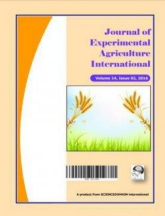

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Effect of Integrated Nutrient Management on Soil Fertility and Productivity on Wheat Crop

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted during Rabi season 2013-14 and 2014-15 on sandy loam soil to study on crop research Centre Chirori of Sardar Vallabhbhai Patel University of Agriculture and Technology; Meerut utter Pradesh (India). The results revealed that application if 125% recommend dose fertilizer of NPK were significantly higher plant height at different stages, number of spikelet's spike^{-1},Number of grains spike^{-1}, Test weight (g) than the other treatments during both the years. Application of 125% recommended dose fertilizer recorded significantly highest grain yield 49.73 to 47.75 q ha^{-1} during 2013-14 & 2014-15, respectively. Among the various treatments where 125% NPK was applied proved to be superior and it statistically at par with T_2 (100 % NPK) and T11 (75 % NPK + vermicompost @ 2.5 t ha-1 + phosphorus solubilizing bacteria + Azotobacter), in terms of growth, yield attributes and yields during first & second years. Moreover, the application of organic in integration with inorganic fertilizers could also maintain the soil fertility which is much important for sustainable crop production. The organic carbon and available NPK in the soil after harvest increase with the combined application of organic and inorganic with

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Biofertilizer. Integration of 75% NPK with vermicompost @ 2.5 t ha-1 + phosphorus solubilizing bacteria + Azotobacter was found better by improving the residual soil fertility status after the harvest of the wheat crop.

Keywords: Nutrient management; FYM; pressmud; vermicompost; azotobactor; phosphorus solubilizing bacteria; growth; yield and yield attributes.

1. INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most important food crop in the world in terms of area, production and nutrition which contribute 20 percent of total food requirement of the world population. It provides more than 19% calories and 21% of the protein besides is a significant source of dietary fiber in human nutrition since decades. Wheat production in India during the 2017-18 Rabi season is likely to see a dip as the area sown to wheat has declined by 4.2 per cent, amounting to 30.4 million hectares, as compared to 31.7 million hectares in 2016-17. According to an official data, the drop in wheat acreage is due to lesser coverage in Madhya Pradesh, Uttar Pradesh, Rajasthan, Haryana, West Bengal, Maharashtra and Uttarakhand, with Madhya Pradesh recording the maximum decline of 1.1 million hectares. Taking into account an average yield of 3.1 tonnes/hectare, the total production could range between 94-96 MT, against the targeted 97.5 MT. The 2017-18 harvesting season will commence from March [1]. The INM refers "a system which aim to improving and maintaining soil fertility for sustaining crop productivity, and involves the use of chemical fertilizers in conjunction with organic manure rice rich input through biological process". Incorporation of organic sources, i.e. farmyard manure (FYM), vermicompost, pressmud, Biofertilizer, phosphate solubilizing bacteria (PSB) and *Azotobactor* along with chemical fertilizers is effective in increasing the nutrient availability in soil, improving physical properties of soil and its organic carbon status. On account of continuing world energy crisis and spiraling price of chemical fertilizer the use of organic manure as a renewable source of plant nutrients is assuming importance. In this endeavor proper balance of organic and inorganic fertilizer is important not only for increasing yield but also for sustaining soil health [2]. The integrated nutrient management favorably affects the physical, chemical and biological environment of soils. Integrated nutrient supply involving conjunctive use of inorganic fertilizers and organic sources of nutrients assumes greater significance. Farmyard manure improves the physical condition of soil by increasing water holding capacity for maximum utilization of water. It also improves the chemical and biological condition of soil by increasing cation exchange capacity and providing various hormones and organic acids which are very important for soil aggregation and for beneficial micro-organism involved in various biochemical processes and release of nutrients. The combination of organic and inorganic N sources resulted in comparable rice yield to the application of inorganic N alone. Inorganic N application increased rice yield by 45.8% over unfertilized control. The increase in yield was due to an increase in the number of panicle per plant and panicle weight [3]. Longtime studies carried out at several locations in India indicate that application of all the needy nutrients through chemical fertilizers have dexterity effect on soil health leading to unsustainable yields. Therefore:, there is a need to improve nutrient supply system in terms of integrated nutrient management involving the use of chemical fertilizer in conjunction with organic manures coupled with input through biological processes. Balanced fertilization is the application of essential plant nutrients in right proportion and in optimum quantity for a specific soil crop condition. Continuous imbalanced use of fertilizer led to the deterioration in the soil fertility and decrease in soil productivity. Integrated plant nutrient supply system could help in meeting the goals of balanced fertilization. The research findings on various aspects of the integrated nutrient management on wheat are reviewed. To meet the ever-increasing demand for food of the huge population of the Indian subcontinent and to exploit the high yield potential of cereals, it requires higher fertilizer doses, which are a non-renewable source of energy. However, long-term fertilizer experiments have revealed that continuous application of suboptimum doses of chemical fertilizers to soil has resulted in the deterioration of soil health, environmental pollution and stagnation or decrease in crop productivity. Thus, integrated use of organic manures with optimal levels of NPK fertilizers is the need of the day that will not only improve the nutrient status and soil health but has also shown greater potential in stabilizing crop yields over a

period of time. Keeping all above facts in view the present investigation entitled "Effect of integrated nutrient management on soil fertility and productivity on wheat crop", will be carried out with the following objectives:

1. To study the effect of integrated nutrient management on growth, yield and yield attributes of wheat.
2. To study the effect of integrated nutrient management on nutrients content and their uptake by wheat.
3. To study the effect of integrated nutrient management on available nutrients status in soil.
4. To study the economic feasibility of different nutrient management strategies.

2. MATERIALS AND METHODS

Field experiments were conducted during winter season 2013-14 and 2014-15 at crop research centre farm Chirrori, Sardar Vallabhbhai Patel Agriculture University Meerut utter Pradesh (India). The soil was sandy loam having organic carbon 0.56 and 0.54% with pH 8.25and 8.10, available N 241 kg ha^{-1} and 240 kg ha^{-1}, available $P_2O_5$13.60 and 13.33 kg ha^{-1} and available K_20 208.6 kg ha^{-1} and 206.25 kg ha^{-1} at the start of the experiment in 0 to 30 cm soil layer during 2013-14 and 2014-15 respectively. The experiment consists of thirteen treatments *viz*., T_1 (Control), T_2 (100 % NPK) , T_3 (75% NPK + FYM @ 7.5 t ha^{-1}), T_4 (75% NPK + vermicompost @ 2.5 t ha^{-1}), T_5 (75% NPK + Press mud 3.0 t ha^{-1}), T_6 (75 % NPK + Press mud @ 1.5 t ha^{-1} + FYM @ 3.75 t ha^{-1}), T_7 (75% NPK + vermicompost @ 1.25 t ha^{-1} + Press mud @1.50 t ha^{-1}), T_8 (75 % NPK + vermicompost @ 1.25 t ha^{-1} + FYM @3.75 t ha^{-1}), T_9 (75% NPK+ *Azotobacter* + PSB), T_{10} (75 % NPK+ FYM @ 7.5 t ha^{-1} + PSB+ *Azotobacter*) ,T 11(75% NPK +vermicompost @ 2.5 t ha^{-1} + PSB + *Azotobacter*), T_{12} (75 % NPK + press mud @ 3.0 t ha^{-1}+PSB+ *Azotobacter*) ,T_{13} (125% NPK),. The experiment was laid out in Randomized Block Design with three replications. Vermicompost was applied 15 days before sowing as per treatment. Wheat cultivar PBW-550 was sown in rows to row 20 cm apart on sowing 12 Nov. in 2013-14 and 14 Nov. in 2014-15 and harvested on 15 March in 2013-14 and 12 March in 2014-15 respectively. Half of the nitrogen and full dose of phosphorus and potash were applied at the time of sowing as per treatment combination. The remaining nitrogen as per treatment was top-dressed after first irrigation. N, P, and K were applied through urea, single super phosphate and muriate of potash respectively. The seeds were inoculated with phosphate solubilizing bacteria (PSB), i.e. *Pseudomonas strata* before sowing as per treatments. The crop received three regular irrigations (at Crown Root Initiation, flowering and milking stages). Postharvest soil samples were drawn and analyzed for organic carbon by wet digestion method [4], available N by alkaline permanganate method [5] available phosphorus (P) by 0.5 M $NaHCO_3$ Extractable Olsen's Colorimetric method (Olsen's [6]) and available potassium (K) by neutral normal ammonium acetate method) [7]. The treatment comparisons were made using t-test at 5% level of significance. The economics was calculated from prevailing local market price of wheat grains and cost of inputs.

3. RESULTS AND DISCUSSION

Plant height increased at a faster rate between 60-90 DAS as affected significantly by different nutrient treatments. The plant height was affected considerably at 30, 60, 90 DAS and harvest in different treatments (Table 1). The Application of 125% NPK produced maximum plant height which was at par 75% NPK with Vermicompost @ 2.5 t ha^{-1} + PSB +*Azotobacter*. Control plots produced shorter plant at all the growth stages. The higher plant height with the application of 125% NPK and 75% NPK + vermicompost @ 2.5 t ha^{-1} + PSB + *Azotobacter*, can be associated with sufficient nutrient supply at the active growth stage. Similar results of increased plant height with growing nutrient level were also reported by Singh et al. [8] said that the treatments consisted of FYM, vermicompost, green manure, *Azotobacter*, phosphate solubilizing bacteria (PSB) and NPK fertilizers.

3.1 Yield Attributes

Significantly higher number of spikelet per spike, number of grains per spike and test weight recorded with the application of 125% NPK which was at par with 75% NPK with vermicompost @ 2.5 t ha^{-1} + PSB +*Azotobacter* (Table 2). It might be due to the stimulated vegetative growth of wheat on account of adequate and prolonged supply of essential nutrients. Afzal et al. [9] also reported that PSB along with organic manures or with other combinations significantly increased the number of tillers m-2. These results are in line with the findings of Kumar et al. [10] who

Table 1. Effect of integrated nutrient management on plant height (cm) of wheat at various stage

Treatment	30 DAS		60 DAS		90 DAS		At harvest	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Control	13.84	13.20	43.11	42.45	65.83	63.83	68.17	66.50
100 % Recommended dose of NPK	17.19	16.22	59.13	58.47	84.48	83.46	86.80	86.10
75% NPK + FYM @ 7.5 t ha^{-1}	16.43	16.29	58.86	58.2	83.58	82.58	85.9	85.23
75 % NPK + Vermicompost @ 2.5 t ha^{-1}	17.07	16.20	59.70	59.03	85.32	84.32	87.65	86.98
75 % NPK + Press mud 3.0 t ha^{-1}	16.07	15.25	56.17	55.52	80.70	76.37	83.03	78.70
75 % NPK + Press mud @ 1.5 t ha^{-1} +FYM @ 3.75 t ha^{-1}	16.27	16.07	57.08	56.41	80.00	78.90	85.57	81.57
75 % NPK + Vermicompost @ 1.25 t ha^{-1}+ Press mud @1.50t ha^{-1}	16.76	16.39	57.37	56.72	81.97	80.97	84.3	83.63
75 % NPK + Vermicompost @ 1.25 t ha^{-1} + FYM @3.75 t ha^{-1}	16.97	16.80	58.53	57.88	82.63	81.63	84.95	84.28
75 % NPK+ *Azotobacter* + PSB	15.73	15.52	55.25	54.58	76.50	75.50	82.17	78.17
75 % NPK+ FYM @ 7.5 t ha^{-1} + PSB+ *Azotobacter*	16.97	16.27	61.47	60.8	86.05	85.06	88.33	87.36
75 % NPK +vermicompost @ 2.5 t ha^{-1} + PSB + *Azotobacter*	17.27	17.12	62.01	61.34	87.32	86.32	89.65	88.98
75 % NPK + press mud @ 3.0 t ha^{-1}+PSB+ *Azotobacter*	16.22	15.92	56.62	55.96	79.12	78.12	81.43	80.77
125% Recommended dose of NPK	18.47	17.41	63.10	62.43	89.37	88.39	91.73	90.37
SEm(±)	0.39	0.59	0.83	0.91	1.42	0.86	1.59	1.04
C.D. (P=0.05)	1.66	1.75	2.44	2.69	4.17	2.54	4.69	3.06

Table 2. Effect of integrated nutrient management on yield attributes and yield of wheat crop

Treatment	Grain Yield (q ha^{-1})		Spike length (cm)		No of spikelets/spike		No. of grains/spike		Test weight (g)	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Control	26.52	24.57	6.65	6.43	8.33	8.23	28.80	27.65	31.18	30.85
100 % RDF of NPK	47.12	46.02	10.75	10.65	13.85	13.52	45.97	45.58	45.84	45.62
75% NPK + FYM @ 7.5 t ha^{-1}	40.54	38.60	10.32	10.30	13.50	13.28	42.97	42.50	45.18	44.56
75 % NPK + VC @ 2.5 t ha^{-1}	44.40	42.61	10.19	9.88	12.45	12.20	40.40	39.75	43.58	42.84
75 % NPK + PM 3.0 t ha^{-1}	37.47	36.73	8.93	8.85	11.25	10.78	38.00	37.56	40.77	40.60
75 % NPK + PM @ 1.5 t ha^{-1} +FYM @ 3.75 t ha^{-1}	39.32	37.73	9.73	9.68	11.56	11.20	39.23	38.10	42.94	42.75
75 % NPK + VC @ 1.25 t ha^{-1}+ PM @1.50t ha^{-1}	41.62	39.70	10.00	9.90	12.51	12.30	41.30	40.85	43.89	43.50
75 % NPK + VC @ 1.25 t ha^{-1} + FYM @3.75 t ha^{-1}	45.08	43.68	10.58	10.48	13.68	13.45	45.60	45.12	45.28	44.26
75 % NPK+ *Azotobacter* + PSB	36.63	35.73	8.67	8.47	10.85	10.50	37.90	36.83	40.65	40.28
75 % NPK+ FYM @ 7.5 t ha^{-1} + PSB+ *Azotobacter*	42.34	40.55	9.94	10.12	12.58	11.95	42.07	41.21	45.10	44.37
75 % NPK + VC @ 2.5 t ha^{-1} + PSB + *Azotobacter*	47.82	45.68	11.12	11.10	14.23	13.80	46.43	45.30	45.99	45.65
75 % NPK + PM @ 3.0 t ha^{-1}+PSB+ *Azotobacter*	38.80	37.08	9.53	9.48	11.43	11.10	38.30	37.10	42.33	41.64
125% RDF of NPK	49.73	47.75	11.38	11.27	14.56	13.86	49.27	47.42	48.47	47.78
SEm(±)	0.99	0.78	0.44	0.43	0.53	0.52	0.61	0.58	1.67	1.65
C.D. (P=0.05)	2.92	2.30	1.29	1.28	1.57	1.53	4.73	4.65	4.91	4.85

Table 3. Effect of integrated nutrient management on soil nutrient status after harvest of wheat crop

Treatment	OC %		Available N kg ha^{-1}		Available P_2O_5 kg ha^{-1}		Available K_2O kg ha^{-1}	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Control	0.43	0.42	140.17	135.47	7.45	6.85	125.73	124.35
100 % RDF of NPK	0.58	0.57	189.43	188.67	15.45	15.10	208.33	207.13
75% NPK + FYM @ 7.5 t ha^{-1}	0.65	0.65	184.87	183.80	14.65	14.25	198.73	197.5
75 % NPK + VC @ 2.5 t ha^{-1}	0.74	0.74	183.03	183.03	12.45	12.20	201.22	200.35
75 % NPK + PM 3.0 t ha^{-1}	0.73	0.73	172.43	171.80	10.80	10.50	190.40	189.27
75 % NPK + PM @ 1.5 t ha^{-1} +FYM @ 3.75 t ha^{-1}	0.64	0.64	175.90	175.27	12.10	11.75	193.53	192.85
75 % NPK + VC @ 1.25 t ha^{-1}+ PM @1.50t ha^{-1}	0.67	0.66	181.87	181.13	12.83	12.25	198.90	197.42
75 % NPK + VC @ 1.25 t ha^{-1} + FYM @3.75 t ha^{-1}	0.70	0.70	186.23	185.50	14.72	14.42	204.30	202.90
75 % NPK+ *Azotobacter* + PSB	0.69	0.69	170.60	170.13	10.45	10.25	189.60	188.77
75 % NPK+ FYM @ 7.5 t ha^{-1} + PSB+ *Azotobacter*	0.67	0.67	177.17	176.53	13.55	13.10	196.90	195.37
75 % NPK + VC @ 2.5 t ha^{-1} + PSB + *Azotobacter*	0.74	0.74	188.43	187.87	15.85	15.45	210.12	208.83
75 % NPK + PM @ 3.0 t ha^{-1}+PSB+ *Azotobacter*	0.64	0.62	174.23	173.47	11.54	11.07	194.70	193.63
125% RDF of NPK	0.61	0.60	191	190.4	16.5	15.72	212.43	210.23
SEm(±)	0.013	0.011	1.68	1.67	0.49	0.48	1.39	1.34
C.D. (P=0.05)	0.039	0.035	4.94	4.91	1.45	1.41	4.09	3.94

Table 4. Effect of integrated nutrient management on Cost of cultivation, Gross return, Net returns and B: C ratio of wheat

Treatment	Cost of Cultivation (Rs ha^{-1})		Gross Returns (Rs ha^{-1})		Net returns (Rs ha^{-1})		B:C ratio	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Control	24558	24558	52188	51563	27630	27005	1.13	1.10
100 % RDF of NPK	29516	30098	89541	93022	60025	62924	2.03	2.09
75% NPK + FYM @ 7.5 t ha^{-1}	30150	30525	78033	79312	47883	48787	1.59	1.60
75 % NPK + VC @ 2.5 t ha^{-1}	37025	38275	84890	86703	47865	48428	1.29	1.27
75 % NPK + PM 3.0 t ha^{-1}	30975	31275	72864	76103	41889	44828	1.35	1.43
75 % NPK + PM @ 1.5 t ha^{-1} +FYM @ 3.75 t ha^{-1}	30562	30900	76191	77875	45629	46975	1.49	1.52
75 % NPK + VC @ 1.25 t ha^{-1}+ PM @1.50t ha^{-1}	34000	34775	80303	81362	46303	46587	1.36	1.34
75 % NPK + VC @ 1.25 t ha^{-1} + FYM @3.75 t ha^{-1}	33587	34425	85883	88520	52296	54095	1.56	1.57
75 % NPK+ *Azotobacter* + PSB	28625	28675	71405	74319	42780	45644	1.49	1.59
75 % NPK+ FYM @ 7.5 t ha^{-1} + PSB+ *Azotobacter*	30500	30925	81851	82733	51351	51808	1.68	1.68
75 % NPK + VC @ 2.5 t ha^{-1} + PSB + *Azotobacter*	37374	38675	90591	92028	53217	53353	1.42	1.38
75 % NPK + PM @ 3.0 t ha^{-1}+PSB+ *Azotobacter*	31325	31675	75318	76680	43993	45005	1.40	1.42
125% RDF of NPK	30750	31483	93515	95437	62765	63954	2.02	2.03

reported a significant increase in some plants per metre row by inoculation of *Azotobacter chroococcum.* Integrated nutrient management had a beneficial effect on yield attributes, the maximum value of all yield attributes of rice and wheat were recorded under treatment receiving 100% NPK + 5 t FYM ha^{-1} followed by 75% NPK + 5 t FYM ha^{-1} as compared to100% NPK. The better crop growth with the combined use of nutrient may be attributed to improvement in physicochemical and biological properties of soil which maintained a continuous supply of nutrient to crop. Similar higher values of yield attributes with combined use of an inorganic + organic source of nutrients were reported by Davari and Sharma [11].

3.2 Yield (q ha^{-1})

The grain yield of wheat which ranged from 26.52 to 49.73 and 24.57 to 47.75 q ha^{-1} during 2013-14 and 2014-15, respectively was influenced significantly by different treatments (Table 2). The maximum grain yield 47.75 to 49.73 q ha^{-1} during the first and second year, respectively recorded with the application was 125% NPK was found statistically at par with treatment T_2, T_{11} during both the years. The minimum yield of wheat 24.57 to 26.52 q ha^{-1} was recorded from the treatment under control. The effect of FYM, vermicompost and presumed application with 75% NPK was not similar and the grain yield in 75% NPK + vermicompost 2.5 t ha^{-1} was significantly higher than 75% NPK+FYM or pressmud. Grain yield was statistically similar in the treatments receiving 100% NPK and 75% NPK + vermicompost. The effect of biofertilizers inclusion with 75% NPK was not appreciable, but when biofertilizers were applied with vermicompost, it yielded statistically at par to T_{13} during both the years. This might be due to the direct and quick supply of plant nutrients through chemicals for crop growth and a steady amount of plant nutrient by organics throughout growing period. The FYM released nutrients following decomposition and mineralization that would have increased the availability of plant nutrients at the later stage and brought improvement in physical, chemical and biological properties of soil. As a result, the fertility status of land might have increased and thus increasing the absorption of plant nutrients.

3.3 Effect on Soil Nutrient Status

The application of 75 % NPK +Vermicompost @ 2.5 t ha^{-1} + PSB + *Azotobacter* significantly increase the Organic carbon, available nitrogen, phosphorus and potash status of the soil (Table 3). Which was found at par with 75% NPK with vermicompost @ 2.5 t ha^{-1}? Available NPK of land after the harvest of wheat was found to be maximum with the application of 75 % NPK +Vermicompost @ 2.5 t ha^{-1} + phosphorus solubilizing bacteria (PSB) + and the lowest from Control. It might be due to the application of vermicompost and phosphorus solubilizing bacteria (PSB) which enhances the activity of some microbial populations, and there was a high level of total N in an experimental plot. Pandey et al. [12] also reported that addition of organic manure (FYM) with fertilizer levels significantly increased the nutrient uptake by wheat, improved the organic carbon content N, P and K status as compared to chemical fertilizer alone.

3.4 Economics

The highest cost of cultivation 37374 and 38675 Rs ha^{-1} was found in T_{11} where 75% NPK with vermicompost @ 2.5 t ha^{-1}+PSB + *Azotobacter* was applied which was the minimum cost of cultivation than the rest of the treatments Rs. 24558 and Rs. 24558 Rs. ha^{-1}during 2013-14 and 2014-15, respectively was found recorded control (Table 4). The highest gross return Rs. 90591 and Rs. 920228 ha^{-1}, Net return Rs. 60025 and Rs. 62924 ha^{-1} and benefit: cost ratio 2.03 and 2.09 was found in T_{11} (75% NPK +Vermicompost @ 2.5 t ha^{-1} + PSB + *Azotobacter*) while minimum gross return Rs. 52188 and Rs. 51563 ha^{-1}, net return Rs. 27630 and Rs. 27005 ha^{-1} and benefit-cost ratio 1.13 and1.10 during 2013-14 and 2014-15, respectively. The observation conforms with those reported by Pandey et al. [12] and Singh et al. [13] who also reported a higher benefit ratio while using INM. Suthar [14] reported that integrated application of NPK fertilizers along with vermicompost in field crops not only influences growth and production of a plant but at the same time also reduces the production budget.

4. CONCLUSION

Biological, grain and straw yields of wheat were influenced significantly by different treatments. Super-optimal application of NPK (125% NPK of RDF) was found statistically at par to T_2 (100%NPK) and $T_{11,}$ where 75% NPK along with vermicompost @ 2.5 t ha^{-1} + PSB + Azotobacter were applied. These treatments were found significantly higher than the rest of the

procedures during both the years. Comparison of various parameters like growth, yield, plant nutrient content and uptake by plant etc., revealed that these parameters recorded in T_{11} with the application of 75% NPK with vermicompost @ 2.5 t ha^{-1}+ PSB + Azotobacter were found statistically similar to T_2 and T_{13} during both the years. This combination also enhanced the soil health by improving the availability of the different nutrient.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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