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Research Paper

Real-time nitrogen management using leaf colour chart in rice (*Oryza sativa*) genotypes

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ABSTRACT

A field experiment was conducted during 2012 and 2013 at Shalimar, Jammu and Kashmir, to study the response of rice (*Oryza sativa* L.) genotypes to real-time nitrogen (N) management as guided by leaf colour chart (LCC). Treatments included 2 rice varieties 'Jhelum' and 'SR 2' and 8 rates of N application [control (No N), recommended practice (120 kg N/ha), LCC ≤ 3 (4 splits of 20 kg N/ha each -N_{80} and 3 splits of 30 kg N/ha each -N_{90}), LCC ≤ 4 (5 splits of 20 kg N/ha each -N_{100} and 4 splits of 30 kg N/ha each -N_{120}) and LCC ≤ 5 (6 splits of 20 kg N/ha each -N_{120} and 5 splits of 30 kg N/ha each -N_{150})]. Variety 'SR 2' recorded significantly higher grain yield (7.3 t/ha) than 'Jhelum' (6.6 t/ha). Total N uptake and agronomic efficiency were significantly higher in 'SR 2' than 'Jhelum'. LCC ≤5 (150 kg N/ha applied in 5 splits) recorded significantly higher grain yields (8.2 t/ha) than recommended dose of 120 N/ha (7.1 t/ha) and LCC ≤ 3 (80 and 90 kg N/ha), but remained at par with 120 kg N/ha applied in 6 splits through LCC ≤ 5 @ 20 kg N/ha (7.9 t/ha). The LCC ≤ 3 (80 and 90 kg N/ha applied in 4 and 3 splits respectively) was statistically at par with recommended dose of 120 kg N/ha with respect to yield. The total N uptake and nitrogen-use efficiency were significantly higher with LCC-based N management than the recommended N management. Further higher agronomic efficiency (33.8 kg grain/kg N applied) was recorded with LCC ≤3 @ 20 kg N/ha (80 kg N/ha) applied in 4 equal splits.

Key words **:** Agronomic efficiency, Economics, Genotypes, LCC, Rice, Yield

Improving fertilizer nitrogen (N)-use efficiency in rice is vital to achieve and sustain high crop yields and reduce N losses via ammonia volatilization, leaching of nitrate and denitrification. Nitrogen fertilizer is an expensive input but farmers have a tendency to apply N in large amounts to minimize the risk of deficiency. Efficiency of applied N generally declines with increased fertilizer use, and seldom exceeds 40%. The requirement of rice for N fertilizer can vary greatly from field to field, season to season, and year to year because of high variability among fields, in soil N-supplying capacity and crop growth due to differences in climate factors. Real-time corrective N management is based on the periodic assessment of plant-nitrogen status and the appearance of nitrogen-deficiency symptoms, especially on the leaves. Thus, the key ingredient for real-time N management is a method of rapid assessment of leaf N content that is closely related to the photosynthetic rate and biomass production and is a sensitive indicator of changes in crop N demand within the growing season (Sen *et al*., 2011). A simple and quick method for estimating plant N demand is LCC, i.e. leaf colour chart (Gupta *et al*., 2011) and SPAD (chlorophyll meter) readings which can estimate leaf chlorophyll content in a non-destructive manner, thereby providing an indirect assessment of leaf N status. The LCC is easy to use and is an inexpensive diagnostic tool for monitoring the relative greenness of a rice leaf as an indicator for the plant N status and can be used as an alternative to chlorophyll meter. It offers substantial opportunities to farmers for timely application of nitrogen for efficient N use and high rice yield. Thus LCC, becomes useful in avoiding under or above fertilization besides maintaining the appropriate time. Use of LCC for N management has consistently increased grain yield and profit in comparison to the farmers' fertilizer practices. Keeping this in view, the experiment was conducted to determine the critical threshold LCC values for 2 rice genotypes on the basis of yield, N

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uptake and agronomic efficiency of N.

MATERIALS AND METHODS

The field experiment was conducted during the rainy (*kharif*) season of 2012 and 2013 at the Research Farm of the Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir at Shalimar (34^o–08' N and 74^o–83' and 1,587 m above the mean sea-level). The soil field was silty clay loam, containing 0.92 % organic C, with pH 6.6, electrical conductivity EC 0.22 dS/m, available N 308.9 kg/ha, P 33.4 kg/ha and ammonium acetate-extractable K 169.3 kg/ha. Under average climatic conditions, the area receives 690 mm mean annual rainfall, most of which occurs from December to April. Rainfall received during the rice-growing season (June to September) was 222.2 and 375 mm during 2012 and 2013 respectively. The mean monthly maximum and minimum temperatures during the rice growing seasons varied from 9.9 to 19.4°C and 9.5 to 19.1°C and 22.1 to 32.4°C and 23.0 to 32.6°C during 2012 and 2013 respectively. The experiment was laid out in a randomized block design with 3 replications. The experiment was conducted using 2 rice varieties and 8 rates of N application [control (No N), recommended practice (120 kg N/ha), LCC ≤ 3 (4 splits of 20 kg N/ha each -N_{80} and 3 splits of 30 kg N/ha each -N_{90}), LCC ≤ 4 (5 splits of 20 kg N/ha each -N_{100} and 4 splits of 30 kg N/ha each -N_{120}) and LCC ≤ 5 (6 splits of 20 kg N/ha each -N_{120} and 5 splits of 30 kg N/ha each -N_{150})] (Table1). In recommended practice, N (120 kg N/ha) was applied in 3 equal splits–at transplanting (basal), mid-tillering and panicle initiation. For leaf colour chart-based N management, LCC readings were taken at 4 days interval, starting from 12 days after transplanting (DAT) till 50% flowering. 10 disease-free hills were selected at random from the sampling area in each plot. From each hill, top-most fully expanded leaf was selected and LCC readings were taken by placing the middle part of the leaf on the chart and the leaf colour was observed by keeping the sun blocked by body as sun light affects leaf colour reading. Whenever the green colour of more than 5 out of 10 leaves were observed equal to or below a set critical limit of LCC score, N was applied as per the treatments in both the varieties (Table 1). Field preparation for rice included 2 disc ploughings in dry soil followed by 2 puddlings. Thirty-five days old seedlings of rice genotypes were transplanted manually at 15 cm × 15 cm in the second week of June. All the treatment plots received uniform dose of 60 kg P/ha, 30 kg K/ha and 15 kg zinc sulphate/ha. Whole of the P, K and Zn were applied into the soil basal dose before transplanting. The crop was irrigated daily during the first 2 weeks and thereafter as needed to prevent the soil surface from being without overlying water for more than 2 days. Plant height at 30, 60, 90 days after rice transplanting and at harvesting was measured from randomly selected 5 plants. Similarly, leaf-area index was also measured from 5 random plants 30, 60, 90 days after rice transplanting. Rice was harvested manually in the third week of September. Grain and straw yields were expressed on the basis of t/ha at 18% moisture content. Grain and straw samples were analysed for total N content by digesting the samples in sulphuric acid (H_2SO_4) followed by analysis of total N by the Kjeldahl method using a Kjeltec-auto-analyser. The N uptake was calculated by multiplying grain yield and straw yield by N content. Agronomic efficiency (AE) and physiological efficiency (PE) were calculated using the following formulae.

$$\text{AE (kg grain/kg N applied)} = \frac{\text{Grain yield in N-fertilized plots} - \text{Grain yield in zero-N plot}}{\text{Quantity of N fertilizer applied in N-fertilized plot}}$$

$$\text{PE (kg grain/kg N uptake)} = \frac{(\text{Grain yield in N fertilized plot}) - (\text{Grain yield in zero-N plot})}{(\text{N uptake in N fertilized plot}) - (\text{N uptake in zero-N plot})}$$

Economics was calculated using prevailing prices of inputs and outputs. Analysis of variance (ANOVA) was performed using SPSS. Critical difference (CD) at a 0.05 level of probability was used to compare differences among treatment means.

RESULTS AND DISCUSSION

Plant height

Plant height was significantly influenced by rice genotypes. 'Jhelum' recorded taller plants over variety 'SR 2' 30 days after transplanting; however, thereafter 'SR 2' recorded significantly taller plants than 'Jhelum' at all the stages of growth (Table 2) might be due to genetic make-up of the varieties. Laza *et al*., (2004) and Singh *et al*., (2004) also reported variation in the plant height of rice varieties under varied agro-climatic conditions. Among LCC-based treatments, application of N through LCC ≤ 5 [30 and 20 kg N/ha receiving N_{150} and N_{120} in 5 and 6 splits] recorded significantly taller plants at all the growth stages than the other LCC scores and recommended nitrogen level. The increased plant height at LCC ≤ 5 (N_{120} and N_{150}) might be attributed to the increased level of N fertilization as compared to other LCC scores and recommended N. The higher level of N encouraged the carbohydrate synthesis that resulted in the taller plant in above said LCC value. The results confirm the findings of Gupta *et al*. (2011).

Leaf-area index

Leaf-area index (LAI) values varied significantly with real-time N management; however, rice cultivars did not showed significant influence on LAI at all the stages of growth (Table 2). The LCC ≤ 5 @ 30 kg N/ha (N_{150}) recorded the highest LAI values at 30, 60 and 90 DAT over LCC ≤ 4 (N_{100} and N_{120}), LCC ≤ 3 (N_{80} and N_{90}) and recommended nitrogen level (N_{120}) at all the growth stages; however, it was statistically at par with LCC ≤ 5 (N_{120}) at 30 and 60 days after transplanting. This could be due to increased plant height (Gupta *et al*., 2011). The increased LAI provided potential source of photosynthesis in plant resulting in higher growth.

Effective panicles/m²

Pooled data (Table 3) indicated that variety 'SR 2' recorded significantly more panicles/m² than variety 'Jhelum'. Significant variations among rice cultivars with regard to panicles/m² might be due to their genetic potential. Besides, more LAI and tillers/m in variety 'SR 2' might also have resulted in higher value of yield attributes compared to variety 'Jhelum'. Earlier, Laza *et al*. (2004) also reported variations in yield contributing characters of different rice cultivars. The LCC-based N application with LCC ≤ 5 (N_{120} and N_{150}) and LCC ≤ 4 (N_{120}) produced significantly higher panicles/m² than LCC score 3 and recommended N level (Table 1). The highest number of panicles/m² were recorded with LCC ≤ 5 (N_{150}) followed by LCC ≤ 5 (N_{120}). It might be due to higher availability and uptake of N which is a substrate for synthesis of organic compounds, which constitute protoplasm and chlorophyll (Sen *et al*., 2011). The treatments receiving higher N dose produced higher panicle number than other LCC scores and recommended nitrogen level which is attributed to increased levels of N application in splits synchronizing the nutritional demand of rice at all the stages. The results are in close conformity with the findings of Srinivasagam and Stephan (2013).

Table 1. Total quantity of nitrogen (N) applied under different treatments

Treatment	Number of splits	Total N applied	Symbol
Absolute control	0	0	N_0
Recommended dosage of N	3	120	N_{120}
LCC ≤ 3 (20 kg N/ha each split)	4	80	N_{80}
LCC ≤ 3 (30 kg N/ha each split)	3	90	N_{90}
LCC ≤ 4 (20 kg N/ha each split)	5	100	N_{100}
LCC ≤ 4 (30 kg N/ha each split)	4	120	N_{120}
LCC ≤ 5 (20 kg N/ha each split)	6	120	N_{120}
LCC ≤ 5 (30 kg N/ha each split)	5	150	N_{150}

LCC, Leaf-colour chart

Grain and straw yield

The grain yield recorded with variety 'SR 2' was more than that recorded with variety 'Jhelum' (Table 3). Since rice yield is dependent on panicles/m², which were significantly higher in variety 'SR 2' and hence the higher grain yield. Sen *et al*. (2011) and Ganajaxi *et al*. (2001) also reported variation in the grain yield of different rice cultivars. Grain yield exhibited remarkable variation at differ-

Table 2. Effect of genotypes and real time nitrogen management on periodic plant height (cm) and leaf area index in rice genotypes (pooled data over 2012 and 2013)

Treatment	Plant height (cm)				Leaf-area index		
	30 DAT	60 DAT	90 DAT	At harvesting	30 DAT	60 DAT	90 DAT
Varieties							
'Jhelum'	51.3	103.1	122.7	122.9	1.95	3.83	2.68
'SR 2'	50.3	112.3	138.7	138.9	1.99	3.88	2.72
SEm±	0.3	0.7	0.76	0.77	0.02	0.03	0.02
CD (P=0.05)	0.87	2.18	2.3	2.3	NS	NS	NS
Nitrogen management							
Control (N_0)	43.9	84.9	112.7	112.8	0.98	2.76	1.88
Recommended (N_{120} in 3 splits)	52.9	104.7	133.1	133.2	1.70	3.35	2.16
LCC ≤ 3 (N_{80} in 4 splits)	48.5	100.0	129.0	129.1	1.87	3.46	2.54
LCC ≤ 3 (N_{90} in 3 splits)	51.3	102.4	130.7	130.8	1.93	3.63	2.69
LCC ≤ 4 (N_{100} in 5 splits)	55.2	108.2	135.4	135.5	2.12	4.14	2.85
LCC ≤ 4 (N_{120} in 4 splits)	56.2	110.8	138.4	138.4	2.28	4.25	3.05
LCC ≤ 5 (N_{120} in 6 splits)	58.5	112.9	141.0	141.1	2.39	4.43	3.10
LCC ≤ 5 (N_{150} in 5 splits)	59.8	114.2	143.0	143.0	2.50	4.80	3.34
SEm±	0.6	1.08	1.38	1.50	0.06	0.17	0.07
CD (P=0.05)	1.75	3.2	4.1	4.5	0.17	0.50	0.21

DAT, days after transplanting; LCC, leaf colour chart ent scores of LCC. Real-time nitrogen application with LCC ≤ 5 (N_{150}) registered the highest grain yield and was found at par with the treatment LCC ≤ 5 (N_{120}) (Table 3). Similarly, treatment LCC ≤ 4 (N_{100} and N_{120}) recorded significantly higher grain yield than LCC ≤ 3 (N_{80} and N_{90}) but were statistically at par with the recommended N level (N_{120}). Higher grain yield obtained in LCC ≤ 5 (N_{120} and N_{150})-based nitrogen management might be owing to higher quantum of nitrogen and more number of splits compared to other levels. Application of nitrogen through LCC ≤ 3 (N_{80} and N_{90}) were at par with recommended N level but superior to the control treatment. Application of nitrogen at LCC ≤ 5 (N_{120} and N_{150}) matched the crop demand at different physiological stages which might had reduced the losses through denitrification, volatilization and resulted in the highest grain yield. The increased availability of nutrient at distinct physiological phases would have supported for better assimilation of photosynthates towards grain and also owing to the favourable effect of accelerating the yield characters. Besides, the higher yield obtained in LCC ≤ 5 (N_{120} and N_{150}) treatments was obviously owing to favourable nutrition resulting in more panicles/m^2. The results are in conformity with Ravi *et al.* (2007). The straw yield of rice genotypes in different treatments followed the similar trend.

Use of LCC with a critical shade 4 (N_{100}) in rice resulted in the application of 100 kg N/ha, thus effecting a saving of 20 kg N/ha compared to application 120 kg N/ha in 3 equal splits at fixed growth stages. Management of N using LCC as threshold greenness of leaves 5 (N_{150}) resulted in the application of high rates of N of 150 kg N/ha. Likewise, LCC shade as threshold value of 3 (N_{80} and N_{90}) resulted in the application of 80 and 90 kg N/ha, thus saving 40 and 30 kg N/ha compared to recommended nitrogen application. The LCC threshold value 5 (20 and 30 kg N/ha) seems to be optimum for need-based N application to rice genotypes.

Nitrogen uptake

The data (Table 3) indicated that variety 'SR 2' recorded the higher total N uptake as compared to variety 'Jhelum'. Since nutrient uptake is a function of biomass production. The rapid increase in biomass in variety 'SR 2' has demanded more nutrients, thus resulting in higher rate of N uptake (Gupta *et al*. 2011). Significant variation in N uptake among rice cultivars was also recorded by Sikander *et al*. (2008). Application of nitrogen through LCC ≤ 5 (N_{150}) recorded higher total N uptake, being at par with LCC ≤ 5 (N_{120}) but significantly superior to all other LCC scores and recommended N level (Table 3). Total N uptake generally followed the trend as observed with grain yield, thereby confirming that grain yield of rice was delivered by the amount of N taken by the crop. The uptake of N may also be higher due to frequent application of N besides greater mineralization of native N, as evident from significantly higher availability of N in the soils even after harvest of rice under N management through LCC at higher thresholds. The lower total N uptake with fixed

Table 3. Effect of genotypes and real-time nitrogen management on effective panicles, yield and N-use efficiency in rice genotypes (pooled data over 2012 and 2013)

Treatment	Effective panicles/m^2	Grain yield (t/ha)	Straw yield (t/ha)	Total N uptake (kg/ha)	Agronomic efficiency (kg grain/kg N applied)	Physiological efficiency (kg grain/kg N uptake)
Varieties						
'Jhelum'	374	6.6	8.2	117.3	30.4	73.4
'SR 2'	405	7.3	8.7	131.7	29.4	73.5
SEm±	3.64	0.08	0.07	1.51	0.29	0.26
CD (P=0.05)	10.92	0.24	0.22	4.6	0.87	NS
Nitrogen management						
Control (N_0)	348	4.1	6.0	76.2	-	-
Recommended (N_{120} in 3 splits)	411	7.1	8.6	128.5	20.5	75.2
LCC ≤ 3 (N_{80} in 4 splits)	400	6.8	8.1	120.4	33.8	80.5
LCC ≤ 3 (N_{90} in 3 splits)	404	7.0	8.4	126.0	31.2	77.0
LCC ≤ 4 (N_{100} in 5 splits)	417	7.4	8.9	134.9	32.6	74.1
LCC ≤ 4 (N_{120} in 4 splits)	427	7.6	9.0	137.9	28.8	70.4
LCC ≤ 5 (N_{120} in 6 splits)	431	7.9	9.3	145.1	31.7	69.7
LCC ≤ 5 (N_{150} in 5 splits)	439	8.2	9.6	151.8	27.1	66.9
SEm±	6.71	0.11	0.12	3.31	0.80	1.66
CD (P=0.05)	20.21	0.34	0.37	9.9	2.40	4.98

LCC, leaf colour chart

Table 4. Relative economics of different treatments (pooled over 2012 and 2013).

Treatment	Cost of cultivation (× 10³ ₹/ha)	Gross returns (× 10³ ₹/ha)	Net returns (× 10³ ₹/ha)	Benefit: cost ratio
Varieties				
'Jhelum'	37.1	123.3	86.2	2.32
'SR 2'	37.1	133.3	96.2	2.59
Nitrogen management				
Control (N_0)	35.9	85.3	49.4	0.99
Recommended (N_{120} in 3splits)	37.4	127.4	89.9	1.87
LCC ≤ 3 (N_{80} in 4 splits)	36.9	122.5	85.6	1.79
LCC ≤ 3 (N_{90} in 3 splits)	37.1	127.4	90.4	1.89
LCC ≤ 4 (N_{100} in 5 splits)	37.2	134.4	97.3	2.04
LCC ≤ 4 (N_{120} in 4 splits)	37.4	137.7	100.3	2.1
LCC ≤ 5 (N_{120} in 6 splits)	37.4	143.7	106.3	2.24
LCC ≤ 5 (N_{150} in 5 splits)	37.8	148.2	110.4	2.31

Input cost, seed, ₹20/kg; urea, ₹5.5/kg; MOP, ₹17/kg; labour, ₹150/labour (8 hours); DAP, ₹22/kg
Output cost, paddy @ ₹1,200/q; straw @ ₹30/bundle (12 kg)

schedule recommended N application method than with LCC managed N could be associated with sub-optimal rates of N application in the recommendation, which could have limited rice growth (Gupta *et al*., 2011). These results indicated that the current recommendation of fixed-time split N applications at specified growth time is not adequate to synchronize N supply with actual crop N demand due to poorly designed N splitting and variations in crop N demand. Nachimuthu *et al*. (2007) and Gupta *et al*. (2011) also reported similar results.

Agronomic efficiency and physiological efficiency

The data revealed that different LCC treatments had significant effect on agronomic efficiency (AE) and physiological efficiency (PE), however the 2 rice varieties did not showed significant difference in AE and PE (Table 3). Both AE and PE declined with the increased application of nitrogen. Application of nitrogen through LCC ≤ 3 (N_{80} and N_{90}) recorded highest AE and PE followed by LCC ≤ 4 (N_{100}), whereas the lowest AE and PE was recorded in recommended N level and LCC ≤ 5 (N_{150}), respectively. The highest AE and PE recorded with LCC ≤ 3 (N_{80}) was 33.8 kg grain/kg N applied and 80.59 kg grain/kg N uptake. The synchronization between crop N demand and the available N supply is an important key to improve nitrogen use efficiency (Gupta *et al*., 2011). These results indicated that the application of N, based on LCC effectively matched the rice crop N demand.

Economics

Among the 2 varieties, 'SR 2' recorded the highest gross returns, net returns and benefit: cost ratio compared to 'Jhelum' (Table 4). Application of nitrogen through LCC ≤ 5 (30 kg N/ha) recorded the highest gross returns, net returns and benefit: cost ratio followed by LCC ≤ 5 (N_{120}). The higher net returns in treatment LCC ≤ 5 (N_{150}) was owing to steady supply of nitrogen which synchronized with the peak period of nitrogen requirement that had resulted higher yield. Similar results were obtained by Gupta *et al*. (2011). Similarly, Reddy and Pattar (2006) also reported that higher net returns were recorded with leaf colour chart-based nitrogen management as compared to recommended practices.

Thus, variety 'SR 2' recorded the higher grain yield than 'Jhelum'. The current fertilizer N recommendations for rice do not match with the crop demand. Hence LCC ≤ 5 (N_{150} applied in 5 splits) recorded significantly higher grain yield but remained at par with 120 kg N/ha applied in 6 splits through (LCC ≤ 5) but better than all other nitrogen schedules. Leaf colour chart is one of the best tool for real-time N management in order to increase grain yield and N-use efficiency of rice genotypes simultaneously.

REFERENCES

Ganajaxi, M.H.D., Hedge, Y. and Angadi, V.V. 2001. Effect of planting dates and nitrogen levels on the grain yield of aromatic rice genotypes under rainfed conditions. *Karnataka Journal of Agricultural Sciences* **14**(3): 758–59.

Gupta, R.K., Varinderpal-Singh, Yadvinder-Singh, Bijay-Singh, Thind, H.S., Kumar, A. and Vashisat, M. 2011. Need-based fertilizer nitrogen management using leaf colour chart in hybrid rice (*Oryza sativa*). *Indian Journal of Agricultural Sciences* **81**(12): 1,153–57.

Laza, R.C., Peng, S., Akita, S. and Saka, H. 2004. Effect of panicle size on grain yield of IRRI-released indica rice cultivars in the wet season. *Plant Production Science* **73**(3): 271–76.

Nachimuthu, G., Velu, V., Malarvizhi, P., Ramasamy, S. and Gurusamy, L. 2007. Standardisation of leaf colour chart based nitrogen management in direct wet seeded rice (*Oryza* *sativa* L.). *Journal of Agronomy* **6**(2): 338–43.

Ravi, S., Ramesh, S. and Chandrasekaran, B. 2007. Exploitation of hybrid vigour in rice hybrid (*Oryza sativa* L.) through green-manure and leaf colour chart (LCC) based N application. *Asian Journal of Plant Sciences* **6**(2): 282–87.

Reddy, M.B.G. and Pattar, P.S. 2006. Leaf colour chart–a simple and inexpensive tool for nitrogen management in transplanted rice (*Oryza sativa* L.). *Indian Journal of Agricultural Sciences* **76**(5): 289–92.

Sen, A., Srivastava, V.K., Singh, M.K., Singh, R.K. and Suneel, K. 2011.Leaf colour chart vis-a-vis nitrogen management in different rice genotypes. *American Journal of Plant Sciences* **2**(2): 223–36.

Sikandar, M.S.I., Rahman M.M., Islam M.S., Yeasmin M.S. and Akhter M.M. 2008. Effect of nitrogen level on aromatic rice varieties and soil fertility status. *International Journal of Sustainable Crop Production* **3**(3): 49–54.

Singh, S.P., Kushwah, Y.S. and Lal, S.S. 2004. Effect of nitrogen on productivity, soil fertility and economics of rice (*Oryza sativa*)–potato (*Solanum tuberosum*), wheat (*Triticum aestivam*) cropping system. *Indian Journal of Agricultural Sciences* **74**(7): 385–87.

Srinivasagam, K. and Stephan, H. 2013.Integrated nutrient management and LCC based nitrogen management on soil fertility and yield of rice (*Oryza sativa* L.). *Scientific Research and Essays* **8**(41): 2,059–67.