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Optimal applied water and nitrogen for winter wheat under variable seasonal rainfall and planning scenarios for consequent crops in a semi-arid region

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ABSTRACT

Water and fertilizer applications should be limited due to scarce resources and environmental protection aspects. An analysis of crop yield production and profit maximisation can be conducted to determine the optimal water and nitrogen allocation. However, there is uncertainty or risk associated with this analysis due to unpredictable factors, among which the amount of seasonal rainfall (green-water) is an important one. In this study, equations were derived for determination of water and nitrogen levels at variable seasonal rainfall leading to maximum crop yield or profit with controlled water conditions for winter wheat in a semi-arid region. When land is limiting, for a given crop production and cost function, the sum of optimum applied water (w_l) and seasonal rainfall (R); $w_l + R$; and the sum of optimum applied nitrogen (N_l) and soil residual nitrogen (N_r); $N_l + N_r$; are constant (1.47 m and 190 kg ha $^{-1}$, respectively) and w_l or N_l does not depend on each other. The values of w_l are much greater than those available in the area for wheat farming. When water is limiting, the sum of optimum applied nitrogen (N_w) and N_r; $N_w + N_r$; is constant (190 kg ha $^{-1}$) similar to that obtained when land is limiting. The value of w_w is dependent on R and N_w. For seasonal rainfall of greater than 300 mm, no w_w is required. At a given amount of N_r, N_w and R, the values of w_w increased as price of nitrogen increased. The optimum nitrogen application was mainly influenced by soil residual nitrogen, but not by the water or land limiting conditions. The greatest applied water reduction occurred at water limiting conditions (when 70 kg ha $^{-1}$ soil residual nitrogen presented) with 42.0 and 64.0% for 0 and 0.2 m seasonal rainfall, respectively, which corresponded to the cultivated land increase of 72 and 178%, respectively. The greatest income per unit applied water was occurred for water limiting condition and it increased from 31 to 56% as the seasonal rainfall was increased from 0 to 0.2 m, with respect to maximum yield conditions. However, increase for land limiting condition was negligible (7–8%). Based on the sum of rainfall in autumn and winter seasons, the seasonal rainfall can be estimated which can then be used in the proposed equation to estimate the value of w_w. Further, based on a probability of occurrence for seasonal rainfall, i.e., 50 or 80%, the value of w_w is estimated and the cultivation area can be determined from the total available water.

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