from the harvested grains of each plot and the test weight was calculated using the following formula (Sharma *et al*., 2018):

$$\text{Test weight} = \frac{\text{Grain weight}}{\text{Number of grains}} \times 100$$

Straw and grain yield were recorded after separating the grains by threshing and winnowing from each plot and the values were then converted into kg ha^{-1} (Kumar *et al*., 2018).

The HI was computed as (Midya *et al*., 2021):

$$\text{HI \%} = \frac{\text{Grain yield}}{(\text{Grain + Straw) yield}} \times 100$$

The market prices for inputs and outputs were used to compute the economic variables for all treatments. BCR (Benefit cost ratio), was calculated as under (Midya *et al*., 2021):

$$\text{BCR} = \frac{\text{Cost of cultivation (Rs.)}}{\text{Gross returns (Rs.)}} \times 100$$

OPSTAT (free online statistical software) was used to statistically analyse the data obtained. The critical difference (CD) at the 0.05 level of probability was determined after two-way analysis of variance (ANOVA) in each case to compare the treatment means.

RESULTS AND DISCUSSION

Growth attributes

Plant height (cm)

Plant height up to 90 DAS increased gradually regardless of treatment effects and then remained steady till maturity. During both cropping seasons, T_{10} showed the greatest increase in plant height compared to the other treatment combinations. However, it varied significantly with the INM treatments wherein T_{10} (100 % RDF+FYM+*Azospirillum lipoferum*+PSB+KMB+*Glomus*+ZnSB) showed the highest growth (Fig 1). However, plant height did not vary between 1st and 2nd year cropping.

The integration of nutrients could assist the crop acquire better nutrition, minimizing N loss and prolonging its availability to the rice plant, as well as improving plant height (Kashyap *et al*., 2017). Plant height is increased by chemical fertilizer, organic manure plus bio-fertilizers due to increased nutrient availability driven by the solubilization effect and microbial decomposition (Wailare and Kesarwani, 2017). Furthermore, FYM supplemented the soil with significant amounts of NPK, as well as other macro and micronutrients required for plant growth. However, because of the sluggish release of nutrients, all plant height was lowered in the organic treatment compared to the conventional treatment, as reported by Sharma *et al*. (2018).

Number of tillers $hill^{-1}$

The number of tillers $hill^{-1}$ started to propagate at 45 DAS and indicated a linear increase up to 60 DAS. It was the greatest in INM treatments (T_{10}), followed by sole use of chemical fertilization and organic fertilization and this might be due to more supply of nutrients during growth stages. INM treatments influenced number of tillers $hill^{-1}$ significantly ($p<0.05$) in both the cropping years, but the treatment wise effect was similar between the cropping years (Fig 2).

The INM treatment (T_{10}) might have increased the nutrient content in rice plants at the tillering stage, leading to a significant increase in the number of tillers $hill^{-1}$ at 60 days. Besides tillering, INM improves crop nutrition too by reducing N loss and increasing N availability to rice plants (Choudhary *et al*., 2007). After 60 days, there were fewer tillers, which was likely due to ageing and senescence, which caused the secondary and tertiary tillers to die (Singh *et al*., 2018). The number of tillers $hill^{-1}$ was lower in the organic and bio-fertilizer treatments compared to the chemical treatment (Sharma *et al*., 2018). FYM application produced more tillers as compared to treatments without FYM that had the same NPK levels. The conventional approach combined with FYM and bio-fertilizers may result in maximum tiller counts than chemical fertilizers or organic alone (Kumar *et al*., 2012). Fig 2 shows a significant difference among treatments and cropping year but the interaction between them had a non-significant effect on number of tillers hill^{-1}.

Number of panicles tiller^{-1}

The number of panicles climbed steadily as fertility levels rose as a result of better crop nutrition (Table 1). This eventually led to a steady increase in grain and straw yields of rice. Rice panicles grew consistently with fertility levels when plants received higher nourishment (Choudhary and Suri, 2014). Similar to observation by Borah *et al.* (2016) crop receiving INM produced higher number of panicles than those obtained with the other treatments (during both the years), whereas the lowest was recorded with control. Slow release and continuous supply of nutrients in balanced amounts during different growth phases, ensured by the application of organic and conventional fertilizers led to the production of more panicles with more fertile grains and promoted better plant growth (Singh *et al.*, 2018).

Panicle length

Compared to control, panicle length significantly increased with different fertilizer treatments. During both years, crops receiving INM treatments generated longer panicles than those obtained with other treatments. Panicle length rose in a consistent manner as fertility levels improved with greater nutrition for rice plants, showing the largest magnitude in plots fed with INM and the lowest in those using only NPK (Table 1).

Using organic with chemical fertilizers increased the effectiveness of native and applied nutrients being utilised at a faster rate, favouring panicle length (Sharma *et al.*, 2018). When compared to each counterpart treatment with the identical NPK levels, FYM resulted in the longest panicle length. FYM may have provided essential minerals and influenced the efficient utilization of applied nutrients to lengthen panicles (Singh *et al.*, 2018).

Number of grains panicle^{-1}

Maximum number of grains panicle^{-1} was produced by application of RDF + FYM + bio-fertilizers (T_{10}), over other treatments during both the cropping years. Higher grains panicle^{-1} were recorded with INM treatments and also in RDF; the lowest was recorded in control. Number of grains panicle^{-1} resulted from INM and chemical treatments were at par (Fig 3).

The fertility level in (T_{10}) improved plant nutrition, hence, the filled grains panicle^{-1} grew constantly, leading to steady increases in rice yields (Choudhary *et al.*, 2007). Combining organic and chemical fertilizers helps to provide all of the balanced and high-quality nutrients throughout the growing season, allowing rice plants to assimilate enough photosynthetic products and produce more viable grains (Singh *et al.*, 2018).

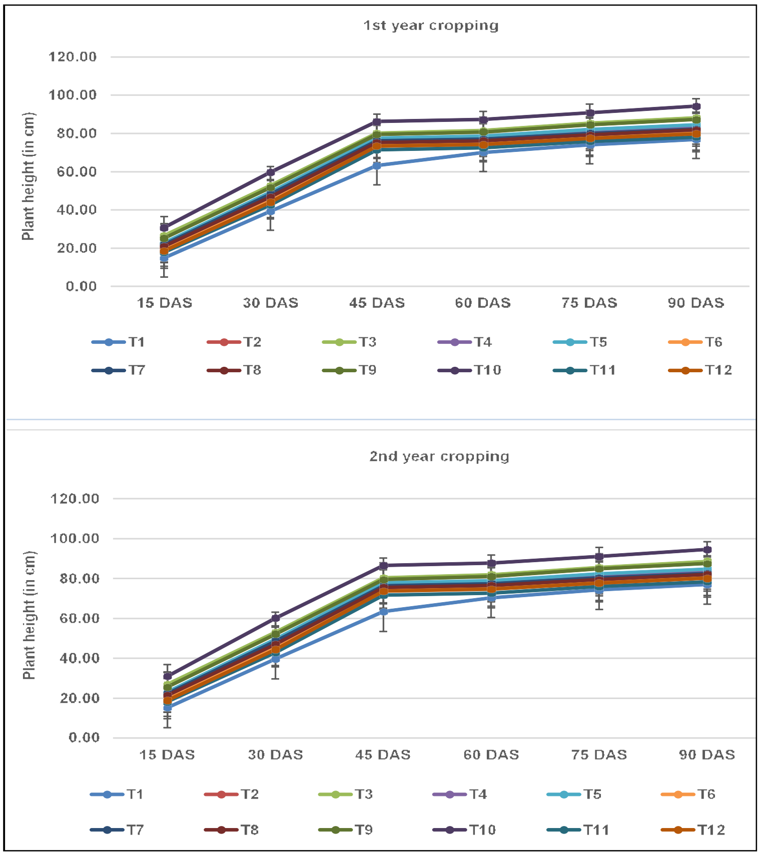

Fig 1: Effect on INM on plant height (cm) during the1st year and 2nd year of cropping.

Solitary application of chemical, organic, or bio-fertilizers was found to be less effective in raising the number of panicles tiller^{-1}, in improving the panicle length and in raising the number of grains panicle^{-1} of upland rice (Borah *et al*., 2016), as it inhibits the inability to give plant the needed nutrients in accordance with the crop's demand, as also reported by Sharma *et al*. (2018).

Test weight (g)

Fertility treatments significantly raised test weight compared to the unfertilized plots. INM treatments received the most weight. During both the cropping years, the test weight (1000-grain weight) varied from 24.07 to 27.03 g. The sequence in which different treatments had an impact on the weight of 1000 seeds was $T_{10}>T_3>T_9>T_5>T_4>T_7>T_8>T_6>T_2>T_{12}>T_{11}>T_1$ (Fig 4).

According to Subramani *et al*. (2005), test weight is rather stable and does not vary noticeably among methods for nutrient fertility management (Fig 4). Higher plant nutrition for rice plants led to constant increase in 1000-grain weight with increasing fertility levels, with the largest increase occurring in plots supplied with organic and inorganic fertilizer. During the various growth phases, nutrients required by the crop are continuously supplied in a balanced quantity, so it enable the plant to digest sufficient photosynthetic products, resulting in increased test weight (Singh *et al*., 2018). Control plots reported the lowest 1000-seed weight as it was devoid of any nutrient application.

The study reveals that all the growth parameters except test weight showed significant variation among the treatments and between the cropping years. Growth variables also increased significantly from 1st year to 2nd year cropping. However, initially plant height did not vary between the cropping years till 60 DAS but induced a significant variation among treatments throughout the growing period, thereafter it showed significant enhancement in height growth in 2nd year crops compared to 1st year crops.

Yield attributes

Grain and straw yield

The highest grain and straw yield were recorded in the INM plots (T_{10}) (Table 2) during both the years. Better yield attributes accrued from the integrated use of fertilizers resulted in the highest grain and straw yield of upland rice which was, however, statistically at par with treatments applied.

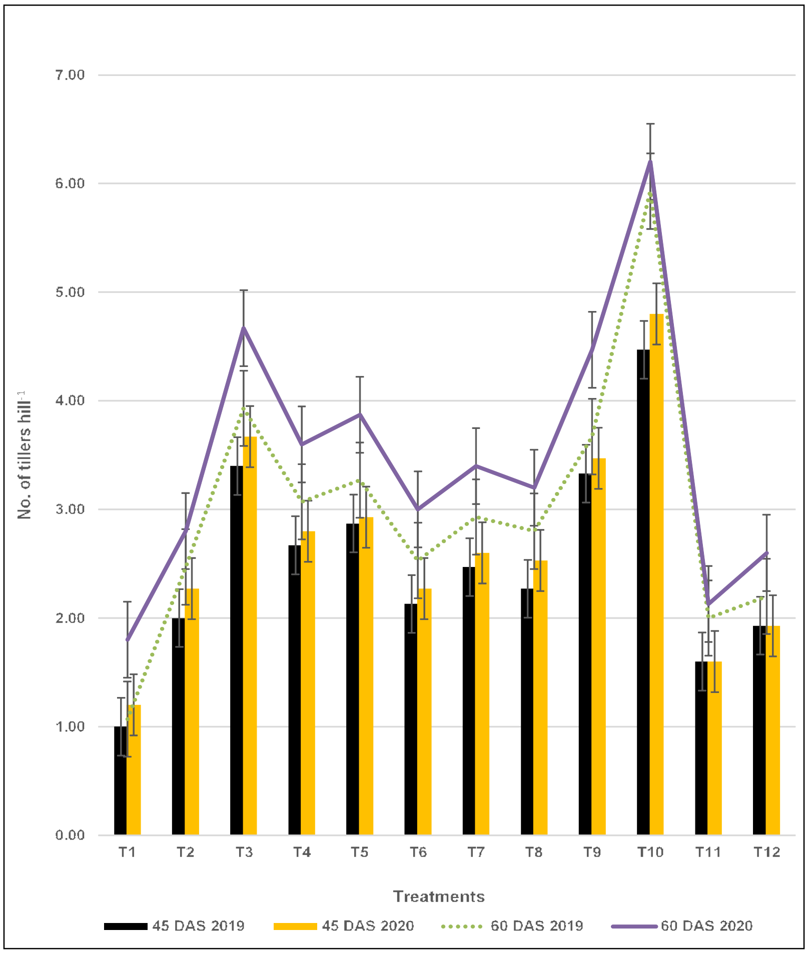

Fig 2: Effect on INM on the number of tillers hill^{-1} during the1st year and 2nd year of cropping.

Compared to solitary fertilizer application, Sharma *et al.* (2018) found that INM treatments produced the maximum grain and straw yield. Furthermore, under the impact of better physical and chemical soil features, INM plots absorb more nutrients, resulting in increased yield (Tripathi *et al.*, 2013).

Rice yield improved in RDF plots and they improved more when organic sources were substituted (Padbhushan *et al.*, 2021; Singh *et al.*, 2018). Sowmya *et al.* (2011) also stated that integrated nutrient management, is necessary for long-term output. Organic manure's improved effect on grain and straw yields could be attributed to a more consistent supply of plant nutrients (Aruna and Mohammad, 2011; Kumar *et al.*, 2018). Also, when chemical fertilizers and bio-fertilizers were combined, the yield was higher than when organic fertilization were used alone, emphasising the importance of INM to achieve higher production (Kumar *et al.*, 2018). Because of poor and fragile upland soils, control plots yielded the lowest grain and straw yield (Table 2).

Grain yield did not vary with treatments, but showed a significant variation between the cropping years. However, straw yield was significantly ($P<0.05$) higher in T_{10}, but shows a non-significant variation between the cropping years. On the other hand, the grain yield increased from 1st year to 2nd year crops in all the treatments. Straw yield, however was at par between the two cropping years.

Economics

HI and BCR were recorded the maximum in T_{10} (100 % RDF + FYM + *Azospirillum lipoferum* + PSB + KMB + *Glomus* + ZnSB) in 1st year cropping. On the other hand T_9 (100% RDF + *Azospirillum lipoferum* + PSB + KMB + *Glomus* + ZnSB) showed maximum value of HI and BCR in 2nd year crops. However, the economic parameters increased from 1st year to 2nd year cropping irrespective of treatments applied (Table 3).

Since fertility practises had a similar impact on grain and straw yields, nutrient management had no impact on HI (Borah *et al.*, 2016). Furthermost, the cost benefit analysis of the present study shows that T_{10} and T_9 under improved nutrient management gave the highest BCR. Similar findings was also reported by Srinivasarao *et al.* (2020). Both grain and straw yield did not vary with various

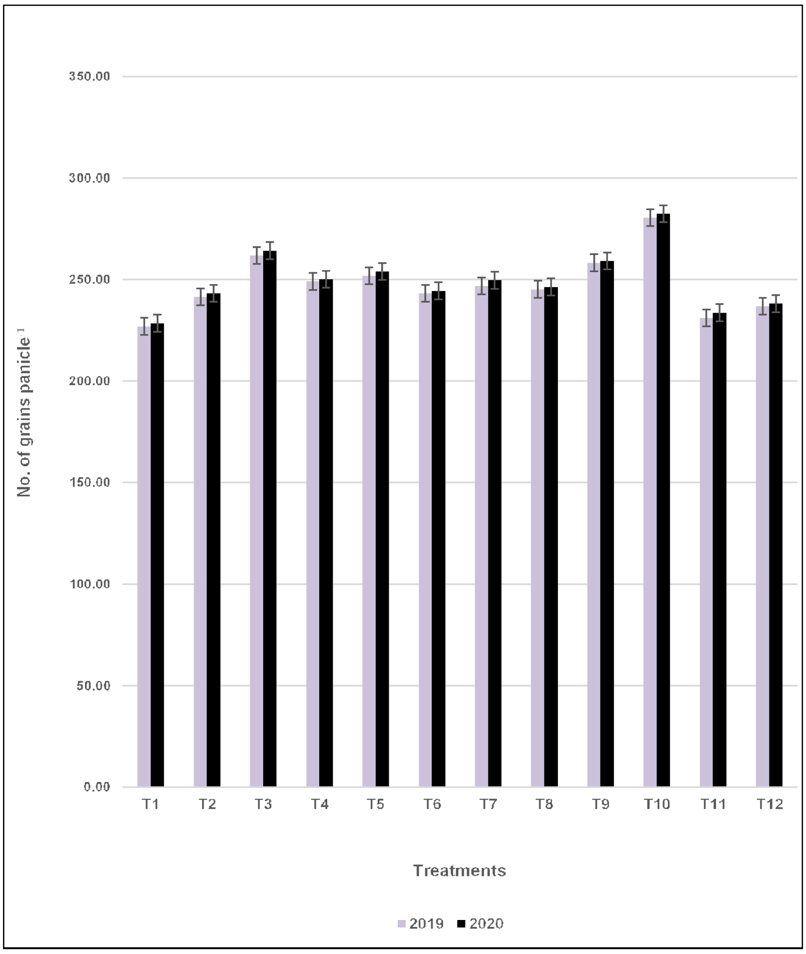

Fig 3: Effect on INM on the number of grains panicle^{-1} during cropping years.

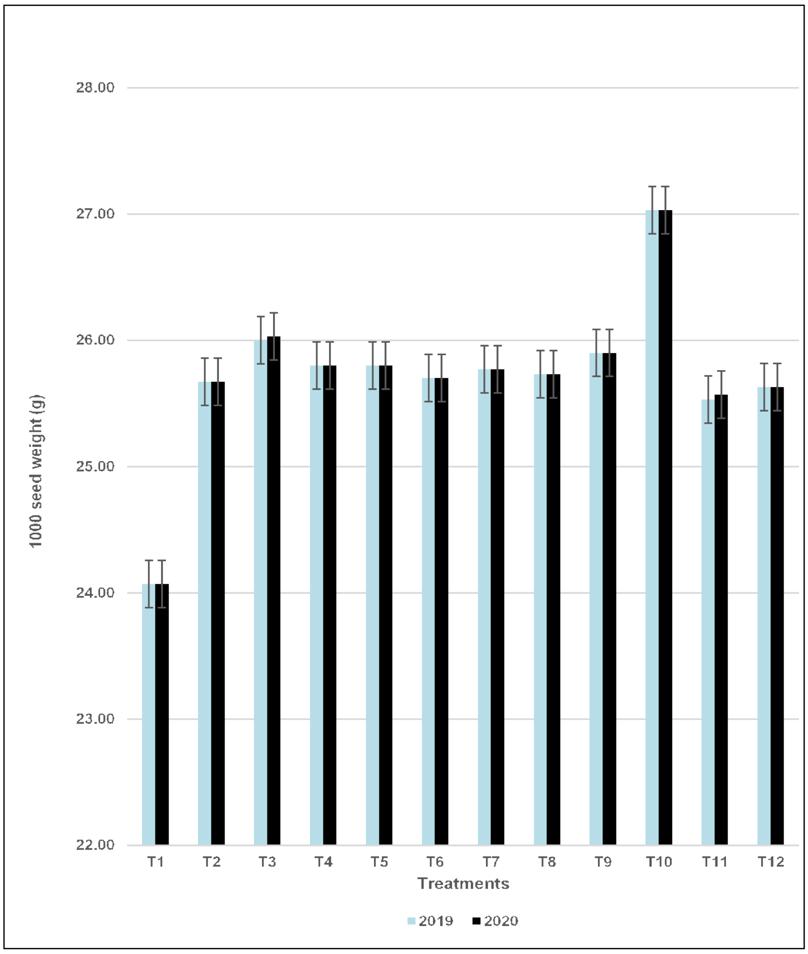

Fig 4: Effect on INM on the test weight in gram (1000 seed weight) during cropping years.

Table 1: Effect of INM on the number of panicles tiller^{-1} and panicle length at 150 DAS.

Treatments	Number of panicles tiller^{-1}		Panicle length (cm)	
	1st year cropping	2nd year cropping	1st year cropping	2nd year cropping
T_1	2.93	3.40	14.73	14.93
T_2	5.60	6.13	16.09	16.29
T_3	8.07	8.60	18.35	18.54
T_4	6.80	7.33	17.17	17.37
T_5	7.07	7.60	17.47	17.67
T_6	6.07	6.40	16.39	16.45
T_7	6.60	7.07	16.93	17.13
T_8	6.33	6.73	16.67	16.87
T_9	7.73	8.40	18.19	18.39
T_{10}	10.13	10.67	19.67	19.94
T_{11}	4.80	5.20	15.14	15.34
T_{12}	5.40	5.87	15.88	16.08
	CD	SE(m) ±	CD	SE(m) ±
Treatments (A)	0.334*	0.117	0.167*	0.058
Cropping years (B)	0.136*	0.048	0.068*	0.024
A × B	NS	0.165	NS	0.082

*(P<0.05) significant at 0.05 level of probability.

Table 2: Effect of INM on the grain and straw yield during the cropping years.

Treatments	Grain yield (kg ha^{-1})		Straw yield (kg ha^{-1})	
	1st year cropping	2nd year cropping	1st year cropping	2nd year cropping
T_1	3875.00	4883.33	13333.33	13333.33
T_2	4258.33	5783.33	15166.67	15250.00
T_3	5316.67	6633.33	16583.33	16666.67
T_4	4525.00	6208.33	15916.67	15916.67
T_5	4616.67	6275.00	15916.67	16000.00
T_6	4325.00	5925.00	15500.00	15500.00
T_7	4441.67	6091.67	15500.00	15666.67
T_8	4366.67	6025.00	15500.00	15583.33
T_9	5050.00	6550.00	16083.33	16250.00
T_{10}	6483.33	7266.67	18250.00	18500.00
T_{11}	3991.67	5500.00	14000.00	14083.33
T_{12}	4158.33	5708.33	14666.67	14750.00
	CD	SE(m) ±	CD	SE(m) ±
Treatments (A)	NS	568.937	2,249.47*	787.672
Cropping years (B)	663.32*	232.268	NS	321.566
A × B	NS	804.599	NS	1113.94

*(P<0.05) significant at 0.05 level of probability.

Table 3: Effect of INM on the harvest index and BCR during the cropping years.

Treatments	Harvest Index (%)		BCR	
	1st year cropping	2nd year cropping	1st year cropping	2nd year cropping
T_1	22.80	26.31	1.20	1.41
T_2	21.12	26.81	1.31	1.61
T_3	24.52	28.20	1.27	1.49
T_4	22.25	27.90	1.37	1.71
T_5	22.65	28.18	1.37	1.70
T_6	21.67	27.24	1.32	1.64
T_7	22.40	27.88	1.34	1.68
T_8	21.97	27.82	1.33	1.66
T_9	23.83	28.64	1.43	1.72
T_{10}	26.32	28.28	1.45	1.58
T_{11}	22.22	27.12	1.19	1.48
T_{12}	21.41	27.61	1.02	1.27
	CD	SE(m) ±	CD	SE(m) ±
Treatments (A)	NS	2.057	NS	0.115
Cropping years (B)	2.398*	0.84	0.134*	0.047
A × B	NS	2.909	NS	0.163

*(P<0.05) significant at 0.05 level of probability.

treatments, but showed a significant increase in the second year of cropping.

CONCLUSION

The present findings reveals that T_{10} (100 % RDF + FYM + *Azospirillum lipoferum* + PSB + KMB + *Glomus* + ZnSB) enhances the growth and yield attributes and the economics of upland paddy in both the years of cropping. So, it can be concluded that integrated nutrient management practices help improving productivity of upland paddy crop on sustained basis by maintaining soil fertility in jhumlands of North East hilly region of India.

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Conflict of interest: None.

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