ENHANCING FERTILIZER NITROGEN USE EFFICIENCY IN IRRIGATED RICE BY USING A CHLOROPHYLL METER AND LEAF COLOUR CHART

JAGDEEP SINGH* AND C. S. KHIND
Department of Soil Science,
Punjab Agricultural University, Ludhiana -141 004, Punjab, INDIA
e-mail: jagdeep_76@pau.edu

INTRODUCTION
Nitrogen (N) is a key nutrient element for achieving the high yield potential of modern rice varieties. In order to improve rice growth and increase profitability, farmers in many parts of the world are applying excessive fertilizer N doses than required. This is true in rice crop grown in Indo-Gangetic plain of northwest India and leads to lowering the N recovery efficiency which is not more than 50% (Katyal et al., 1985 and Bijay-singh et al., 2001). For rice in Punjab, 120 kg N/ha is recommended in three equal splits applied at transplanting, 21 days after transplanting (DT) and 42 DT. These N fertilizers, application events may not synchronize well with need patterns of the plants, leading to N losses through NH$_3$ volatilization, NO$_3$ leaching, nitrification and denitrification or both (Aulakh and Bijay-Singh, 1997) and enhances low fertilizer N use efficiency. The present recommendation of 120 kg N/ha to rice is based on soil test crop response functions and do not take into account on the spot yield limiting factors like changing weather and crop conditions. Stalin et al., (1996) also found that fertilizer N recommendations on soil test basis in flooded rice are not appropriate for achieving higher yields. The recent research has shown that there is a need of sufficient N-supply beyond panicle initiation (after 42 days) in order to lengthen the duration of photosynthetic activity, and for meeting N demands during grain filling period (Peng et al., 1996). Peng and Cassman (1998) demonstrated that recovery efficiency can be increased by 78% by topdressing urea at panicle initiation stage. Therefore, achieving higher yields and N use efficiency, there is need to manage fertilizer N more efficiently by making its application based on actual needs of rice plant. The Chlorophyll meter, also known as SPAD (soil plant analysis development) instantly and reliably measure the leaf greenness, which is linear to leaf chlorophyll content of rice leaves. Therefore, this instrument has the potential to provide insight into the N status of rice plants, on the spot detects N deficiencies, and shows a great promise as a tool for improving N management. It is true that farmers cannot afford chlorophyll meter due to its high cost. Therefore, another nondestructive, simple and cheap diagnostic tool leaf colour chart (LCC), efficient in determining N fertilizer application to rice according to crop demand and can be used as an alternative to chlorophyll meter (Avijit et al., 2011). Therefore, a study for fine-tuning of fertilizer N program to actual needs of plant under field conditions, reducing the risk of yield-limiting N deficiencies or costly over- fertilizing by using a chlorophyll meter and LCC was carried out.

MATERIALS AND METHODS
To study the effect of fertilizer N management using SPAD and LCC on rice yield and fertilizer N use efficiencies a field experiment was conducted with rice (Oryza sativa L.) at the Punjab Agricultural University Farm, Ludhiana (30°56' N and

ABSTRACT
Excessive use of nitrogen (N) in irrigated rice results in low fertilizer N use efficiency. Need-based fertilizer N management in irrigated rice using chlorophyll meter (SPAD meter) and leaf color chart (LCC) was investigated compared with state recommendation fixed timing N applications. Treatments consists of different rates of N application based on SPAD threshold value of 37.5, sufficiency index approach and LCC score 4 and 5 were compared with state recommendation fixed timing N applications (120 kg N/ha). The results showed that N application using SPAD based sufficiency index approach (80 kg N/ha) and LCC 4 (100 kg N/ha) were more useful in increasing grain yield. No significant impact on total N uptake was recorded when N was applied using SPAD and LCC over recommended fixed timing N application. Significantly higher N recovery and agronomic efficiencies were calculated when N was applied using SPAD based sufficiency index approach (80 kg N/ha) and LCC @ 4 (100 kg N/ha). The results of this study suggested that to avoid over application of N and to obtain high yields and N-use efficiencies in irrigated rice, fertilizer N application should be guided by sufficiency index approach using SPAD or LCC score 4.

KEY WORDS
Chlorophyll meter (SPAD)
Leaf colour chart (LCC)
Sufficiency index
Recovery and Agronomic efficiencies

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*Corresponding author
75°52'E) on a sandy loam soil. Soils of selected site were coarse textured, well drained with a pH of 8.6, EC of 2.0 dS/m and organic carbon 0.21%. The available N, P and K were 133 kg/ha, 11.2 kg/ha and 101 kg/ha respectively. The experimental field was laid out in a randomized block design with three replications. Rice (Oryza sativa L) variety PR 111 was the test crop. The treatments consists of SPAD and LCC thresholds comparable with state recommendations of 120 kg N/ha. In the recommended fixed N schedule, urea was applied in three equal splits at transplanting, early tillering (21 days after transplanting (DT) and panicle initiation (42 DT). In the over - fertilized reference (OFR) treatment, 240 kg N/ha was applied in six splits at 0, 14, 28, 42, 56 and 70 DT. The SPAD and LCC readings were taken at 7 days interval, starting from 14 DT. The periodic readings continued up to the first (10%) flowering. Two approaches have been used to apply N using SPAD i) Whenever the SPAD value fell below the pre-designated critical value of 37.5 ii) when sufficiency index (defined as SPAD value of plot in question divided by that of a designated critical value of 37.5 ii) when sufficiency index (defined as SPAD value of plot in question divided by that of a designated critical value of 37.5). As per guidelines N applied at early growth stage (30 kg N/ha), at rapid growth stage (45 kg N/ha) and at late growth stage (30 kg N/ha). Recommended doses of 60 kg P₂O₅/ha and 60 kg K₂O/ha were uniformly incorporated in all treatments at transplanting. Using LCC, leaf colour was measured by holding the second expanded leaf counted from the uppermost leaf placing the middle part of leaf in front of colour strip for comparison. The frame work of Nova and Loomis (1981) was used to estimate agronomic efficiency, N recovery efficiency and physiological efficiency based on comparison of yield performances in the plots with and without applied N. The various N efficiencies were computed as follows.

Agronomic efficiency (kg grain/ kg N applied) = (Grain yield with N applied - Grain yield in control)/ N applied

Recovery efficiency (%) = (N uptake with N applied - N uptake in control)/ N applied x 100

Physiological efficiency (kg grain/kg N uptake) = (Grain yield with applied N - Grain yield in control)/ N uptake with N applied - N uptake in control

Mean comparisons between N treatments were evaluated by the least significant difference (P=0.05) based on analysis of variance.

RESULTS AND DISCUSSION

Grain and straw yield

The results in Table 1 showed that grain yield with SPAD-based N treatments with critical value of 37.5 was on par with the yield achieved following the recommended fixed-schedule N fertilizer splits. Plots receiving no basal N application and application of 20 kg N/ha as basal coupled with SPAD-based N applications, resulted in fertilizer N saving of 15 and 25 kg N/ha, respectively over the fixed-timing N splits. These results are in agreement with findings of Ghosh et al., (2012) and Duttarganvi et al., (2014) who reported that the SPAD-guided N treatments produced the higher grain yield but with less total N fertilizer use than recommended blanket N rates. Further, the application of 20 kg N/ha at 7 DT did not project any N saving compared to the fixed-schedule N fertilizer treatment. Using SPAD based sufficiency index approach, rice grain yield was at par with that recorded in recommended splits with a saving of 40 kg N/ha. More fertilizer N saving in SPAD based sufficiency index approach treatment was probably due to the fact that the concept of critical SPAD value did not take into account the factors such as the prevailing weather conditions and soil N supply etc encountered during the crop growth, whereas the sufficiency index approach based on OFR took care of these variables (Bijay-singh et al., 2000). In LCC based N management, maximum yield of 6.62 t/ha was obtained in treatment N₂₀ at 7DT + N₂₀ at <LCC4, but with a net saving of about 15% of fertilizer N over the fixed-timing N splits. Bijay-Singh et al., (2002) and Shukla et al., (2004) reported LCC 4 as the critical shade for saving fertilizer N and getting similar yield to that obtained by 120 kg N /ha in recommended splits in transplanted rice in northwestern India. The equivalent grain yield with less N dose compared to the fixed-schedule fertilizer under SPAD and LCC guidance was due to adequate N supply during crop growth phase resulting enhanced yield. No significant difference in straw yields in the treatments where fertilizer N was either applied following the recommended fixed-timing N splits or using the SPAD or LCC. Therefore, the

<table>
<thead>
<tr>
<th>Fertilizer Treatment</th>
<th>Total N applied (kg/ha)</th>
<th>Yield (t/ha)</th>
<th>Strain</th>
<th>Total N uptake (kg N/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Zero N (control)</td>
<td>0</td>
<td>3.38</td>
<td>2.97</td>
<td>36.8</td>
</tr>
<tr>
<td>2. Recommended splits, N₁₂₀</td>
<td>120</td>
<td>5.78</td>
<td>5.28</td>
<td>89.4</td>
</tr>
<tr>
<td>3. N at SPAD &lt; 37.5, no basal</td>
<td>105</td>
<td>5.86</td>
<td>5.59</td>
<td>90.5</td>
</tr>
<tr>
<td>4. N at SPAD &lt; 37.5, N₂₀ basal</td>
<td>95</td>
<td>5.72</td>
<td>5.01</td>
<td>79.2</td>
</tr>
<tr>
<td>5. N at SPAD &lt; 37.5, N₂₀ at 7 DT</td>
<td>125</td>
<td>5.79</td>
<td>5.47</td>
<td>92.5</td>
</tr>
<tr>
<td>6. Over fertilized reference (OFR) at 7 DT (Sufficiency Index Approach)</td>
<td>240</td>
<td>7.71</td>
<td>6.73</td>
<td>136</td>
</tr>
<tr>
<td>7. N at SPAD &lt; 90% of OFR, N₂₀ at 7 DT</td>
<td>80</td>
<td>5.93</td>
<td>5.79</td>
<td>84.6</td>
</tr>
<tr>
<td>8. N₂₀ at 7DT, N₅₀ at &lt;LCC4</td>
<td>110</td>
<td>6.28</td>
<td>5.76</td>
<td>97.4</td>
</tr>
<tr>
<td>9. N₂₀ at 7DT, N₅₀ at &lt;LCC5</td>
<td>110</td>
<td>6.10</td>
<td>5.53</td>
<td>90.4</td>
</tr>
<tr>
<td>10. N₂₀ at 7DT, N₅₀ at &lt;LCC4</td>
<td>100</td>
<td>6.62</td>
<td>6.12</td>
<td>102.0</td>
</tr>
<tr>
<td>LSD (5%)</td>
<td>0.67</td>
<td>0.77</td>
<td>21.3</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Yields of rice grain, straw and total N uptake as influenced by need-based fertilizer N management using chlorophyll meter and leaf colour chart.
observed pattern of straw yields supported the earlier findings on grain yield.

Total N uptake

N uptake is a product of biomass yield and N content in the biomass. Results in table 1 revealed that in SPAD-based N fertilizer management, treatment sufficiency index approach showed application of 80 kg N/ha to yield a total N uptake of 84.6 kg/ha, which is statistically at par to total uptake of 89.4 kg N/ha with 120 kg N/ha in recommended fixed-timing N splits. Interpretively, it can be said that about 40 kg applied N per hectare in the recommended fixed-schedule N fertilizer treatment was probably got lost by different pathways from the soil-plant system. This showed that SPAD-based N application was probably efficient in absorption of N from soil as N fertilizer application synchronizes with crop demand. These results are in well agreement with those reported by Bijay-singh et al. (2006) who observed that SPAD-based N management resulted in the improved congruence of N supply and crop demand thereby resulted in more total N uptake by the rice plant. Likewise, LCC guided fertilizer - N timing resulted in a total uptake of 102 kg N/ha by applying 10 to 20 kg N/ha less for getting total N uptake at par with the recommended fixed-timing N.

Recovery, agronomic and physiological efficiencies

The data on nitrogen use efficiencies in table 2 depict that comparing recommended fixed-timing N versus SPAD-based threshold of 37.5, equivalent N recovery efficiencies were attainable by saving of 20 to 25 kg N/ha in SPAD-based N treatment threshold of 37.5. Valnejad et al., (2010) reported comparable N recovery efficiency in SPAD-based N treatment with the threshold of 35 than obtained with any of the fixed-timing N fertilizer treatments with lower doses of N application. Similarly, no significant difference in N recovery following LCC 4 or LCC 5 (110 kg N/ha) in comparison to recommended fixed-schedule was observed. However, a significant increase in recovery efficiency of 59.7% in SPAD-based sufficiency index approach and 65% in LCC 4 (100 kg N/ha) treatment over 43.7% in the recommended fixed-timing N treatment was noticed. As mentioned earlier, lower N rate of 40 and 20 kg N/ha in the SPAD-based sufficiency index and LCC approaches were due to improved congruence of N supply and rice crop demand resulted in more productive tillers (Table 2) and also improved other yield contributing factors than the recommended fixed-timing N treatment. Yadavinder et al. (2007) observed that following the sufficiency index approach and LCC shade 4, yields of rice obtained with 90 kg N/ha were always at par with those from 120 kg N/ha applied in the recommended splits in the coarse textured soils of Punjab. The results (Table 2) suggested that agronomic efficiency (32.4) was greatest in treatment LCC 4 (100 kg N/ha) based N application followed by SPAD based sufficiency index approach (31.8). The agronomic efficiency in SPAD based sufficiency index and LCC 4 was 59% and 62%, greater than recommended fixed-schedule N fertilizer treatment. Peng et al. (1996) and Debtanu et al. (2004) reported 45 to 110% greater agronomic efficiencies in SPAD-based N treatments and LCC 4 level as best for N management in rice than fixed-timing N splits. Results related to physiological efficiency in SPAD-based N treatments (threshold of 37.5 and the sufficiency index approach) showed physiological efficiency at par with the fixed-timing N splits, but with lower N rates. These results are in agreement with those of Peng et al. (1996) who reported larger N physiological efficiency in SPAD-based N treatments than fixed split - N treatments, due to synchronized N topdressings with the crop demand in SPAD-based N treatments in irrigated rice. In LCC managed treatments the physiological efficiency did not differ significantly among different treatments (Table 2). Highest physiological efficiency of 52.3 was obtained at LCC 4 by applying 100 kg N/ha, which was at par with 53.3 in sufficiency index approach managed by SPAD meter.

REFERENCES


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