Utilization of $^{15}$N-urea fertilizer by irrigated wheat in Zambia*

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Abstract
A two year field study was conducted to assess the efficiency of urea-N use under various irrigation schedules and fertilizer N placement methods and application times. The field studies were conducted during the cool and dry season (May–October) at the National Irrigation Research Centre, Nanga, Zambia on a typic Haplustalf. Broadcast applications of 150 kg N ha$^{-1}$ resulted in higher utilization and efficiency of fertilizer N use compared to placement of fertilizer in a narrow band 2.5 cm to the side of the seeding row. Maximum fertilizer utilization and grain dry matter yields, however, were obtained with split application of urea-N of which the initial portion was broadcast and incorporated prior to sowing or broadcast two weeks after sowing and topdressing was applied at tillering under a weekly irrigation schedule at which irrigation was applied at 70 percent of the total class A pan evaporation during the whole irrigation interval. The percent N derived from fertilizer was independent of fertilizer placement at various water regimes, thus leading to the conclusion that under the experimental conditions N utilization was primarily a function of water availability.

Introduction
Fertilizer along with complementary inputs will continue to play a significant role in accelerating agricultural growth in Zambia. Since Zambia imports N fertilizers to meet the shortfall in domestic production, efficient use of N fertilizers is of utmost importance to the country.

The transitory nature of N in soil, its tendency for loss from soil, acceleration of the acidification process and its potential for becoming a pollutant of water and air demands that N receive a higher management level than any other of the primary and secondary nutrients.

For cereals, maximum efficiency of fertilizer N is obtained when fertilizer is applied shortly before the period of most rapid growth and greatest demand by the crop permitting ready uptake (Herron et al., 1971; Hucklesby et al., 1971; Miller et al., 1975; Olson et al., 1964; Welch et al., 1971).

Depending on soil and climatic conditions, N application has been divided into two or more increments during the growing season for maximum fertilizer efficiency. Seasonal increments are especially favored with humid region cropping and with irrigation of sandy soils. Split applications of N reduce the opportunity for N losses through leaching, runoff, volatilization and denitrification because an active root system is present for absorbing the fertilizer N when it is applied (Olson and Kurtz, 1982). When split application of N was superior to the single application, the uptake efficiency was higher from the N applied at tillering...
and boot stage (International Atomic Energy Agency, 1974).

Isotope studies on wheat fertilization (Carter and Rennie, 1984; International Atomic Energy Agency, 1974; Tomar and Soper, 1981) showed that the best method of placement was side-banding. Nitrogen was less efficiently taken up by wheat when it was incorporated in the soil prior to sowing as compared to side-banding at planting time. Under a drier moisture regime, however, side-banding was inferior to the broadcast application (International Atomic Energy Agency, 1974).

Contrary to expectations, broadcasting in the humid and subhumid tropics performed significantly better than either band or point placement (Mughogho and Bationo, 1985). Over all zones, point-placed urea tended to be less effective than other sources in the semi-arid zone as represented by the Niger site (Vlek, 1985). Concentrated placement of urea in points or in bands may lead to increased leaching of fertilizer N due to limited access to the sorption sites of the soil. The problem is accentuated in light textured soils (Miller et al., 1975; Mughogho and Bationo, 1985; Vlek et al., 1980).

The objective of this study was to assess the effect of various placement methods and application times on the efficiency of urea-N use by irrigated wheat in Zambia.

Materials and methods

The comparison of application times and placement methods of ¹⁵N-urea under various irrigation schedules was conducted in 1982 and 1983 at adjacent sites on a nearly level sandy clay loam at the National Irrigation Research Station at Nanga, Zambia. The soil belongs to the Mazabuka series, which includes Chromic Luvisols or Dystric Nitosols (FAO-UNESCO) or Typic Haplustalfs (USDA) occurring on elevated sites under miombo Savannah of moderate rainfall. They are deep well-drained soils with a characteristic argillic B horizon developed over calcium-silicate schists. The soil had a pH of 5.5, CEC of 7 cmol(+)/kg and total N content of 80 mg kg⁻¹. The experimental designs for the two years have been described in detail by Munyinda et al. (1985). In summary, wheat (Triticum aestivum L., cv. EMU'S) was grown each year. A heavy pre-sowing irrigation was applied each season to saturate the field to a depth of 1.2 m. Phosphorus was broadcast at a rate of 60 kg P₂O₅ ha⁻¹ each year prior to sowing. The experiment in 1982 was a partly randomized split plot design with irrigation (non-randomized component) treatments as the main plots and N application time (single, two-split and three-split totaling 150 kg N ha⁻¹) (randomized component) as subplots. In 1983, a completely randomized split-split plot design was utilized with irrigation treatments as main plots, N rate (75 and 150 kg N ha⁻¹) as subplots and N placement method (broadcast, broadcast and incorporation prior to sowing, banding 2.5 cm to the side of the seed row at sowing and broadcast two weeks after sowing) and N application time (single and two-split) as sub-subplots. The irrigation regimes in both years were implemented at tillering and included: (i) irrigation on a weekly basis at the rate of 70% of the total class A pan evaporation during the whole irrigation interval; (ii) every two weeks irrigation at 60% of the total class A pan evaporation during the whole irrigation interval; and, (iii) every three weeks at 50% of the total class A pan evaporation during the whole irrigation interval.

The ¹⁵N-urea treatments were applied in microplots (1.5 m × 1.5 m in 1982 and 0.6 m × 0.6 m in 1983) within the subplots and sub-subplots of the 1982 and 1983 experiments, respectively. The ¹⁵N-urea was applied to all treatments in the 1982 experiment and only to the 150 kg N ha⁻¹ broadcast and incorporation, side-band and late broadcast treatments in the 1983 experiment.

Samples for grain and straw yield determination were harvested from a 1.5 m² (4 rows 1.5 m long) area in 1982 and 1 m² area in 1983. An area half the linear dimensions of the microplots (0.75 m × 0.75 m in 1982 and 0.30 m × 0.30 m in 1983) was harvested in the centre of each microplot for ¹⁵N assay.

All plant samples from both field experiments were dried at 60°C to constant weight and ground to pass a 425-μm sieve. The straw samples from all microplot replicates of both experiments were composited for each treatment. Total N content was determined using a modified semi-micro Kjeldahl procedure (Rennie and Paul, 1971). After Kjeldahl analysis, the distillate was acidified with 0.5 M H₂SO₄ and concentrated for ¹⁵N analysis. Assay for