# Managing Fertiliser Nitrogen to Optimise Yield and Economics of Maize-Wheat Cropping System in Northern Karnataka

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**Farmers in northern Karnataka apply very high doses of fertiliser N to maize-wheat cropping system to maintain the yields of both the crops. This study attempted to estimate right rate and time of N application for improving the yield and profitability of maize-wheat system.**

After rice, wheat and maize are the two major cereals contributing to food security and farm income in India. Maize is steadily becoming an important option for diversifying agricultural production owing to its growing demand for human, dairy, and poultry consumption, and its increasing use in pharmaceuticals and other allied industries. Maize-based cropping systems are gaining significance in India, and maize-wheat is an important cropping system occupying about 1.8 million (M) ha in the country (Timsina et al., 2010). In Karnataka, maize is grown on about 1 M ha with a production of about 3.6 M t and an average productivity of 3.1 t/ha; while wheat is grown on about 0.3 M ha with a production of about 0.23 M t (Anonymous, 2010).

High yielding MWCS extract large amounts of mineral nutrients from the soil and proper nutrient management should aim to supply fertilisers adequate to meet the requirement of both crops. Much information on the source, rate, method, and time of N application in India is available for the individual maize and wheat crops, rather than for the system as a whole. Nitrogen plays an important role in the MWCS and applying right rates of N at the right time, through split application matching stages of high physiological N demand, is critical to achieve higher yields. However, current official recommendations for N use in the MWCS of Northern Karnataka is generally based on fixed rates and timing of application (blanket recommendation), which is not sufficient to harness the yield potential of hybrid genotypes of maize and leads to low N use efficiency. Also, farmers in this region do not apply N in the right rate at the right time and generally use higher doses of N in order to sustain the yields of previous years. Improved N management using the LCC has consistently shown to increase yield and profit as compared to FFP (Rajendran et al., 2010). We designed a study to develop schedules for the right rate and time of N application in MWCS of northern Karnataka.

The experimental site was located at the main agricultural research station of the University of Agricultural Sciences in Dharwad, Karnataka. Field experiments were conducted on a fixed site for three consecutive years (from 2009-10 to 2011-12) during *kharif* and *rabi* seasons to assess the effect of N rate, time of application, and real-time N management using LCC on productivity of *maize-wheat* cropping system. The soil of the experimental field was slightly alkaline (pH 7.4) and the EC measured in 1:2.5 soil:water suspension was non-saline (0.4 dS/m). Available N, $P_2O_5$, and $K_2O$ contents were low (208 kg/ha), high (35 kg/ha), and high (350 kg/ha), respectively and available contents of secondary and micronutrients were adequate. The experiment was laid out in a split-plot design. Maize was grown during the rainy season (*kharif*), with four N levels (0, 80, 160, and 240 kg N/ha) and three N application timings including: $T_1$ (33% basal + 33% at $V_4$ to $V_6$ growth stages + 33% at $V_{10}$ stage), $T_2$ (same as $T_1$ but N application guided by LCC use), and $T_3$ (50% basal + 50% at $V_{10}$ stage). Cargill M-900 was the maize hybrid used in the study with a planting geometry of 60 x 20 cm. Similarly, wheat was grown during winter season (*rabi*), with four N levels (0, 50, 100, 150 kg N/ha), and three timings including: $T_1$ (33% as basal + 33% at crown root initiation (CRI) + 33% at Panicle Initiation), $T_2$ (same as $T_1$ but N application guided by LCC use), and $T_3$ (50% as basal + 50% at CRI). The treatments were replicated thrice with a common dose of $P_2O_5$ and $K_2O$ (each 100 kg/ha) for maize and 90 kg $P_2O_5$/ha and 80 kg $K_2O$/ha for wheat. DWR-162 was the wheat variety used with a spacing of 25 x 10 cm.

**Common abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; EC = electrical conductivity; MWCS = maize-wheat cropping system; LCC = Leaf colour chart; FFP = Farmer Fertiliser Practice; CRI = crown root initiation; PI = panicle initiation; MEqY = maize equivalent yield of wheat; B:C ratio = benefit to cost ratio; $AE_N$ = agronomic efficiency of N; ROI = return on investment.**


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LCC-based, real time N-management included monitoring leaf colour at weekly intervals during the crop-growing season. Nitrogen was applied whenever leaves were less green than a threshold LCC value, which corresponds to a critical leaf N-content. Uniform cultural practices and plant protection measures were adopted in all treatments. Yield observations were recorded in all the treatments for both the crops, and the average of three years data is reported in this paper. System productivity (in terms of maize equivalent yield) is reported, which was calculated as:

**Table 1.** Effect of rate and time of nitrogen application on yield of maize and wheat crops (mean of three years, 2009-10 to 2011-12).

| | Maize | | | | Wheat | | | |
|---|---|---|---|---|---|---|---|---|
| Treatments | Grain yield, kg/ha | Stover yield, kg/ha | Harvest Index | 100 seed weight, g | Grain yield, kg/ha | Straw yield, kg/ha | Harvest Index | 100 seed weight, g |
| Main plots (N rate) | | | | | | | | |
| $N_1$ | 1,578 | 4,067 | 0.28 | 25.1 | 1,373 | 2,470 | 0.36 | 5.33 |
| $N_2$ | 4,123 | 6,286 | 0.40 | 30.2 | 2,515 | 4,320 | 0.37 | 6.33 |
| $N_3$ | 6,196 | 7,940 | 0.44 | 31.3 | 3,331 | 5,876 | 0.36 | 6.66 |
| $N_4$ | 6,950 | 9,073 | 0.43 | 33.3 | 3,781 | 6,942 | 0.35 | 6.88 |
| SEm± | 98 | 120 | 0.04 | 0.6 | 44 | 42 | 0.003 | 0.36 |
| C.D. (5%) | 338 | 416 | 0.03 | 1.9 | 152 | 145 | 0.01 | NS |
| Sub plots (Time of Application) | | | | | | | | |
| $T_1$ | 4,838 | 7,033 | 0.41 | 30.4 | 2,793 | 4,947 | 0.36 | 6.33 |
| $T_2$ | 4,978 | 7,122 | 0.41 | 30.8 | 2,827 | 4,959 | 0.36 | 6.67 |
| $T_3$ | 4,320 | 6,370 | 0.40 | 28.8 | 2,630 | 4,801 | 0.35 | 5.92 |
| SEm± | 63 | 102 | 0.002 | 0.6 | 46 | 61 | 0.003 | 0.21 |
| C.D. (5%) | 187 | 307 | NS | NS | 138 | NS | NS | NS |
| Interaction | * | NS | NS | NS | NS | NS | NS | NS |

MEqY = [(kg yield of wheat crop in maize based system x unit price of wheat)/unit price of maize) + actual maize yield].

We also calculated gross return, net return and B:C ratio using maize and wheat prices during the experimental year.

## Results

Increasing levels of N application led to increases in grain yield, stover yield, harvest index and test weight of both maize and wheat crops (**Table 1**). Interestingly, this trend persisted during all the three years of this study. Application of N in three splits with and without the use of LCC resulted in significantly higher maize and wheat yields than those obtained with N application in two splits. Except for the grain yield of maize, the interaction effects of N rate and time of application with respect to other parameters were non-significant for both crops. Harvest index and 100 seed weight for both maize and wheat crops did not differ significantly with rate and time of N application.

Economic analysis of data followed a similar trend to grain yields of maize and wheat crops with significant increases in gross and net returns as well as in B:C ratios with increasing levels of N application and with three splits of N application with and without the use of LCC (**Table 2**). However, a significant interaction effect of N rate and time existed for all the three economic parameters measured for maize, while the same did not exist in wheat.

Calculation of system productivity showed a significantly higher grain yield, net returns, and B:C ratios of maize-wheat system with increasing levels of N (**Table 3**). These findings are in line with Gill et al. (2009), who reported a system productivity of 9,122 kg/ha and a total net return of Rs 52,842/ha for the MWCS. Yield responses to applications of 390, 260, and 130 kg N/ha were 9,017, 7,585, and 4,274 kg/ha, respectively, over the no-N treatment.

Even though the yield increase due to N fertilisation was substantial (248% at 390 kg N/ha and 118% at 130 kg N/ha), the $AE_N$ (kg grain/kg N) decreased from 32.9 to 23.1 with increasing N rates from 130 to 390 kg N/ha (**Table 4**). This indicated lower N use efficiencies at higher N application rates. Also, with increasing N rates, ROI for N fertiliser in the MWCS, decreased from 20.4 to 12.7 with a mean return of 16.6 Rs/Re invested. The results indicated that although the net returns increased with increasing N rates, but they also came at the cost of increased risk level for the farmer. Therefore, in addition to crop response, $AE_N$ and ROI also need to be considered while deciding on the N application rate in the MWCS. Further, the information on crop yield response to N fertiliser application helps to improve crop yields through the use of nutrients at the right rate and time. This helps to effectively manage escalating fertiliser price scenarios. Relatively better AEN (30.7) and ROI (17.7) noticed with N application in three splits using LCC indicated the right time of N application in maize-wheat cropping system.

**Table 2.** Effect of rate and time of nitrogen application on economics of maize and wheat crops (mean of three years, 2009-10 to 2011-12).

| | Maize | | | Wheat | | |
|---|---|---|---|---|---|---|
| Treatments | Gross returns, Rs/ha | Net returns, Rs/ha | B:C ratio | Gross returns, Rs/ha | Net returns, Rs/ha | B:C ratio |
| $N_1$ | 15,841 | 4,986 | 1.45 | 18,018 | 6,648 | 1.87 |
| $N_2$ | 39,444 | 25,927 | 2.91 | 33,402 | 20,186 | 2.89 |
| $N_3$ | 58,710 | 42,863 | 3.69 | 44,464 | 30,488 | 3.54 |
| $N_4$ | 65,915 | 48,660 | 3.81 | 50,450 | 35,884 | 3.82 |
| SEm± | 892 | 824 | 0.04 | 571 | 545 | 0.05 |
| C.D. (5%) | 3,086 | 2,851 | 0.15 | 1,975 | 1,887 | 0.16 |
| $T_1$ | 46,203 | 31,746 | 3.02 | 37,158 | 23,825 | 3.07 |
| $T_2$ | 47,458 | 32,904 | 3.08 | 37,599 | 24,249 | 3.10 |
| $T_3$ | 41,271 | 27,177 | 2.79 | 34,993 | 21,831 | 2.93 |
| SEm± | 568 | 525 | 0.03 | 592 | 565 | 0.05 |
| C.D. (5%) | 1,702 | 1,572 | 0.08 | 1,774 | 1,692 | NS |
| Interaction | * | * | * | NS | NS | NS |

## Conclusion

Application of N at 390 kg/ha resulted in higher maize-wheat yields and higher net returns than other treatments. Thus, applying the right rate of N (240 and 150 kg/ha in maize and wheat), coupled with the right timing for N fertiliser (i.e. 3-split applications) using LCC-based real time

**Table 3.** Effect of rate and time of N application on yield and economics of maize-wheat cropping system (mean of three years, 2009-10 to 2011-12).

| | System yield, kg/ha (Maize yield + MEqY of wheat) | | | | - - - - - - - - - Net returns, Rs/ha - - - - - - - - - | | | | - - - - - - - - - - - B:C Ratio - - - - - - - - - - - | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatment | $T_1$ | $T_2$ | $T_3$ | Mean | $T_1$ | $T_2$ | $T_3$ | Mean | $T_1$ | $T_2$ | $T_3$ | Mean |
| $N_1$ | 3,683 | 3,609 | 3,608 | 3,634 | 8,542 | 7,936 | 7,927 | 8,135 | 1.37 | 1.35 | 1.35 | 1.36 |
| $N_2$ | 8,113 | 8,270 | 7,340 | 7,908 | 41,338 | 42,580 | 35,341 | 39,753 | 2.5 | 2.54 | 2.31 | 2.45 |
| $N_3$ | 11,534 | 11,898 | 10,224 | 11,219 | 67,033 | 69,906 | 56,752 | 64,564 | 3.16 | 3.24 | 2.88 | 3.09 |
| $N_4$ | 12,842 | 13,158 | 11,954 | 12,651 | 75,984 | 78,494 | 69,114 | 74,531 | 3.29 | 3.35 | 3.12 | 3.25 |
| Mean | 9,043 | 9,234 | 8,282 | | 48,224 | 49,729 | 42,284 | | 2.58 | 2.62 | 2.42 | |

| | SEm± | C.D. (5%) | S.Em± | C.D. (5%) | S.Em± | C.D. (5%) |
|---|---|---|---|---|---|---|
| Main plot | 103 | 359 | 817 | 2,830 | 0.024 | 0.082 |
| Sub plot | 103 | 309 | 821 | 2,462 | 0.026 | 0.079 |
| Interaction | 206 | 618 | 1,643 | 4,924 | 0.053 | 0.158 |

N management proved to be beneficial in increasing the yield and profitability of maize-wheat farmers of northern Karnataka. Under the increasing price scenario of fertilisers, a wise decision on fertiliser application must consider the crop yield response to N fertiliser application and its associated $AE_N$ and ROI to match the socio-economic condition of the farmer. BC-SA


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**Table 4.** Interaction effect of nitrogen rate, time of application and real-time N management on agronomic efficiency of N (AEN) and return on investment (ROI) under maize-wheat system (mean of three years, 2009-10 to 2011-12).

| | AEN, kg grain increase/kg N | | | | ROI, Rs/Re invested in N | | | |
|---|---|---|---|---|---|---|---|---|
| Treatment | $T_1$ | $T_2$ | $T_3$ | Mean | $T_1$ | $T_2$ | $T_3$ | Mean |
| $N_1$ | – | – | – | – | – | – | – | – |
| $N_2$ | 34.07 | 35.85 | 28.71 | 32.88 | 21.20 | 21.84 | 18.12 | 20.39 |
| $N_3$ | 30.19 | 31.88 | 25.45 | 29.17 | 17.19 | 17.92 | 14.55 | 16.55 |
| $N_4$ | 23.48 | 24.48 | 21.40 | 23.12 | 12.99 | 13.42 | 11.81 | 12.74 |
| Mean | 29.25 | 30.74 | 25.18 | 28.39 | 17.13 | 17.73 | 14.83 | 16.56 |

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# Videos Available from IPNI South Asia Program

A significant part of IPNI's global mandate includes disseminating appropriate crop nutrient management information/knowledge through printed and audio-visual medium. IPNI South Asia Program staff has been active in developing crop and nutrient specific videos for extension purpose. Developed in regional languages, these simple videos are expected to help industry as well as other stakeholder extension systems to convey simple messages about the importance of specific nutrients as a part of balanced fertilisation or the right ways of managing nutrients for specific crops for higher yields, farmer profitability and better environmental stewardship of nutrients. A video on the importance of Potassium in Crop Production, made in Hindi, is now also available in Bengali, Oriya, and Telegu regional languages. A Hindi video on nutrient management in sugarcane and a Telegu video on nutrient management in cotton were also developed through the support of fertiliser industry and the cooperators from the National Agricultural Research System. These two videos are also available in Oriya language. BC-SA