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Water and nitrogen interaction on soil profile water extraction and ET in maize–wheat cropping system

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ABSTRACT

In the present study, water and nitrogen interaction on soil profile water extraction and evapo-transpiration (ET) was investigated taking a field experiment on a clay loam soil (Typic Haplustept) at the Indian Agricultural Research Institute, New Delhi with four consecutive crops (maize–wheat–maize–wheat) taken from July 2002 to April 2004. Three levels of water regime, namely W1, W2 and W3 referring to limited, medium and maximum irrigation were applied to each crop depending on the seasonal rainfall and the critical crop growth stage. The three water regimes were used with five nitrogen levels from T1 to T5, (T1, 0% N; T2, 75% N; T3, 100% N; T4, 150% N; T5, 100% N from organic source) in a split plot design for the four crops grown in sequence.

Significant water and nitrogen interaction was observed for ET and soil profile water extraction pattern. Averaged across nitrogen treatments, ET in W2 and W3 were higher by 17 and 26%, respectively than W1 in maize 2002 and by 12 and 19% in maize 2003. In case of wheat, ET in W2 and W3 were higher by 27 and 58% than W1 in 1st crop and by 37 and 70% in 2nd crop. The effect of nitrogen regime, however, was prominent in both crops of maize and wheat, with significantly higher profile soil moisture depletion in T4 of each water regime. In all cases, lowest water depletion was observed in control plots receiving 0% N.

In both crops, water extraction from surface 60 cm was highest in W3 followed by W2 and W1. In maize, the % extraction from 0 to 60 cm layer varied from 71 to 76% (W1), 70–79% (W2) and 75–82% (W3), whereas the values for wheat were 70–77, 72–79 and 75–83% for W1, W2 and W3, respectively. The 90–120 cm layer contributed only 3–14% to total water extraction in both the crops. From 90 to 120 cm layer, higher extraction was observed in W1 as compared to W3. The extraction values in W1, W2 and W3 in maize were 9–13, 7–14 and 3–9, respectively, whereas the corresponding values in wheat were 8–14, 5–12 and 3–7% for the three water regimes. Effect of nitrogen treatments on water extraction from deeper layer was observed with higher extraction in highest fertilized treatment (T4) as compared to other treatments.

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1. Introduction

The unprecedented demands of the spiraling population are putting a considerable strain on the natural resources. In the past the focus was on increasing food production to attain self-sufficiency, but indiscriminate use of resources not only led to the reduction in total factor productivity but also resulted in environmental degradation (Yadav, 2003). The focus has now shifted to sustainable production technologies and resource efficient cropping systems. Among the various inputs, water and fertilizer (nutrients) are considered as the two key inputs making maximum contribution to crop productivity. Irrigation currently uses two thirds of the developed water supplies worldwide and agriculture faces competing demands for water from all other sectors. Unless properly managed, lack of access to fresh water may well emerge as the key constraint to global food production (Harwood et al., 2005).

Among food crops, maize and wheat are two important cereals contributing to food and nutritional security at the global level and particularly so in the developing countries. According to FAO, the two crops occupy 200 million ha of area and account for 40% of world's food and 25% of calories consumed in developing countries.

Continuous adoption of rice–wheat cropping system in the Indo-Gangetic plain of the Indian sub-continent has led to a number of adverse effects including deterioration of soil health and severe ground water depletion. There has also been reports of emergence of pest and weed infestation. The above factors have led to a replacement of one cereal particularly rice, which is high water demanding with maize, comparatively a low water requiring crop. Researchers have also suggested that maize–wheat cropping system having low irrigation requirement can be an appropriate alternative to rice–wheat cropping system for maintaining balanced hydrology (Jalota and Arora, 2002) and soil health in the Punjab plains of India.

Both the crops of maize and wheat have similarity in their water and nutrient uptake behaviour, in the sense that both are water demanding and nutrient responsive, even though, water requirement of both the crops are much below that of transplanted rice. Doorenboss and Pruitt (1983) reported that for maximum productivity of maize, water requirement varies from 430 to 490 mm depending on climate and length of growing period. Doorenbos and Pruitt (1977) reported that little water was extracted below a depth of 120 cm in maize. Benbi (1989) based on the data from field experiments on two soils (sandy loam and loam) reported that the FYM application to maize increased its water use by 3.0–3.3 cm and N application increased it by 6.2–7.1 cm in the two soils. In both soils, residual moisture was negatively related to N application rates. Hussaini et al. (2002) reported significant influence of N and water regimes on water use efficiency of maize.

Eck (1988) with four water treatments in winter wheat: non-stressed (I_1), stressed during heading and grain filling (I_2), stressed during tillering and jointing (I_3), and stressed throughout spring (I_4), reported that water use efficiency increased with increments of N through 140 kg ha^{-1} on treatment I_1, and through 70 kg ha^{-1} on treatments I_2 and I_3 but applied N did not affect WUE on treatment I_4. Abderrazak et al. (1995) reported that increasing rates of N fertilizer up to 140 kg ha^{-1} in wheat significantly increased the water use efficiency, grain yield, grain protein content and total protein yield, while capacity for N uptake decreased. Hussain and AlJaloud (1995) reported that the WUE increased with increase in N rates from 0 to 100%.

Results from the experiment combining four irrigation levels (non-irrigation and allowing 65, 50, and 35% depletion of soil-available water) with four rates of nitrogen fertilizer (0, 40, 80, and 120 kg ha^{-1}) conducted by Karim et al. (1997) from Bangladesh, reported a satisfactory yield of 4.13 t ha^{-1} with the highest water use efficiency of 196.5 kg ha^{-1} cm^{-1} under 65% depletion of soil-available water with the application of 80 kg N ha^{-1}. The water use efficiency of wheat gradually decreased with increasing irrigation level, but increased with increasing N rate up to 120 kg ha^{-1} in wheat (Rahman et al., 1999).

From an experiment in black soils of India, Hati et al. (2001) found that fertilized plots retained less water at harvest than unfertilized ones. Soil water extraction from deeper layers was higher in fertilized plots than unfertilized ones. ET was higher for irrigated plots (303 mm) than unirrigated ones (148.7 mm).

Studies separately on maize and wheat have shown that ET behaviour is regulated by water and nutrient regime. Apart from their independent impacts, water and nitrogen may also have their interaction effect in regulating the ET and water extraction behaviour of the crops individually, which may also differ if grown in a sequential intensive cropping system. Works have been reported about the water and nitrogen effects on water use of maize and wheat separately. However, there is almost dearth of information on interaction effect of water and nitrogen on soil water extraction pattern of the above crops in a cropping system mode. Again, very limited findings are available on the interaction effect of water and nitrogen on water use and ET behaviour of maize–wheat cropping system in Indo-Gangetic plains, where maize–wheat cropping system assumes importance to be an alternative to rice–wheat cropping system.

Keeping the above in view, the reported study was made to investigate the effect of various levels of water and nitrogen and their interaction on evapo-transpiration and soil profile water extraction pattern in a sequential cropping system with maize and wheat grown in sequence for two consecutive years.

2. Materials and methods

A field experiment was carried out in a clay loam soil (Typic Haplustept) in the research farm of Indian Agricultural Research Institute, New Delhi with maize and wheat crops grown in sequence for two consecutive cropping seasons from 2002 to 2004. The experimental site is located between 28° 37′ and 28° 39′ N latitude and 77° 90′ and 77° 11′ E longitude and at an altitude of 225.7 m above mean sea level in a semi-arid subtropical climatic belt. It is characterized by extreme temperatures, the annual maximum temperature goes as