The Pharma Innovation Journal 2023; 12(10): 2038-2044

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(10): 2038-2044

www.thepharmajournal.com
Received: 07-08-2023
Accepted: 15-09-2023

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Effect of integrated nutrient management on nutrient content, nutrient uptake, balance sheet and yield in direct seeded rice (*Oryza sativa* L.) under midland situations of Bastar plateau

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Abstract
During the Kharif season of 2021, an experiment was conducted at the Instructional Cum Research Farm, S.G. College of Agriculture and Research Station, Jagdalpur, Chhattisgarh, India. The soil in the research location was Inceptisol, which had low organic carbon, less readily available nitrogen and phosphorus and medium potassium concentration. The experiment was conducted in randomized block design (RBD) with 3 replications having 9 treatments. Treatment T_5 (100% NPK + 5 t FYM ha^{-1} + Azospirillum and PSB) produced significantly greater grain Yield, straw yield, nutrient content, nutrient uptake, and post-harvest nutrient availability over other treatments. But the highest nutrient use efficiency was observed in treatment T_4 (25% RDF). However, the positive nutrient balance was recorded in control in case of nitrogen and phosphorus. While, treatment T_1 (75% NPK + 5 t FYM ha^{-1} + Azospirillum and PSB) reported the highest solubilisation of potassium.

Keywords: INM, DSR, bio-fertilizers, FYM

Introduction
Over 50 percent of the world's population is dependent on rice as their primary food supply, causing many of them specifically prone to rising rice prices. Rice is also the most important food crop in nations with lower incomes. More than 3.3 billion people, primarily in countries that are developing, rely on rice for more than 20% of the calories they consume every day. The cultivation of rice provides a living for nearly 1 billion people, or 1/5 th of the world's population. (Zeigler, 2017) [34]. Crop nutrient shortage is fulfilled by an integration of inherent soil fertility and fertilizers applied externally. To Rice production will need to increase by 60% over the next twenty five years to meet the food needs of a growing population. (Arth and Frenzel, 2000) [1]. NPK fertilization must be used approximately three times as much as it is now in order to attain this increase. However, the need for prudent use of chemical fertilizers is justified by the rising costs of industrial fertilizer as well as the potential deterioration of soil health and environmental pollution (Collins *et al*., 1992) [7]. It is crucial to use alternate sources of nutrients such as organic manure, legumes in crop rotation, and bio fertilizer to keep up productivity and soil fertility with a more environmentally friendly nutrient management system. (Fageria and Baligar, 1997) [11]. The addition and utilization of organic manures enhances the physical, chemical, and biological characteristics of the soil as well as the effectiveness of applied NPK fertilizer and other inputs (Pramnik and Mahapatra, 1997; Kalyanasundaram *et al*., 1997) [21, 18]. To increase grain yield and NPK uptake in lowland rice, integrated use of NPK fertilizer and organic manures is beneficial in conserving higher soil accessible nutrient concentrations for extended periods of time. (Devi *et al*., 1999) [8].

Material and Methods
The experiment took place at the Instructional Cum Research Farm, Shaheed Gundadhoor College of Agriculture and Research Station, Kumhrawand, Jagdalpur, Chhattisgarh, during the Kharif season of 2021. The soil in the area under study field was Inceptisol, which had low organic carbon, less readily available N and P, and a medium K content. The experiment was carried out in randomized block design (RBD) with 3 replication having 9 treatments i.e., T_1:

100% RDF, T_2: 75% RDF, T_3: 50% RDF, T_4: 25% RDF, T_5: 100% NPK + 5 t FYM ha^{-1} + Azospirillum and PSB, T_6: 75% NPK + 5 t FYM ha^{-1} + Azospirillum and PSB, T_7: 50% NPK + 5 t FYM ha^{-1} + Azospirillum and PSB, T_8: 25% NPK + 5 t FYM ha^{-1} + Azospirillum and PSB, T_9: Control. On all plots, the recommended fertilizer dose of 120:60:40 kg N: P: K ha^{-1} was applied by urea, single Block Design suggested by Gomez and Gomez (1984) [14].

Result and Discussion

Yield: According to the data in Table 1, treatment T_5 had significantly greater grain yield and straw production which had similar results with treatment T_1. However, control had the lowest yield. The greater nutrient supply from more organics, which enhanced soil physico-chemical and biological characteristics by providing microbes with essential nutrients, may be the cause of the increased grain production of INM treatments. (Subha *et al*., 2004) [30]. The nitrogen included in urea has encouraged crop development in its early stages. (Zaidi *et al*., 2016) [33]. The considerable increase in grain yield is attributable to improved nutrient mobilisation by Azospirillum and PSB, as well as their synergistic beneficial interaction in soil, which is reflected in more panicles per plant, total number of grains per panicle, individual panicle weight, and test weight (Gogoi *et al*., 2010; Reddy *et al*., 2006; Roul and Sarawgi *et al*., 2005 and Sudha and Chandini, 2003) [13, 22, 23, 31]. The soil's adequate and consistent capacity for nitrogen supply and nutrient translocation to the sink is responsible for the increased yield characteristics. (Subehia and Sepehya, 2012; Gautam *et al*., 2013 and Mahmud *et al*., 2016) [29, 12, 19]. The data shows that treatment T super phosphate, and muriate of potash excluding the control. The crop was sown with 50 percent of the nitrogen, 100 percent of the phosphorus, and 100 percent of the potash. The remaining 50 percent of the nitrogen was used at 25 to 30 days after sowing and 40 to 45 days after sowing. Farm yard manure was given along with Azosprillum and PSB as a base dose. All of the data derived on various factors was statistically analyzed using the Randomized 7 (41.62%) observed a considerable impact from INM on the harvest index but it was found on par with treatments T_1, T_2, T_3, T_4, T_5, T_6 and T_8. While, the lowest harvest index was recorded in control. Higher yields of rice grains per unit of biological yield were reported which led to a higher harvest index. (Stoop *et al*., 2005 and Hussain *et al*., 2003) [28, 16].

Table 1: Effect of different INM on grain yield, straw yield and harvest index of direct seeded rice

Treatment	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Harvest index (%)
T_1	46.97	68.10	40.76
T_2	33.13	47.37	41.13
T_3	28.90	42.99	40.18
T_4	24.65	35.98	40.62
T_5	50.95	73.00	41.13
T_6	41.07	60.26	40.55
T_7	32.41	45.37	41.62
T_8	25.61	39.95	39.02
T_9	15.97	30.77	34.38
SEm±	1.65	1.85	1.18
CD @ 5%	5.00	5.61	3.58
CV%	8.60	6.51	5.13

Post-harvest nutrient availability

Table 2 shows that the effect of different INM had non-significant effect on available nitrogen, phosphorus and potassium respectively. But numerically treatment T_5 recorded maximum amount of available nitrogen and the minimum amount was observed in control. The highest amount of available phosphorus found in treatment T_5 while the lowest was in control. The maximum amount of available potassium recorded in treatment T_5 whereas the lowest was observed in control. Organic manure combined with chemical fertilizer increased the N, P and K contents post-harvest soil. (Ayoola and Makinde, 2009) [2]. The incorporation of organic manure with nitrogen fertilizer improved the effective K content of soil (Bhat, 1988) [4].

Table 2: Effect of different INM of DSR on available NPK at harvest

Treatment	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T_1	244.30	13.21	211.65
T_2	236.61	12.79	210.50
T_3	234.83	12.49	209.45
T_4	232.96	12.08	208.85
T_5	249.52	15.29	214.95
T_6	241.26	14.62	214.45
T_7	240.76	14.49	213.35
T_8	239.79	15.08	212.95
T_9	231.09	12.43	205.89
SEM±	17.06	0.86	13.69
CD @ 5%	NS	NS	NS
CV%	12.36	10.97	10.97

Nutrient content in plant

The data presented in Table 3 shows that various INM treatments affected the nitrogen content in grain and straw. Data revealed that it had no significant effect on the content of N in grain but treatment T_5 recorded maximum N content in grain of rice. The mineralization of nitrogen from organic manures by increased soil microbial activity was the main factor contributing to the improved nutrient availability. (Chinnusamy *et al.*, 2006) [5]. But treatment T_5 noted significantly highest N content in straw and it was found at par with treatment T_6, T_1, T_7, T_2 and T_8. Different INM treatment had significant effect on P content in grain. The higher P content was recorded in treatment T_5 which was found on par with all the treatments except control. Whereas, in straw maximum P content was reported in treatment T_5 but had the similar results with treatment T_6, T_2 and T_3 and minimum was found in control. Treatment T_5 had a much higher K content in rice grains but had likewise results with treatments T_1, T_2, and T_6. While, the lowest K content was found in T_9 which is control. The data revealed that different INM influence the levels of K content in straw non-significantly. However, highest K content was reported in treatment T_5 among all other treatments, and control noted the lowest K content in straw. The combined application of fertilizer and manure showed the higher levels of NPK content in straw over the chemical fertilizer alone (Singh *et al.*, 2001 and Islam *et al.*, 2013) [26, 17]. Similar results were also observed by Srivastava *et al.*, (2008) [27].

Nutrient uptake by plant

The data presented in Table 4 shows that various INM treatments had the significant result on the uptake of nitrogen by plant. The data reveals that total uptake of nitrogen, phosphorus and potassium by plant including grain and straw recorded

Table 3: Effect of different INM of DSR on nutrient content of NPK

Treatment	Nitrogen (%)			Phosphorus (%)			Potassium (%)		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
T_1	1.19	0.37	1.56	0.24	0.10	0.34	0.30	1.10	1.39
T_2	1.17	0.35	1.52	0.23	0.12	0.35	0.28	1.08	1.36
T_3	1.13	0.33	1.46	0.22	0.11	0.33	0.27	1.05	1.32
T_4	1.10	0.32	1.41	0.20	0.07	0.27	0.22	0.98	1.20
T_5	1.21	0.40	1.61	0.24	0.13	0.37	0.31	1.10	1.41
T_6	1.20	0.38	1.58	0.23	0.12	0.35	0.30	1.10	1.41
T_7	1.19	0.35	1.54	0.23	0.10	0.32	0.27	1.04	1.32
T_8	1.15	0.35	1.51	0.21	0.08	0.29	0.26	1.05	1.31
T_9	1.08	0.30	1.39	0.17	0.06	0.23	0.20	0.96	1.16
SEM±	0.04	0.02	0.05	0.01	0.01	0.01	0.01	0.04	0.04
CD @ 5%	NS	0.05	0.14	0.04	0.02	0.04	0.03	NS	0.12
CV%	5.91	7.69	5.28	10.78	8.68	7.85	7.34	6.77	5.34

Table 4: Effect of different INM of DSR on uptake of NPK

Treatment	Nitrogen (kg ha^{-1})			Phosphorus (kg ha^{-1})			Potassium (kg ha^{-1})		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
T_1	55.75	30.99	86.75	11.00	8.44	19.44	13.94	91.20	105.15
T_2	38.72	18.72	57.45	7.58	6.24	13.82	9.18	57.90	67.08
T_3	32.55	14.98	47.53	6.39	4.92	11.32	7.62	46.85	54.47
T_4	27.14	15.17	42.31	4.99	3.53	8.52	5.45	46.68	52.14
T_5	57.34	34.24	91.58	11.61	10.86	22.47	14.63	94.25	108.88
T_6	40.62	19.82	60.43	7.77	6.45	14.22	10.31	58.01	68.33
T_7	38.30	21.27	59.57	7.28	5.92	13.21	8.78	63.58	72.36
T_8	29.45	21.25	50.70	5.38	4.52	9.90	6.52	63.19	69.71
T_9	19.25	10.24	29.49	3.03	2.13	5.16	3.62	32.67	36.30
SEM±	1.72	1.24	2.51	0.29	0.28	0.43	0.43	3.52	3.61
CD @ 5%	5.19	3.76	7.59	0.88	0.84	1.30	1.31	10.64	10.93
CV%	7.88	10.39	7.44	7.00	8.18	5.68	8.46	9.90	8.88

Significantly highest in treatment T_5 which was found at par with treatment T_1. While, the minimum NPK uptake was recorded in control. The N mineralized during FYM decomposition would have boosted rhizosphere N availability, resulting in increased available nutrient uptake and dry matter production (Thirunavukkarasu and Vinoth, 2013) [32]. This might be since organic and inorganic sources of nitrogen have continued to be available, leading to an increase in N consumption. (Dixit and Gupta, 2000) [10]. Higher nutrient uptake is the result of greater root proliferation which was made possible by PSB and higher P solubilization and increased nitrogen availability is the result of Azospirillum in the soil. This resulted in enhanced plant nutrient concentration which was demonstrated by better crop growth, yield and low soil nutrient status after crop harvest. (Babu and Reddy, 2000; Choudhary *et al.*, 2010; Dhanya *et al.*, 2006 and Mankotia *et al.*, 2008) [3, 6, 9, 20]. Higher K absorption could be attributed to improved soil conditions and less fixation of potassium.

Nutrient use efficiency

The agronomic nutrient use efficiency of NPK of every treatment was estimated using the data of available grain yield and applied nutrient. The data showed in Table 5 reveals that treatment T_4 recorded significantly maximum nitrogen, phosphorus and potassium use efficiency which had the same result with treatment T_1 in case of nitrogen. Applying proper fertilizers at regular intervals in varying splits as the crop required, promoted effective absorption by the crop with little to no waste resulted in enhancing nutrient use efficiency. (Hebbar *et al*., 2004 and Shaymaa *et al*., 2009) [15, 24]. Similar results were also reported by Singh and Kumar (2014) [25].

Table 5: Nutrient use efficiency of NPK as influenced by various INM of direct seeded rice

Treatment	N use efficiency	P use efficiency	K use efficiency
T_1	25.83	51.67	77.50
T_2	19.06	38.12	57.18
T_3	21.54	43.08	64.62
T_4	28.92	57.84	86.77
T_5	21.67	44.89	48.34
T_6	15.52	32.48	32.48
T_7	19.33	41.08	36.52
T_8	17.52	38.53	27.52
T_9	0.00	0.00	0.00
SEM±	1.38	2.03	2.84
CD @ 5%	4.16	6.14	8.60
CV%	12.65	9.10	10.29

Balance sheet of NPK

In the Table 6 and 7 and Fig. 1 and 2, the data shows that the maximum total available nitrogen and phosphorus recorded highest at treatment T_5 and minimum in control which is the sum total of initial available nitrogen and phosphorus present in the soil, applied fertilizers and manures. The uptake of N and P noted highest at treatment T_5 and the lowest uptake were recorded in control i.e., T_9. The maximum apparent N and P balance was recorded at T_6 and minimum in control. The real balance was recorded maximum at treatment T_5 and minimum in control.

Treatment T_9 recorded the maximum built up of nitrogen and phosphorus and treatment T_6 has the highest fixation. But, Table 8 and Fig. 3 revealed that treatment T_1 recorded the highest solubilisation of K and treatment T_6 recorded minimum solubilisation of K. Data shows that the maximum total available K recorded highest at treatment T_5 and minimum in control. The uptake of K observed highest at treatment T_5 and the lowest uptake was seen in control. The maximum apparent K balance was recorded at T_6 and minimum at T_1. The real balance was recorded maximum at treatment T_5 and minimum in control.

Table 6: Balance sheet of nitrogen as influenced by different INM of DSR

Treatment	Initial available N (kg ha^{-1})	Fertilizer N (kg ha^{-1})	Manure (kg ha^{-1})	Total available N (kg ha^{-1})	N uptake (kg ha^{-1})	App N balance (kg ha^{-1})	Real balance (kg ha^{-1})	Solubilisation/ fixation of available N (kg ha^{-1})
	1	2	3	4 (1 + 2 + 3)	5	6 (4-5)	7	8 (7-6)
T_1	215.18	120	0	335.18	86.75	248.43	239.52	-8.91
T_2	215.18	90	0	305.18	57.45	247.73	236.61	-10.12
T_3	215.18	60	0	275.18	47.53	228.05	234.83	6.78
T_4	215.18	30	0	245.18	42.31	202.87	232.96	30.09
T_5	215.18	120	25	360.18	91.58	268.60	244.30	-24.30
T_6	215.18	90	25	330.18	60.43	269.75	241.26	-28.49
T_7	215.18	60	25	300.18	59.57	240.61	240.76	0.15
T_8	215.18	30	25	270.18	50.70	219.48	239.79	20.31
T_9	215.18	0	0	215.18	29.49	185.69	231.09	45.40
SEM±	-	-	-	-	2.51	-	7.25	-
CD @ 5%	-	-	-	-	7.59	-	NS	-
CV%	-	-	-	-	7.44	-	5.28	-

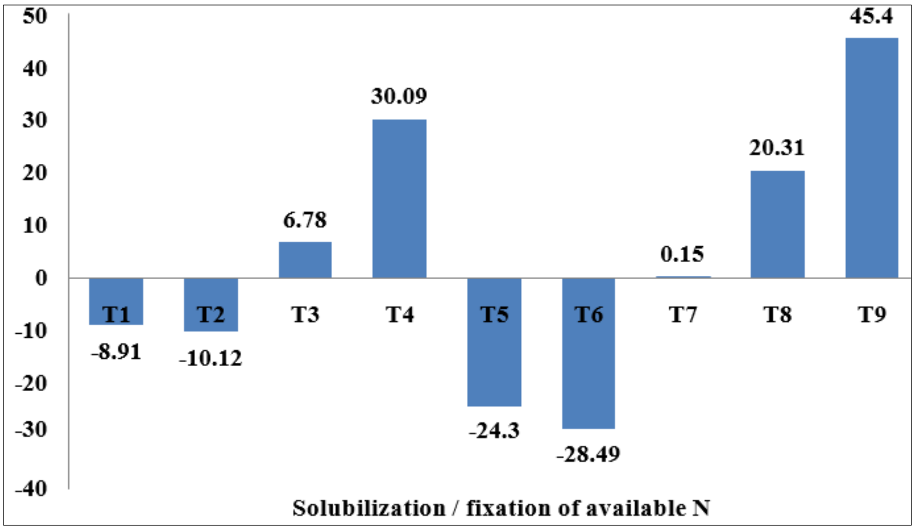

Fig 1: Effect of different INM on Solubilisation / fixation of available Nitrogen (kg ha^{-1})

Table 7: Balance sheet of phosphorus as influenced by different INM of DSR

Treatment	Initial available P (kg ha^{-1})	Fertilizer P (kg ha^{-1})	Manure (kg ha^{-1})	Total available P (kg ha^{-1})	P uptake (kg ha^{-1})	App P balance (kg ha^{-1})	Real balance (kg ha^{-1})	Solubilisation/fixation of available P (kg ha^{-1})
	1	2	3	4 (1 + 2 + 3)	5	6 (4-5)	7	8 (7-6)
T_1	12.38	26.20	0	38.58	19.44	19.14	13.21	-5.93
T_2	12.38	19.65	0	32.03	13.82	18.21	12.79	-5.42
T_3	12.38	13.10	0	25.48	11.32	14.16	12.49	-1.67
T_4	12.38	6.55	0	18.93	8.52	10.41	12.08	-6.78
T_5	12.38	26.20	10	48.58	22.47	26.11	15.29	-10.82
T_6	12.38	19.65	10	42.03	14.22	27.81	14.62	-13.19
T_7	12.38	13.30	10	35.68	13.21	22.47	14.49	-7.98
T_8	12.38	6.55	10	28.93	9.90	19.03	15.08	-3.95
T_9	12.38	0	0	12.38	5.16	7.22	12.43	5.21
SEm±	-	-	-	-	0.43	-	0.86	-
CD @ 5%	-	-	-	-	1.30	-	NS	-
CV%	-	-	-	-	5.68	-	10.97	-

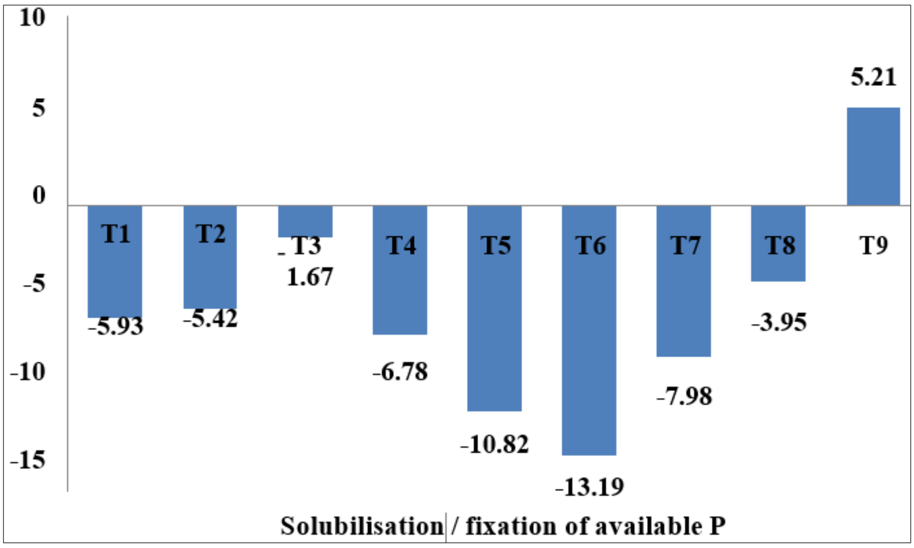

Fig 2: Effect of different INM on Solubilisation/ fixation of available Phosphorus (kg ha^{-1})

Table 8: balance sheet of potassium as influenced by different INM of DSR

Treatment	Initial available K (kg ha^{-1})	Fertilizer K (kg ha^{-1})	Manure (kg ha^{-1})	Total available K (kg ha^{-1})	K uptake (kg ha^{-1})	App K balance (kg ha^{-1})	Real balance (kg ha^{-1})	Solubilisation/ fixation of available K (kg ha^{-1})
	1	2	3	4 (1 + 2 + 3)	5	6 (4-5)	7	8 (7-6)
T_1	203.50	33.33	0	236.83	105.15	131.68	211.65	79.97
T_2	203.50	25.00	0	228.50	67.08	161.42	210.50	49.08
T_3	203.50	16.66	0	220.16	54.47	165.69	209.45	43.76
T_4	203.50	8.33	0	211.83	52.14	159.69	208.85	49.16
T_5	203.50	33.33	25	261.83	108.88	152.95	214.95	62.00
T_6	203.50	25.00	25	253.50	68.33	185.17	214.45	29.28
T_7	203.50	16.66	25	245.16	72.36	172.80	213.35	40.55
T_8	203.50	8.33	25	236.83	69.71	167.12	212.95	45.83
T_9	203.50	0	0	203.50	36.30	167.20	205.89	38.69
SEm±	-	-	-	-	3.61	-	6.46	-
CD @ 5%	-	-	-	-	10.93	-	NS	-
CV%	-	-	-	-	8.88	-	5.30	-

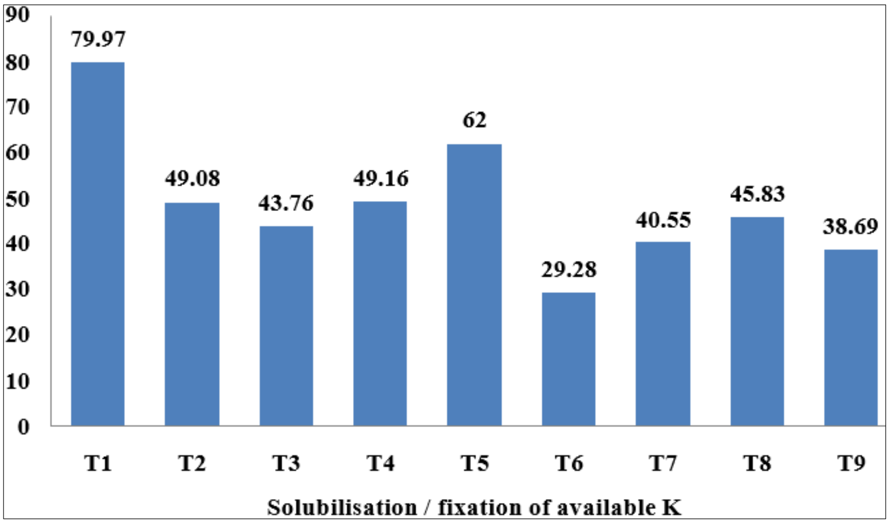

Fig 3: Effect of different INM on Solubilisation/ fixation of available potassium (kg ha^{-1})

Conclusion

According to the findings of the 1-year trial the treatment T_5 (100% NPK + 5 t FYM ha^{-1} + Azospirillum and PSB) reported the maximum yield, nutrient content, and nutrient uptake. Whereas, the influence of various INM treatments had non-significant effect on available nitrogen, phosphorus and potassium in soil respectively. In case of nutrient use efficiency, treatment T_4 (25% RDF) recorded significantly maximum nutrient use efficiency of nitrogen, phosphorus and potassium. While, treatment T_9 recorded the maximum built up of nitrogen and phosphorus but treatment T_1 (100% RDF) has the highest fixation of potassium and there were no fixation of potassium in the soil.

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