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Research Paper

Effect of *in-situ* and *ex-situ* green manuring and zinc fertilization on growth and productivity of *Basmati* rice (*Oryza sativa*) under rice–wheat cropping system

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ABSTRACT

A field experiment was conducted at the research farm of ICAR-Indian Agricultural Research Institute, New Delhi, India during summer and rainy (*kharif*) seasons of 2015 and 2016 to study the effect of *in-situ* and *ex-situ* green manuring crops and zinc fertilization strategy on growth, yield attributes and productivity of *Basmati* rice (*Oryza sativa* L.). The experiment was conducted in a split-plot design, keeping 2 *in-situ* green manuring crops viz. *Sesbania aculeata* Poir (dhaincha) and *Vigna umbellata* Thunb. (rice bean), 1 *ex-situ* green manuring crop viz. *Leucaena leucocephala* (*subabul*) and summer fallow as main-plot treatments and 4 zinc (Zn) fertilization treatments viz. 5 kg Zn through chelated Zn-EDTA as soil application, 2.5 kg Zn through chelated Zn-EDTA as soil application + 1 foliar application of 0.5% solution of chelated Zn-EDTA at flowering, foliar application of 0.5% solution of chelated Zn-EDTA at active tillering + flowering + grain filling, foliar application of 0.5% solution of chelated Zn-EDTA at 20, 40, 60 and 80 days after transplanting (DAT) and a control (no Zn) in sub-plots and was replicated thrice. Results showed that the incorporation of *Sesbania aculeata* green manure @ 34.7 t/ha (based on fresh weight) prior to transplanting of *Basmati* rice (based on mean of 2 years) produced higher growth parameters, viz. plant height, effective tillers, dry-matter; yield attributes, viz. panicle length, panicle weight and 1,000-grain weight, correlation between yield and yield attributes and yields than *Vigna umbellata*, *Leucaena leucocephala* and summer fallow. Foliar application of 0.5% solution of chelated Zn-EDTA at 20, 40, 60 and 80 DAT was better than soil application of Zn with regard to growth parameters and grain yield (5.1 t/ha), correlation between yield and yield attributes like grain yield and panicle length (91.3%), grain yield and panicle weight (75.5%) of *Basmati* rice. Incorporation of *Sesbania aculeata* green manure generated highest net income (43.0 × 10^3 ₹/ha) among green manure treatments, while among Zn application treatments application of 0.5% solution of chelated Zn-EDTA at 20, 40, 60 and 80 DAT fetched the highest net returns (64.9 × 10^3 ₹/ha) from *basmati* rice cultivation.

Key words : *Basmati* rice, Growth, *In-situ* and *ex-situ* green manuring, Net returns, Yield, Zn-EDTA

The rice–wheat cropping system (RWCS) is India's most widely adopted system, comprises about 13 million ha area in the Indo Gangetic Plains (IGP), of which the Indian part of the IGP comprises about 10 million ha (Sarkar, 2015). However, recent years have witnessed a significant slowdown in the yield growth rate of RWCS and the sustainability of this important cropping system is at risk (Chauhan *et al.,* 2013) as yield of both rice and wheat are either stagnant or declining due to deterioration of soil health, decrement in total factor productivity or input-use efficiency, increase in cultivation costs and reduction in profit margins (Sarkar, 2015). Combination of poor soil fertility and inadequate, imbalanced and inefficient use of fertilizers contributes much to this problem (Singh *et al.,* 2017). Consequently maintaining long-term soil fertility under rice–wheat cropping system is greater concern for the farmers in present scenario. In regards of maintaining soil fertility under rice–wheat cropping system, green manuring maintains and improves soil structure by addition of organic matter, minimize phosphorus and potassium fixation, produces humus, which enhances the utilization of fertilizer nutrients by plants and helps in reducing leaching losses by enhancing water retention ability of soil. Incorporation of *Sesbania* green manure over the years before transplanting of rice helps in improving DTPA-extractable micronutrient cations of the soil

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(Nayyar and Chhibba, 2000). Among micronutrients, zinc (Zn) is now recognized as a key element and the fifth leading health risk factor in developing countries of Asia, where rice is the staple food (Pooniya and Shivay, 2013; Prasad *et al.,* 2014; Ghasal *et al.,* 2016; Shivay *et al.,* 2016). Almost 50% of the world soils used for cereal production is Zn deficient. This percentage is even higher in RWCS areas which reduce not only grain yield but also nutritional quality of grains (Cakmak, 2008). The role of Zn in improving productivity of rice is as important as that of major nutrients in present day agriculture (Pooniya and Shivay, 2011). Several past studies have been carried out on the effect of summer green manuring on succeeding rice, but there is very scarce information available on the use of rice bean, *Sesbania* and *Leucaena* crops as green manuring crops in conjunction with soil and foliar application of Zn on growth and productivity of *Basmati* rice at present location. Considering these above-mentioned facts, we planned a field experiment on the effect of *in-situ* and *ex-situ* green manuring crops and zinc fertilization strategy on growth and productivity of *Basmati* rice.

MATERIALS AND METHODS

A field experiment was conducted at the research farm of ICAR-Indian Agricultural Research Institute, New Delhi during summer and rainy (*kharif*) seasons of 2015 and 2016. The soil of the experimental field was sandy clay loam (*typic Ustochrept*) in texture with 51.4% sand, 22.2% silt and 26.4% clay. The initial DTPA–extractable Zn concentration in soil was low (0.62 mg/kg of soil). The soil was medium in organic C, low in available nitrogen and medium in available phosphorus and available potassium and had a *p*H of 7.7. The nutrients recycled through various green manure crops are given in Table 1. The experiment was conducted in a split-plot design, keeping 2 *in-situ* green manuring crops viz. *Sesbania aculeata* (dhaincha) and *Vigna umbellata* (rice bean), 1 *ex-situ* green manuring crop viz. *Leucaena leucocephala* (subabul) and summer fallow treatment in main-plot and 4 zinc fertilization treatments, viz. 5 kg Zn through chelated Zn-EDTA as soil application, 2.5 kg Zn through chelated Zn-EDTA as soil application + 1 foliar application of 0.5% solution of chelated Zn-EDTA at flowering, foliar application of 0.5% solution of chelated Zn-EDTA at active tillering + flowering + grain filling, foliar application of 0.5% solution of chelated Zn-EDTA at 20, 40, 60 and 80 DAT and a control (no Zn) in sub-plots and was replicated thrice. Nitrogen, phosphorus and potassium were uniformly applied at the rate of 130, 60 and 50 kg/ha, respectively to all plots. In foliar spray treatments, 0.5% Zn-EDTA solution at the rate of 500 litres/ha was applied in each spray to supply the Zn. Other agronomic practices were followed as per the standard packages of practices to raise the *Basmati* rice crop. Ten hills were randomly selected in each plot for measuring plant height and effective tillers/hill, 10 days before harvest and the average values were computed. For dry-matter computation the rice plants from one square meter areas were collected, air dried and then oven dried and finally dry-matter was recorded. Ten panicles were randomly selected from each plot for recording the data on yield attributes, viz. panicle length, panicle weight and 1,000–grain weight. At harvest, grain and straw yields were recorded separately for each plot and reported at 14% moisture.

RESULTS AND DISCUSSION

Growth parameters

The highest plant height of *Basmati* rice was observed with *Sesbania aculeata* green manuring and it was statistically at par with *Vigna umbellata* and significantly higher than *Leucaena leucocephala* and summer fallow at harvest stage (Table 2). Effective tillers/m^2 and dry-matter production of *Basmati* rice at harvest stage was found significantly higher under application of *Sesbania aculeata* green manure than those *Vigna umbellata*, *Leucaena leucocephala* and summer fallow. Among different soil and foliar Zn fertilization treatments, foliar application of 0.5% solution of chelated Zn-EDTA at 20, 40, 60 and 80 DAT produced significantly higher growth parameters, viz. plant height, effective tillers and dry-matter of *Basmati* rice than other soil and foliar Zn fertilization treatments during both the years. Control (no Zn) recorded

Table 1. Average nutrients recycled through green manure crops during field experiment (mean data of 2 years)

Green manure crop	Nutrients recycled (kg/ha)			
	N	P	K	Zn
Sesbania aculeata	147.2	17.4	213.8	0.38
Leucaena leucocephala (twigs and leaves)	101.6	7.2	53.3	0.80
Vigna umbellata	138.6	16.2	191.2	0.36
SEm±	3.13	0.72	4.43	0.007
CD (P=0.05)	12.31	2.84	17.39	0.030

the shortest plant height, effective tillers and dry-matter of *Basmati* rice. The highest growth parameters, viz. plant height, effective tillers and dry-matter of *Basmati* rice with incorporation of *Sesbania aculeata* and foliar application of 0.5% solution of chelated Zn-EDTA at 20, 40, 60 and 80 DAT might be due to higher nutrient recycling which resulted in higher nutrient availability and better physico-chemical soil properties than other *in-situ* and *ex-situ* green manuring crops incorporation and foliar and soil Zn fertilization. Bisht *et al.* (2006) reported that application of organic manures improved the growth parameters of rice. Increase in plant height with foliar Zn fertilization could be due to higher synthesis of auxins as Zn is required for its normal production (Alloway, 2008). Increase in productive tillers/m^2 might be ascribed to adequate supply of zinc that might had increased the uptake and availability of other essential nutrients, which resulted in improvement of plant metabolic process and finally increased the crop growth (Mustafa *et al.* 2011; Singh and Shivay, 2016).

Yield attributes

Incorporation of *Sesbania aculeata* as green manure recorded the highest panicle length and panicle weight of *Basmati* rice and it was significantly superior compared with *Leucaena leucocephala*, *Vigna umbellata* and summer fallow (Table 2). The significantly higher values of 1,000-grains weight were recorded when *Basmati* rice was grown after *Sesbania aculeata* incorporation compared to *Leucaena leucocephala* and summer fallow treatment, which remained statistically at par with *Vigna umbellata*. Among different soil and foliar Zn fertilization treatments, foliar application of 0.5% solution of chelated Zn-EDTA at 20, 40, 60 and 80 DAT resulted into significantly higher panicle length, panicle weight and 1,000 grain weight of *Basmati* rice than other soil and foliar Zn fertilization treatments, except 1,000-grains weight which remained statistically at par with foliar application of 0.5% solution of chelated Zn-EDTA at active tillering + flowering + grain filling stages. The highest values of yield attributes, viz. panicle length, panicle weight and 1,000-grain weight of *Basmati* rice with incorporation of *Sesbania aculeata* and foliar application of 0.5% solution of chelated Zn-EDTA at 20, 40, 60 and 80 might be due to higher organic matter production and better supply and uptake of nutrients cations through the incorporation of *Sesbania aculeata*, resulting in more leaf area coverage and thereby producing more leaf dry weight and thus improved yield attributing characters of rice than other *in-situ* and *ex-situ* green manuring and foliar and soil Zn fertilization. These observations are in agreement with the findings of Bisht *et al.* (2006) and Singh and Shivay (2016). Pramanik (2006) recorded higher numbers of grains/panicle when *Sesbania*

Table 2. Effect of *in-situ and ex-situ* green manuring crops and Zn fertilization on growth and yield attributes of *Basmati* rice under *Basmati* rice–wheat cropping system (mean data of 2 years)

Treatment	Plant height (cm)	Effective tillers/m^2 (Nos.)	Dry-matter accumulation (g/m^2)	Panicle length (cm)	Panicle weight (g)	1,000–grain weight (g)
In-situ and ex-situ green manuring crops						
Sesbania aculeata	107.2	442	1,252.8	27.6	3.04	23.6
Leucaena leucocephala	103.4	395	1,089.6	26.0	2.47	23.1
Vigna umbellata	105.0	412	1,174.9	27.0	2.68	23.5
Summer fallow	100.4	316	1,016.1	24.8	2.44	23.3
SEm±	0.65	2.3	12.65	0.07	0.085	0.03
CD (P=0.05)	2.56	8.8	49.64	0.26	0.333	0.12
Zn-fertilization						
Control (no Zn)	100.0	312	947.1	24.1	2.15	22.4
5 kg Zn through chelated Zn-EDTA as soil application	103.3	350	1,078.2	25.8	2.58	23.0
2.5 kg Zn through chelated Zn-EDTA as soil application + 1 **foliar application at flowering	104.0	366	1,125.6	26.4	2.68	23.6
**Foliar application of chelated Zn-EDTA at active tillering + flowering + grain filling	105.4	421	1,215.6	27.2	2.83	23.9
**Foliar application of chelated Zn-EDTA at 20, 40, 60 and 80 DAT	106.9	505	1,300.4	28.2	3.05	24.0
SEm±	0.34	3.5	13.46	0.10	0.064	0.06
CD (P=0.05)	1.00	10.2	39.99	0.28	0.189	0.19

**0.5% solution of chelated Zn-EDTA (12% Zn) @ 500 L/ha

rostrata was incorporated in the soil before transplanting of rice. Increase in yield attributes of *Basmati* rice with foliar Zn application might be due to higher Zn uptake, resulting into higher biomass production (Shivay *et al.,* 2008) and photosynthates translocation to reproductive parts. Yield attributes of *Basmati* rice were higher with foliar application of Zn-EDTA than soil application of Zn owing to direct absorption of the Zn in foliar spray treatment.

Yield

Among the *in-situ* and *ex-situ* green-manuring and summer fallow treatments, *Sesbania aculeata* recorded significantly higher grain, straw and biological yields compared to summer fallow, while it remained statistically at par with incorporation of *Vigna umbellata* and *Leucaena leucocephala* (Table 3). Foliar application of 0.5% solution of chelated Zn-EDTA at 20, 40, 60 and 80 DAT resulted into statistically higher grain, straw and biological yields compared with other Zn fertilization treatments and control (no Zn), except grain yield which was statistically at par with foliar application of 0.5% solution of chelated Zn-EDTA at active tillering + flowering + grain filling during both years. The highest grain, straw and biological yields of *Basmati* rice with incorporation of *Sesbania aculeata* and foliar application of 0.5% solution of chelated Zn-EDTA at 20, 40, 60 and 80 DAT might be owing to increased biomass production and nutrient recycling through *Sesbania aculeata*, which resulted in higher yield attributes which further ended in higher yields of *Basmati* rice during both the years than other treatments of green manuring and Zn fertilization. Pooniya and Shivay (2011) and Singh and Shivay (2016) also reported similar findings. Increase in the yields with foliar Zn fertilization over soil Zn application might be attributed to better nutrition and increased dry-matter production of *Basmati* rice. Pooniya and Shivay (2011) also reported significant enhancement of grain yield of basmati rice through incorporation of *Sesbania aculeata* than mungbean and summer fallow.

Correlation between yield and yield attributes

There was a positive and higher correlation between grain yield and yield attributes during both the years of experimentation. The correlation between yield and panicle length was 91.9% and yield and panicle weight 75.5% (Fig. 1). Incorporation of *Sesbania aculeata* along with Zn fertilization led to better growth and yield attributes of rice, which resulted in to higher yields of *Basmati* rice. All of these yield attributing characters were found positively related to grain yield of *Basmati* rice.

Table 3. Effect of *in-situ* and *ex-situ* green manuring crops and Zn fertilization on yields and economics of *Basmati* rice under *Basmati* rice–wheat cropping system (mean data of 2 years)

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Cost of cultivation (× 10^3₹/ha)	Gross returns (× 10^3₹/ha)	Net returns (× 10^3₹/ha)
In-situ and ex-situ green manuring crops						
Sesbania aculeata	4.66	9.09	13.75	58.5	101.6	43.0
Leucaena leucocephala	4.50	8.78	13.28	61.1	98.2	37.0
Vigna umbellata	4.62	8.93	13.56	63.7	100.5	36.7
Summer fallow	3.87	7.82	11.69	48.5	85.4	36.9
SEm±	0.108	0.129	0.234	–	0.94	1.99
CD (P=0.05)	0.422	0.505	0.920	–	3.70	7.80
Zn-fertilization						
Control (no Zn)	3.70	7.45	11.15	37.7	81.5	43.7
5 kg Zn through chelated Zn-EDTA as soil application	4.18	8.78	12.96	57.7	93.4	35.6
2.5 kg Zn through chelated Zn-EDTA as soil application + 1 **foliar application at flowering	4.29	8.87	13.16	48.9	95.3	46.4
**Foliar application of chelated Zn-EDTA at active tillering + flowering + grain filling	4.88	8.92	13.81	41.3	104.4	63.0
**Foliar application of chelated Zn-EDTA at 20, 40, 60 and 80 DAT	5.01	9.26	14.27	42.5	107.5	64.9
SEm±	0.087	0.142	0.180	–	0.36	2.14
CD (P=0.05)	0.257	0.423	0.533	–	1.06	6.36

**0.5% solution of chelated Zn-EDTA (12% Zn) @ 500 L/ha

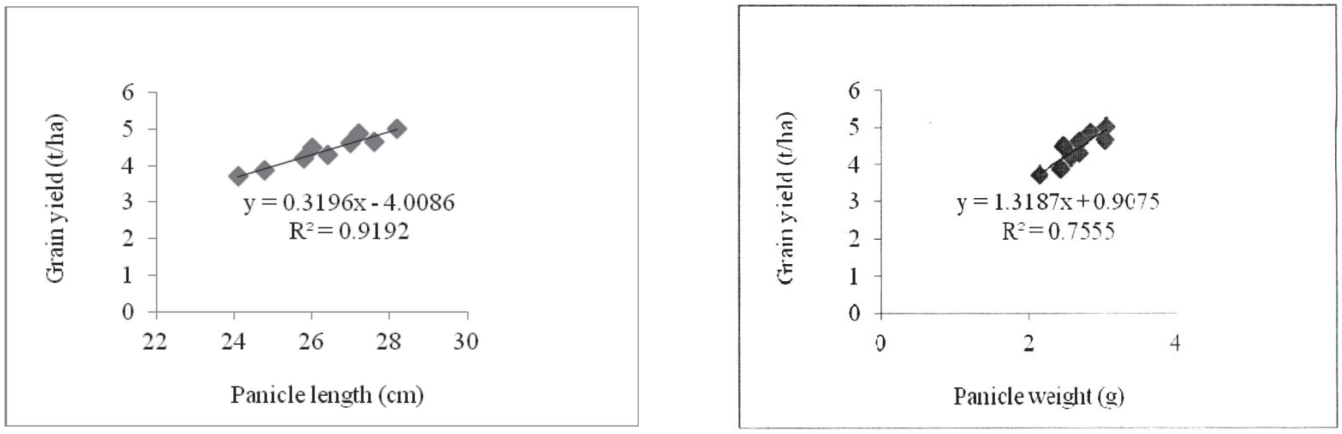

Fig. 1. Effect of *in-situ* and *ex-situ* green manuring crops and Zn fertilization on correlation between grain yield and yield attributes of *Basmati* rice under *Basmati* rice–wheat cropping system (mean data of 2 years)

Economics

The higher gross returns (101.6 × 10^3₹/ha) and net returns (43.0 × 10^3₹/ha) from *Basmati* rice were obtained with incorporation of *Sesbania aculeata*. Significantly higher gross returns was obtained owing to foliar application of 0.5% solution of chelated Zn-EDTA at 20, 40, 60 and 80 DAT compared to other soil and foliar application of Zn treatments, while net returns (64.9 × 10^3₹/ha) and benefit: cost ratio (1.53) were significantly higher compared to 2.5 kg Zn through chelated Zn-EDTA as soil application + 1 foliar application of 0.5% solution of chelated Zn-EDTA at flowering and 5 kg Zn through chelated Zn-EDTA as soil application (Table 3). The highest gross return, net return and net benefit: cost ratio from basmati rice cultivation under the treatment of *Sesbania aculeata* were due to higher economical and biological yields of basmati rice. Larger grain as well as biomass yields of basmati rice was obtained when *Sesbania aculeata* was incorporated as green manure in soil, thus this treatment was more economical as compared to other green manure treatments. Among Zn fertilization treatments, application of 0.5% solution of chelated Zn-EDTA at 20, 40, 60 and 80 DAT produced higher grain and biomass yields and thus found more economical than other Zn application treatments.

From the present study, it may be concluded that incorporation of *Sesbania aculeata* and foliar application of 0.5% solution of chelated Zn-EDTA at 20, 40, 60 and 80 DAT was the best in terms of growth, yield attributes, yield and economics of *Basmati* rice under rice-–wheat cropping system.

REFERENCES

Alloway, B.J. 2008. *Zinc in soils and crop nutrition*. International Zinc Association Publication. International Zinc Association, Brussels, Belgium pp. 135.

Bisht, P.S., Pandey, P.C. and Singh, D.K. 2006. Effect of different sources of nutrients on rice (*Oryza sativa*) yield and soil nutrient status in rice–wheat cropping. (In) *National Symposium on Conservation Agriculture and Environment*, October 26–28, 2006 at Banaras Hindu University, Varanasi, India pp. 193–194.

Cakmak, I. 2008. Enrichment of cereal grains with zinc: Agronomic or genetic bio-fortification? *Plant and Soil* **302**: 1–17.

Chauhan, B.S., Mahajan, G., Sardana, V., Timsinia, J. and Jat, M.L. 2013. Productivity and sustainability of the rice–wheat cropping system in the Indo-Gangetic plains of the Indian subcontinent: Problems, opportunities, and strategies. *Advances in Agronomy* **117**: 316–369.

Ghasal, P.C., Shivay, Y.S., Pooniya, V., Kumar, P. and Verma, R.K. 2016. Zinc fertilization enhances growth and quality parameters of aromatic rice (*Oryza sativa* L.) varieties. *Indian Journal of Plant Physiology* **21**(3): 323–332.

Mustafa, G., Ehsanullah, Akbar, N., Qaisrani, S.A., Iqbal, A., Khan, H.Z., Jabran, K., Chattha, A.A., Trethowan, R., Chattha, T. and Atta, B.M. 2011. Effect of zinc application on growth and yield of rice (*Oryza sativa* L.). *International Journal of Agricultural Sciences and Veterinary Medicine* **5**: 530–535.

Nayyar, V.K. and Chhibba, I.M. 2000. Effect of green manuring on micronutrient availability in rice-wheat cropping system of north-west India. (In) *Rice–Wheat Consortium Paper Series* 6, Long-term soil fertility experiments in rice-wheat cropping systems. Abrol, I.P., Bronson, K.F., Duxbury, J.M. and Gupta, R.K. (Eds.), New Delhi, India. pp. 68–72.

Pooniya, V. and Shivay, Y.S. 2011. Effect of green manuring and zinc fertilization on productivity and nutrient uptake in *Basmati* rice (*Oryza sativa*)–wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agronomy* **56**(1): 28–34.

Pooniya, V. and Shivay, Y.S. 2013. Enrichment of basmati rice grain and straw with zinc and nitrogen through ferti-fortification and summer green manuring under Indo-Gangetic Plains of India. *Journal of Plant Nutrition* **36**(1): 91–117.

Pramanik, M.Y.A. 2006. Effect of green manuring on transplanted aman rice and its residual effect on subsequent *boro* rice. Ph.D. Thesis. Department of Agronomy, Bangladesh Agricultural University, Mymensingsh.

Prasad, R., Shivay, Y.S. and Kumar, D. 2014. Agronomic bio-forti-

fication of cereal grains with iron and zinc. *Advances in Agronomy* **125**: 55–91.

Sarkar, S. 2015. Management practices for enhancing fertilizer use efficiency under rice–wheat cropping system in the Indo-Gangetic Plains. *Innovare Journal of Agricultural Science* **3**(2): 5–10.

Shivay, Y.S., Kumar, D. and Prasad, R. 2008. Relative efficiency of zinc sulfate and zinc oxide-coated urea in rice–wheat cropping system. *Communications in Soil Science and Plant Analysis* **39**(7 and 8): 1,154–1,167.

Shivay, Y.S., Prasad, R., Kaur, R. and Pal, M. 2016. Relative efficiency of zinc sulphate and chelated zinc on zinc biofortification of rice grains and zinc-use efficiency in *Basmati* rice. (In) *Proceedings of the National Academy of Sciences, India, Section B Biological Sciences* **86**(4): 973–984.

Singh, A. and Shivay, Y.S. 2016. Effect of summer green manuring crops and zinc fertilizer sources on productivity, Zn-uptake and economics of *Basmati* rice. *Journal of Plant Nutrition* **39**(2): 204–218.

Singh, S., Bohra, J.S., Singh, Y.V., Upadhyay, A.K., Verma, S.S., Mishra, P.K. and Raghuveer, M. 2017. Effect of integrated nutrient management on growth and development stages of rice under rice–wheat ecosystem. *International Journal of Current Microbiology and Applied Sciences* **6**: 2,032–2,042.