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Effect of integrated nutrient management (INM) on nutrient uptake, yield and quality of potato (*Solanum tuberosum* L.)

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Abstract
A field experiment was conducted at Instructional farm, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal, India during *rabi* season of 2017-18 to evaluate the performance of potato under different integrated nutrient management (INM) options. The experiment was placed in randomised block design (RBD) with seven nutrient management options (T_1-100% RDF, T_2-100% RDF + yeast vinasse @ 2 t/ha, T_3-75% RDF + yeast vinasse @ 2 t/ha, T_4-50% RDF + yeast vinasse @ 2 t/ha, T_5-100% RDF + vermicompost @ 2 t/ha, T_6-75% RDF + vermicompost @ 2 t/ha, T_7-50% RDF + vermicompost@ 2 t/ha) and replicated thrice. Results from the experiment expressed that application of 100% RDF along with supplementation of either vermicompost or yeast vinasse @ 2 t/ha ensured greater nutrient uptake such as N (144.6 kg/ha or 138.9 kg/ha respectively), P (18.3 kg/ha or 16.8 kg/ha respectively) and K (130.2 kg/ha or 134.8 kg/ha respectively), tuber yield (27.29 t/ha or 26.97 t/ha respectively), dry matter yield (6.75 t/ha or 6.66 t/ha respectively) and quality such as carbohydrate (74.7% or 74.9% respectively) and protein (1.23% or 1.22% respectively) of potato over sole application of 100% RDF through chemical sources. Thus, both these integrated nutrient management options can be recommended in place of sole chemical fertilizers to obtain improved potato performance.

Keywords: Integrated nutrient management (INM), nutrient uptake, potato, quality, yield

Introduction
Potato (*Solanum tuberosum* L.) is the most important temperate food crop of the world. High nutrition (carbohydrate, protein, dietary fibre, vitamins, minerals, amino acids etc.), easy digestibility, bulk quantity of production etc. have made potato the most popular vegetable food crop over the years around the world. Potato has achieved the status of 'poor man's friend' due its constant assurance of feeding and supplying low cost energy and high nutrition to people irrespective of economic categories. Globally, India ranks second in terms of potato production after China, where potato is cultivated in the year 2018-19 on an average over 2.18 million ha with annual production of 52.58 million tonnes and productivity of 24.07 tonnes/ha (Horticulture Statistics Division, 2019) [14]. In India, potato cultivation is mostly concentrated in northern hills and plains, eastern hills, plateau region and southern hills. Among the states of India, Uttar Pradesh tops the chart in terms of potato area and production which is followed by West Bengal. Other major potato growing states are Bihar, Madhya Pradesh, Assam, Gujarat, Punjab, Jharkhand, Karnataka, Haryana, Chattisgarh etc. (Horticulture Statistics Division, 2019) [14]. Potato has different forms of use for table consumptions viz. vegetable ingredient in many cooked dishes, potato flour in making snacks, potato chips, slice or shredded potato, smashed potato, french fries etc. Besides, potato also has industrial value in production of dextrin, alcohol and starch (i.e. farina, used in laundries and textiles).
In the present context of rapidly growing population and limited agricultural area with no scope of further area spreading, in order to avoid disparity between demand and supply, potato cultivation highly urges for more and more return. Proper quantity and timely supply of nutrients is the most important factor in realising high productivity of potato cultivation as potato is a heavy feeder and highly responsive to nutrient supply (Westermann, 2005; Pandit *et al.*, 2018) [29, 22]. So far, potato cultivation has mostly remained with the supply of nutrients (nitrogen, phosphorus, potassium etc.) through chemical fertilizers (Pandit *et al.*, 2018) [22]. However, with the increment of the price of these chemical fertilizers as well as its issues of

environmental hazards, potato cultivation is now required to be shifted to a promising alternative of inorganic nutrition, called integrated nutrient management (INM). INM involves supplies of nutrients from various sources (inorganic and organic) to achieve balanced nutrition covering benefits and curtailing limitations of both the sources. Specifically, it addresses the adverse effects of chemical fertilizers on soil health and crop qualities as well as incorporates the benefits of organic manures to improve soil fertility and crop performance (Chang *et al.*, 1991; Ahmed *et al.*, 1996; Brady, 1996; Chung *et al.*, 2000; Keupper and Gegner, 2004) [7, 6, 8, 18]. Previous studies (Raghav *et al.*, 2009; Baishya *et al.*, 2012, Pandit *et al.*, 2018) [23, 4, 22] have already stated the importance of INM on quality and quantity of potato crop over sole application of chemical fertilizers. The present experiment has been framed for confirmation of previous works and also to investigate further the best INM option for potato cultivation.

Materials and Methods

The field experiment was carried out at Instructional farm, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal, India during *rabi* (winter) season of 2017-18 comprising seven nutrient management options (Table 1), replicated thrice under randomised block design (RBD). The soil of the experimental site was sandy clay loam in texture with 61.24% sand, 14.20% silt and 24.56% clay. The soil had 1.51 Mg/m^3 bulk density, 1.2 cm/hour infiltration rate, 6.65 pH, 0.29 dS/m electrical conductivity. Initial soil organic carbon, available nitrogen, phosphorus and potassium were 5.8 g/kg, 159.2 kg/kg, 44.9 kg/kg and 101.8 kg/kg of soil respectively. Climatic condition during the experimental period has been shown in figure 1, 2 and 3. Potato variety 'Kufri Jyoti' was planted (approximately 40-50 g weight of each tuber) on flat bed on 19th November, 2017 at 60cm x 25 cm spacing and harvested on 10th March, 2018. Individual plot size was 5m x 5m. Earthing up was done twice at 30 and 60 days after planting (DAP). Late blight infestation was checked through application of Dithane M 45 as and when required. Agronomic and other plant protection measures were used as per standard recommendations.

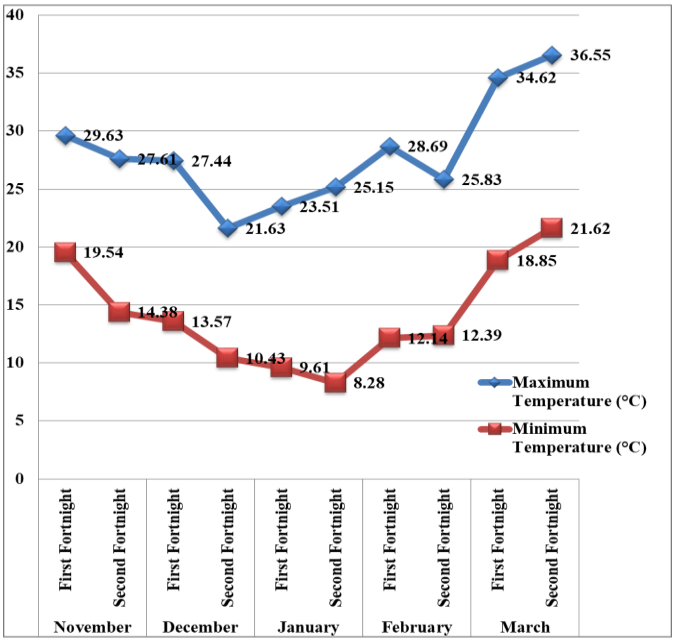

Fig 1: Maximum and minimum temperature during the experimental period at fortnightly interval

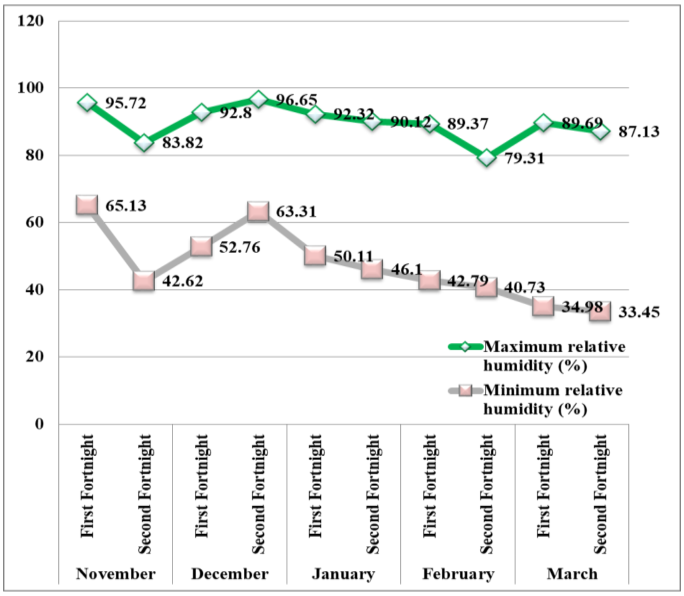

Fig 2: Maximum and minimum relative humidity during the experimental period at fortnightly interval

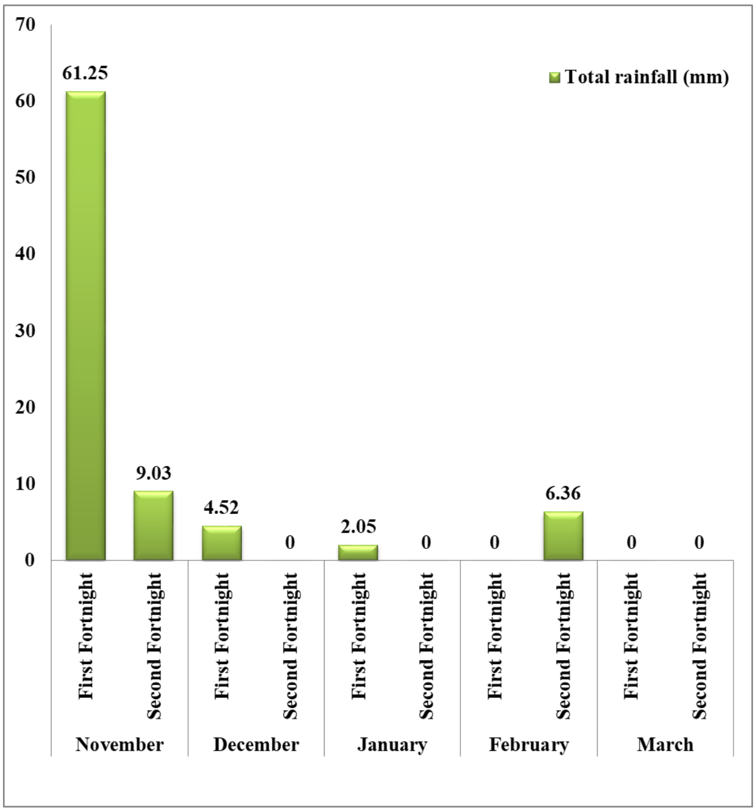

Fig 3: Total rainfall during the experimental period at fortnightly interval

Table 1: Treatment details of the experiment

Symbol	Treatment details
T_1	100% RDF (i.e. 200:150:150 kg $N:P_2O_5:K_2O$/ha)
T_2	100% RDF + Yeast vinasse @ 2 t/ha
T_3	75% RDF + Yeast vinasse @ 2 t/ha
T_4	50% RDF + Yeast vinasse @ 2 t/ha
T_5	100% RDF + Vermicompost @ 2 t/ha
T_6	75% RDF + Vermicompost @ 2 t/ha
T_7	50% RDF + Vermicompost@ 2 t/ha

Recommended dose of fertilizer (RDF) was applied through urea, S.S.P. and M.O.P. respectively for nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O). Entire quantities of P_2O_5 and K_2O and half of N were applied at basal and rest half of N was applied at the time of first earthing up (30 DAP). Entire quantity of yeast vinasse and vermicompost were applied 15 and 7 days before planting respectively during land preparation. Yeast vinasse is a fine brown to dark brown powder obtained after evaporation and drying of semiliquid rejected part derived from reverse osmosis after anaerobic and aerobic microbial digestion of residual liquid part from bakery yeast fermentation (Fig 4). Chemical composition of yeast vinasse analysed is presented in table 2.

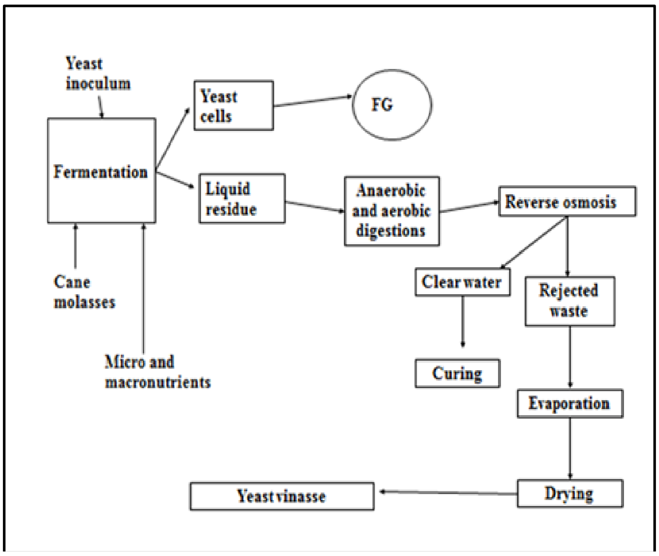

Fig 4: Schematic representation of yeast vinasse preparation

Table 2: Chemical composition of yeast vinasse

Parameter	Value
Organic carbon	37.12%
Total nitrogen	1.92%
available phosphorus	0.24%
available potassium	9.02%
Moisture	4.41%
Calcium	2.32%
Acid soluble ash	0.18%
Crude protein	11.98%
Crude fibre	<0.1%
Crude fat	1.43%

Observations from the experimental field included tuber yield and dry matter yield of potato. Nutrient uptake (nitrogen, phosphorus and potassium), carbohydrate and protein contents of potato were analysed in laboratory. Data collected from the experiment were statistically analysed through OP-STAT online portal using analysis of variance (ANOVA) method (Goulden, 1952 and Cochran and Cox, 1959) [12, 9] and treatment means were compared at 5% level of significance using critical differences (CD) as stated by Gomez and Gomez (1984) [11].

Results and Discussion

Effect of INM on nutrient uptake of potato

Experimental results explored variability in nutrient uptake of potato under different nutrient management options (Table 3). Highest uptake of N (144.6 kg/ha) by potato was noticed when 100% RDF along with vermicompost @ 2 t/ha (T_5) was applied which was closely followed by application of 100% RDF along with yeast vinasse @ 2 t/ha (T_2) (138.9 kg/ha) and both remained statistically at par with each other. Application of 75% RDF along with vermicompost @ 2 t/ha (T_6) (129.3 kg/ha) and application of 75% RDF along with yeast vinasse @ 2 t/ha (T_3) (121.8 kg/ha) remained statistically at par with each other and with sole application 100% RDF (T_1) (125.8 kg/ha) in terms of N (nitrogen) uptake by potato (Table 3 and Fig 5). Results regarding increment of N uptake by potato under integrated application of vermicompost and chemical fertilizers corroborated the findings of Love *et al.* (2005), Haase *et al.* (2007) [13] and Yourtchi *et al.* (2013) [30]. Application of 100% RDF along with vermicompost @ 2 t/ha (T_5) similarly recorded highest P (phosphorus) uptake by potato (18.3 kg/ha), followed by 100% RDF along with yeast vinasse @ 2 t/ha (T_2) (16.8 kg/ha) and application of 75% RDF along with vermicompost @ 2 t/ha (T_6) (15.9 kg/ha) and all the three INM options remained statistically similar to each other (Table 3 and Fig 5). Enhancement of P uptake of various crops by addition of vermicompost in INM was also reported by Sainz *et al*. (1998) [25], Shivaputra *et al*. (2004) [27], Mohanty *et al*. (2006) [21], Zaller (2007) [31] and Yourtchi *et al*. (2013) [30]. Application of 75% RDF along with yeast vinasse @ 2 t/ha (T_3) recorded statistically similar P uptake by potato (12.4 kg/ha) as recorded by sole application of 100% RDF (T_1) (13.1 kg/ha). In case of K (potassium) uptake by potato, slightly different trend was observed, where application of 100% RDF along with yeast vinasse @ 2 t/ha (T_2) recorded highest K uptake (134.8 kg/ha), followed by application of 100% RDF along with vermicompost @ 2 t/ha (T_5) (130.2 kg/ha) and both remained statistically indifferent to each other following the previous trend again (Table 3 and Fig 5). No statistical difference was also noticed among application of 75% RDF along with yeast vinasse @ 2 t/ha (T_3) (119.4 kg/ha), application of 75% RDF along with vermicompost @ 2 t/ha (T_6) (116.6 kg/ha) and sole application of 100% RDF (T_1) (122.3 kg/ha). Improvement of K uptake by potato by application of vermicompost along with chemical fertilizers has been confirmed by Yourtchi *et al*. (2013) [30].

Use of organic sources of nutrients such as vermicompost and yeast vinasse in INM options induced better root system of potato (Barman *et al*., 2018) [5] resulting greater uptake of nutrients than sole application of chemical fertilizers. Vermicompost is a rich source of nutrients and an excellent factor for improvement of soil bio-physical health which enhances root proliferation of crops and helps in higher availability and uptake of nutrients (Khan *et al*., 2017) [16]. Higher availability of nutrients for crops on application of vermicompost has been also reported earlier by Vasanthi and Kumaraswamy (1996) [28]. Enhanced soil microbial activity by application of vermicompost on improvement of uptake nutrients (Alam *et al*., 2007) [2] might be another reason for such results. Beside positive impacts of vermicompost in INM on nutrient uptake, results from the present study (Table 3) stated equal effectiveness of yeast vinasse as organic sources in INM. Specially, best uptake of K by potato through application of yeast vinasse along with chemical fertilizers might be due to high potassium content of yeast vinasse as mentioned in table 2. Increased nutrient uptake by application of yeast vinasse over sole application of chemical fertilizers was earlier reported by Komdorfer and Anderson (1993) in sugarcane, maize, wheat and pigeon pea. High concentration of K and moderate concentrations of P and N in yeast vinasse exerting positive influence on soil properties and nutrient uptake was also stated by Zhou *et al*. (2009) [32], Rajagopal *et al*. (2014) [24] and Mahmoud *et al*. (2019) [20].

Table 3: Effect of integrated nutrient management (INM) on nutrient uptake of potato

Treatments	N uptake (kg/ha)	P uptake (kg/ha)	K uptake (kg/ha)
T_1-100% RDF (i.e. 200:150:150 kg $N:P_2O_5:K_2O$/ha)	125.8	13.1	122.3
T_2-100% RDF + Yeast vinasse @ 2 t/ha	138.9	16.8	134.8
T_3-75% RDF + Yeast vinasse @ 2 t/ha	121.8	12.4	119.4
T_4-50% RDF + Yeast vinasse @ 2 t/ha	108.6	7.01	106.7
T_5-100% RDF + Vermicompost @ 2 t/ha	144.6	18.3	130.2
T_6-75% RDF + Vermicompost @ 2 t/ha	129.3	15.9	116.6
T_7-50% RDF + Vermicompost@ 2 t/ha	112.5	9.5	103.1
S.Em (±)	3.65	1.16	3.32
CD (*p=0.05*)	10.67	3.38	9.81

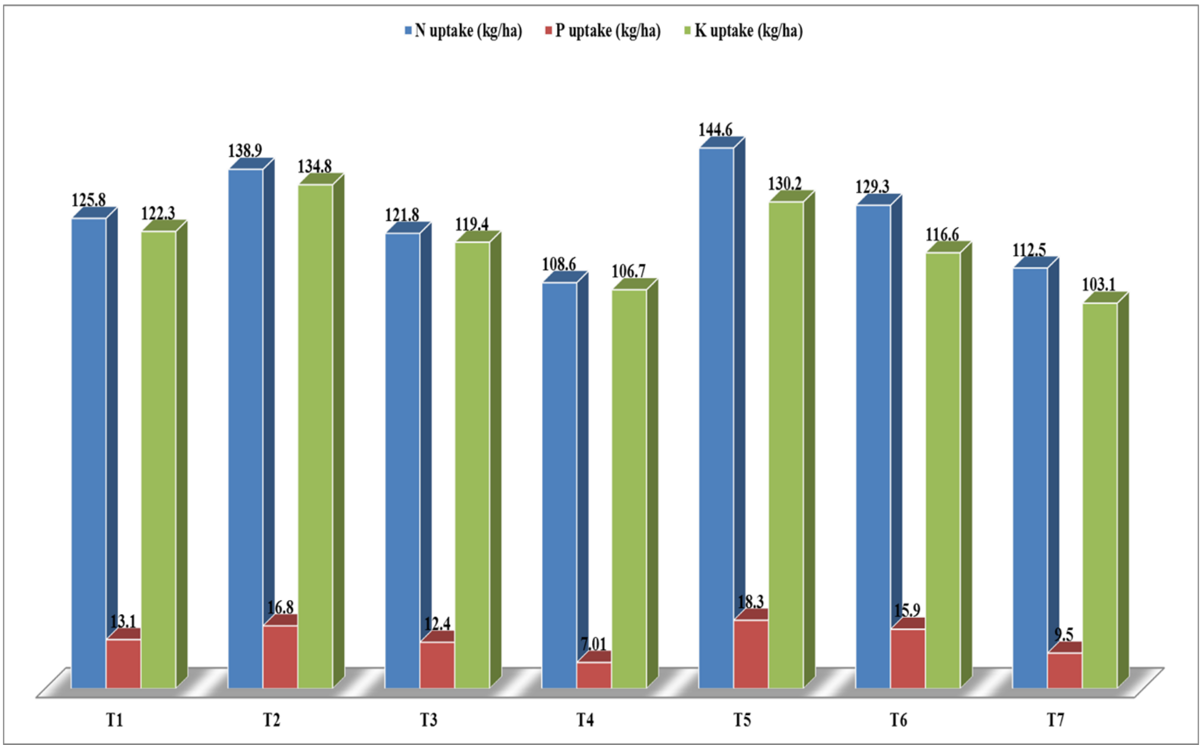

Fig 5: Effect of integrated nutrient management (INM) on tuber and dry matter yield of potato

Effect of INM on yield and quality of potato

Experimental results from table 4 further revealed that various integrated nutrient management options exerted significant effect on potato tuber and dry matter yields. Application of 100% RDF along with vermicompost @ 2 t/ha (T_5) produced maximum potato tuber yield (27.29 t/ha) which was closely followed by application of 100% RDF along with yeast vinasse @ 2 t/ha (T_2) (26.97 t/ha) and both those INM options (T_5 and T_2) remained statistically indifferent to each other. Sole application of chemical fertilizers (100% RDF i.e. T_1) produced potato tuber yield of 25.61 t/ha and both application of 75% RDF along with vermicompost @ 2 t/ha (T_6) (24.96 t/ha) and application of 75% RDF along with yeast vinasse @ 2 t/ha (T_3) (24.68 t/ha) were statistically at par with 100% RDF (T_1) and among each other (Table 4 and Fig 6), indicating the positive effects of vermicompost and yeast vinasse as organic sources under INM on potato tuber yield over sole application of chemical fertilizers. Similarly, maximum dry matter yield (6.75 t/ha) was achieved by application of 100% RDF along with vermicompost @ 2 t/ha (T_5) which was statistically at par with application of 100% RDF along with yeast vinasse @ 2t/ha (T_2) (6.66 t/ha). Applications of 75% RDF along with vermicompost @ 2 t/ha (T_6) (5.63 t/ha) and 75% RDF along with yeast vinasse @ 2 t/ha (T_3) (5.46 t/ha) remained statistically similar with application of chemical fertilizers alone (5.87 t/ha) and among each other in terms of potato dry matter yield (Table 4 and Fig 6). Application of vermicompost or yeast vinasse as a part of INM enhancing the tuber and dry matter yield of potato might be due to improved soil health (as they are rich various macro nutrients, micro nutrients, growth regulators etc.) resulting in better availability, uptakes of nutrients and its translocation inside the plant. Improved vegetative growth in response to application of vermicompost or yeast vinasse along with chemical fertilizers facilitating higher photosynthesis and translocation of assimilates in to reproductive part of the plant, might be another reason for recording such a higher yield of potato under INM as compared to sole application of chemical fertilization. analogous type of results confirming yield enhancement of potato through use of vermicompost was reported by Ghosh *et al*. (1999) [10], Alam *et al*. (2007) [2], Ansari (2008) [3], Yourtchi *et al*. (2013) [30], Pandit *et al*. (2018) [22] and many more. Similarly, yield enhancement through yeast vinasse corroborated the findings of Mahmoud *et al*. (2019) [20] in spinach and barley.

Quality attributes of potato as shown in table 4 revealed that there was no statistically significant effect of various nutrient management options on carbohydrate content of potato. However, highest carbohydrate content of potato was found when 100% RDF along with yeast vinasse @ 2 t/ha (T_2) was applied (74.9%), followed by application of 100% RDF along with vermicompost @ 2 t/ha (T_5) (74.7%) and sole application of 100% RDF (T_1) (74.6%). The result was in line with the findings of Sheth *et al*. (2018) who reported that starch and sugar contents of sweet potato did not vary according to nutrient management option. Yet, in their study, Sheth *et al*. (2018) observed that INM option incorporating vermicompost exhibited highest starch and sugar contents of sweet potato. However, unlike carbohydrate, protein content of potato significantly varied among various nutrient management options (Table 4). Application of 100% RDF along with vermicompost @ 2 t/ha (T_5) helped potato tuber to contain highest protein content (1.23%) which was closely followed by application of 100% RDF along with yeast vinasse @ 2 t/ha (T_2) (1.22%) and sole application of 100% RDF (T_1) (1.21%) and all those three remained statistically same in terms of providing protein content of potato tuber. Nitrogen is the precursor of protein and thus, higher protein content under application of vermicompost or yeast vinasse along with chemical fertilizers might be due the better uptake of nitrogen as compared to application of sole chemical fertilizers. Joshi *et al*. (2014) reported improved quality of crops in terms of carbohydrate, protein and many others through application of vermicompost.

Table 4: Effect of integrated nutrient management (INM) on yield and quality of potato

Treatments	Tuber yield (t/ha)	Dry matter yield (t/ha)	Carbohydrate (%)	Protein (%)
T_1-100% RDF (i.e. 200:150:150 kg $N:P_2O_5:K_2O$/ha)	25.61	5.87	74.6	1.21
T_2-100% RDF + Yeast vinasse @ 2 t/ha	26.97	6.66	74.9	1.22
T_3-75% RDF + Yeast vinasse @ 2 t/ha	24.68	5.46	74.1	1.20
T_4-50% RDF + Yeast vinasse @ 2 t/ha	23.04	4.80	74.5	1.18
T_5-100% RDF + Vermicompost @ 2 t/ha	27.29	6.75	74.7	1.23
T_6-75% RDF + Vermicompost @ 2 t/ha	24.96	5.63	74.3	1.21
T_7-50% RDF + Vermicompost@ 2 t/ha	22.89	5.01	74.1	1.16
S.Em (±)	0.38	0.18	0.33	0.01
CD (*p=0.05*)	1.11	0.51	NS	0.02

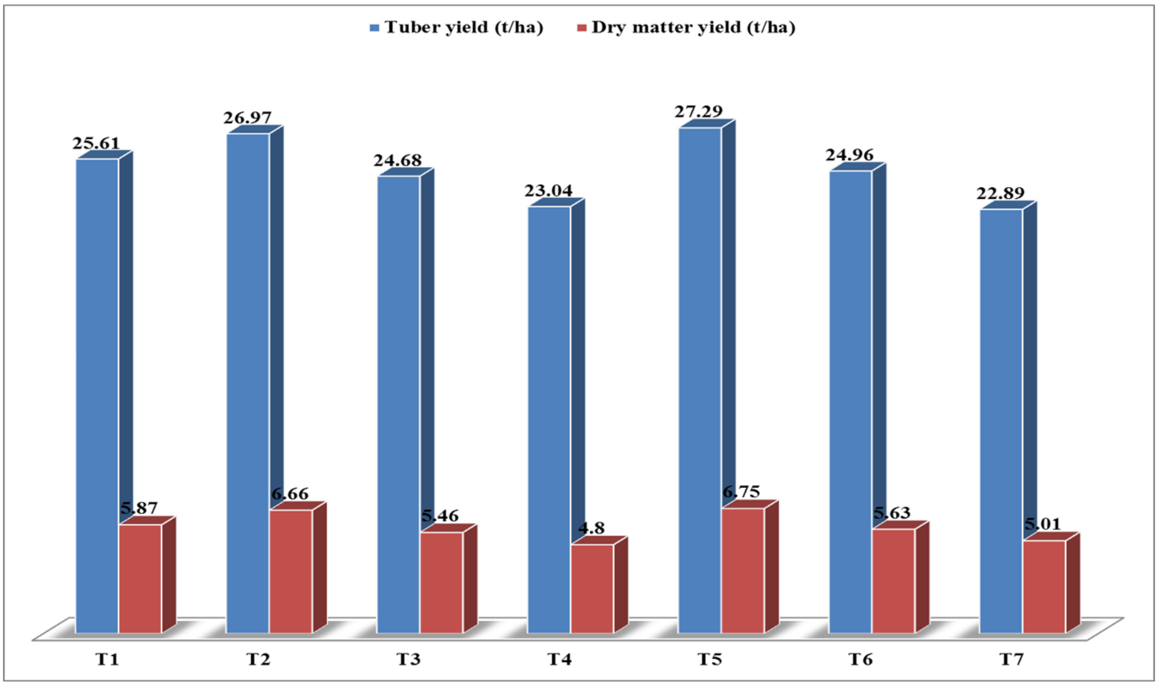

Fig 6: Effect of integrated nutrient management (INM) on tuber and dry matter yield of potato

Conclusion

Finally, the study confirms the wise choice of incorporating integrated nutrient management (INM) in place of sole use of chemical fertilizers for potato cultivation. Supplemental application of either vermicompost or yeast vinasse @ 2 t/ha along with 100% RDF can be recommended to potato growers of new alluvial zone of West Bengal, India for achieving improved nutrient uptake, yield and quality enhancement of potato.

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