Agriculture, Ecosystems and Environment 179 (2013) 108–115

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Soil water and nitrogen interaction effect on residual soil nitrate and crop nitrogen recovery under maize–wheat cropping system in the semi-arid region of northern India

Sangeeta Lenka[1], Anil Kumar Singh[2], Narendra Kumar Lenka*

Division of Agricultural Physics, Indian Agricultural Research Institute, New Delhi 110012, India

ARTICLE INFO

Article history:
Received 12 March 2013
Received in revised form 25 July 2013
Accepted 4 August 2013
Available online 4 September 2013

Keywords:
Soil nitrate build up
Crop N recovery
Soil moisture regime, Nitrate pollution

ABSTRACT

Over fertilization of nitrogen (N) in the premise of higher crop yield has sometimes led to build up of residual soil nitrate and pollution of ground water. Though, maize and wheat are two heavy feeders of N, studies on soil nitrate dynamics under maize–wheat cropping system in the Indo-Gangetic Plains of northern India, are limited. Hence, the present study was carried out at the research farm of Indian Agricultural Research Institute, New Delhi with maize–wheat cropping sequence grown for four consecutive cropping seasons, during 2002–2004. The treatments consisted of three levels of water regimes and five N levels taken in split plot design. Three levels of water regime, namely, W_1, W_2 and W_3 referred to as limited, medium and maximum number of recommended irrigation. The five N levels were T_1 (0% N), T_2 (75% N), T_3 (100% N), T_4 (150% N) and T_5 (100% N from organic source). For both the crops, 100% N corresponded to the recommended dose of 120 kg N ha^{-1} from inorganic source. Irrespective of crop, N recovery was higher under T_2 and W_3 treatment combination, though yield and biomass were highest under T_4 and W_3 treatments. Nitrogen recovery from organic treatment gradually increased from 8.8% in the first crop season (maize, 2002) to 26.1% in the last crop season of the experiment (wheat, 2004). Peak NO_3^- concentration was observed at 15–30 cm soil depth in W_1 and W_2 treatments and at 30–60 cm in W_3 water regime. The NO_3^- buildup was higher in W_1 as compared to W_3 treatment and was to the extent of 62 kg ha^{-1} in the 0–120 cm soil profile under W_1T_4 treatment after four crop seasons. Across water treatments, soil NO_3^- was higher under T_4 (150% N), followed by T_3 (100% N) throughout the experiment period. Despite a trend of soil NO_3^- buildup, application of N (150%) maximized crop productivity (maize and wheat) under W_3. The study revealed that maize–wheat cropping system grown under higher N application levels beyond the recommended dose, would reduce N use efficiency and enhance soil nitrate buildup.

1. Introduction

In the current food production scenario across major cropping systems of the world, crop yield is limited more by availability of nitrogen (N) and water resources, rather than by crop genetics (Sinclair and Rufty, 2012). The need for intensive cropping in the backdrop of depleting water resources and increased pollution of soil and ground water has further enhanced the importance of optimum management of the two inputs. As yields generally increase with application of N and water, higher rates of these two resources, particularly N, are often considered essential to keep pace with food demand (Prihar et al., 1985; Wang et al., 2008). Hence, very often, they are applied at higher doses than required. However, there has been growing concern over the potential environmental impact of higher doses of inorganic N fertilizer use in crop fields. Over fertilization causes water, air and soil pollution (Tong et al., 1997; Mosier and Kroez, 2000). Residual soil nitrate build up and consequent leaching of nitrate to ground water, are the two key offshoots (Varvel and Peterson, 1990; Cui et al., 2010). Varvel and Peterson (1990) reported greater residual soil nitrate to 150 cm soil depth under continuous corn and grain sorghum systems with high N application rates (180 kg ha^{-1}). High soil nitrate-N accumulation ($\geq$172 kg N ha^{-1} in 90 cm soil depth) was observed during wheat growing season in seven wheat growing regions of North China Plain. The extent of soil nitrate accumulation was so high that 55% farmers need not apply N fertilizers before sowing of wheat (Cui et al., 2010), as revealed from data on wheat yield response.

* Corresponding author. Present address: Indian Institute of Soil Science, Nabibagh, Berasia Road, Bhopal, Madhya Pradesh, 462038, India. Tel.: +91 8109237320; fax: +91 755 2733310.

E-mail addresses: nklenka74@gmail.com, nklenka@rediffmail.com (N.K. Lenka).

[1] Present address: Indian Institute of Soil Science, Nabibagh, Berasia Road, Bhopal, Madhya Pradesh 462038, India.

[2] Present address: Rajmata Vijayaraje Scindia Krishi Viswa Vidyalaya, Gwalior, India.

0167-8809/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.agee.2013.08.001

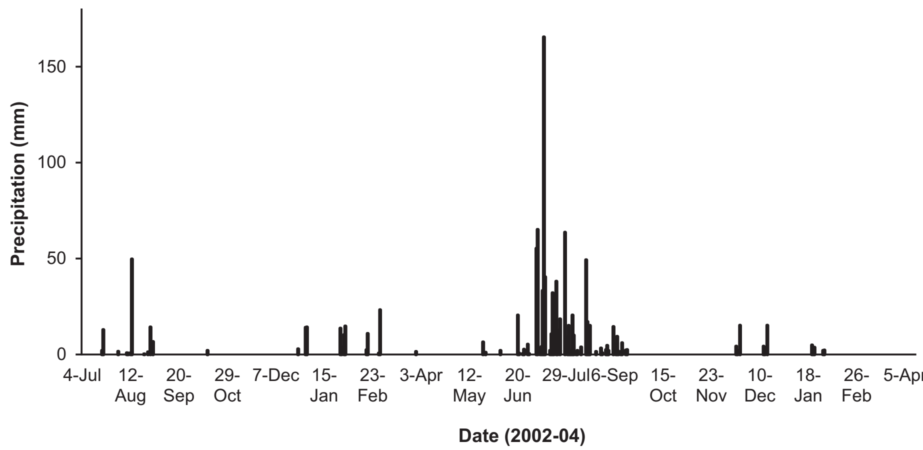

Fig. 1. Daily precipitation during crop season 2002–2004

Residual soil NO_3^- is seldom considered as a source of N. Indiscriminate use of fertilizer – N without considering the contributions of residual soil NO_3^- – N leads to low crop uptake and thus further growth in the residual pool, which leaches down to the lower depths and ground water. Thus, the environmental consequences of N use in food production are strongly related to crop N recovery. The recovery of fertilizer N in global crop production is about 50% (Eickhout et al., 2006; Krupnik et al., 2004; Smil, 1999). The rest is lost to the ecosystem via various pathways or may accumulate in soils. Despite the anticipated improvements in the N use efficiency, the total N loss is expected to increase from 109 to 132 Tg N yr^{-1} (+21%) between 1995 and 2030. The total N loss is projected not to change much in the industrialized countries, but will increase strongly in the developing countries from 67 to 93 Tg N yr^{-1} (+39%) (Eickhout et al., 2006).

Pattern of N use by crops and consequent build up in soil, apart from depending upon levels of N application, also depends on N source, availability of water and their interaction (Lenka et al., 2009). In resource limited conditions, it is highly required to manage water and N in a judicious combination so as to secure higher N recovery with lower losses. In this context, importance of organic sources of N for sustaining crop productivity with minimum environmental pollution, is also highlighted. Studies show soil nitrate levels to be unaffected by compost application but increase with chemical fertilizer application (Schegel, 1992; Hartl and Erhart, 2005). Nutrient based application of N to corn resulted greater residual soil nitrate to a depth of 120 cm under inorganic fertilizers than manure and compost treatments in dry years (Eghball, 2002). On the other hand, high soil nitrate – N accumulation has been reported from North China Plain (Cui et al., 2010) due to continuous addition of high doses of inorganic N fertilizers, without considering contributions of residual soil nitrate.

Rice–wheat cropping system in the Indo-Gangetic Plains (IGP) of Indian sub-continent is a major contributor to food grain production in India. However, its continuous adoption has led to several adverse effects and thus maize–wheat cropping system has been advocated to be a promising substitute to allow diversification (Jalota and Aroa, 2002; Joshi et al., 2005). The pattern of N use by the sole crops of maize and wheat under various levels of water and N may be different than when they are taken in a cropping sequence. Further interaction effect of the two inputs may also affect the N utilization pattern, residual soil build up and economics of crop production. Despite the growing importance of maize–wheat cropping system in the IGP of India, research studies on interaction effect of water and nitrogen on crop N recovery and residual N build-up under maize–wheat cropping system are limited. Thus, the present study was undertaken to evaluate the effect of different levels of water and N (organic and inorganic) on crop N recovery and soil nitrate accumulation in a maize–wheat cropping system grown for four consecutive cropping seasons.

2. Materials and methods

For the present study, a field experiment was taken up on a clay loam soil (Typic Haplustept) at the research farm of the Indian Agricultural Research Institute, New Delhi in four consecutive cropping seasons (*kharif* and *rabi* seasons of 2002 and 2003–2004). Maize was grown in *kharif* (July–October) and wheat in *rabi* (November–April) in both the years. Soil texture varied from loam to clay loam with pH varying from 7.2 in the 90–120 cm layer to 7.6 in the 0–15 cm layer. The temporal distribution of precipitation during the experiment period (2002–2004) is depicted in Fig. 1. The experiment was laid out in a split plot design with three water management treatments as the main plots and five nitrogen treatments as the subplots, with three replications.

The three water management treatments were, W_1 (limited irrigation), W_2 (medium irrigation) and W_3 (maximum irrigation). Irrigation was scheduled based on the critical stage approach. In wheat, four critical stages were selected, viz. crown root initiation (CRI), tillering, flowering and dough. In maize, three stages were selected, viz. 27 days after sowing, knee height, and 15 days after silking. In case of rainfall received during the critical growth stages, the scheduled irrigation was skipped. Therefore, the number of irrigations for W_1, W_2 and W_3 were different for each year and each crop (as outlined below), which was primarily decided by the soil moisture status at the critical stage due to rainfall. Irrigation was applied by a flexible hose and was measured by a water meter. Depth of irrigation water applied each time was 60 ± 2.0 mm.

The details of nitrogen management treatments are T_1 (0% N), T_2 (75% N), T_3 (100% N), T_4 (150% N) and T_5 (100% N from organic source; 50% FYM + 25% biofertilizer + 25% crop residue/green manure). For both the crops, 100% N referred to the recommended dose of 120 kg N ha^{-1} from inorganic source. The recommended dose of P and K, i.e., 75 kg P_2O_5 and 45 kg K_2O per ha,

Details of water management treatments.

Treatment details	Number of irrigations			
	Maize		Wheat	
	2002	2003	2003	2004
*W*1	01	0	02	02
*W*2	02	01	03	03
*W*3	03	02	04	04