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Weeds – Friend or foe? Increasing forage yield and decreasing nitrate leaching on a corn forage farm infested by redroot pigweed

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ABSTRACT

Various weed management methods have been tested without complete success and still represent a major nuisance often negatively effecting yields. Therefore, it may be time to change attitudes about weeds and view them as friends of the agroecosystem rather than as foes. For the first time, field experiments were conducted to introduce and evaluate the yield and quality of corn–redroot pigweed mixture forage in a semi-arid region of Iran during 2010 and 2011. A randomized complete block design with a split factorial arrangement of treatments in four replications was subjected to low irrigation and full irrigation regimes. Subplots consisted of a factorial combination of four N levels (0, 150, 300 and 450 kg N ha^{-1}) and two forage mixtures (corn monoculture and corn–redroot pigweed mixture). When averaged over both years, N addition (from 0 to 450 kg N ha^{-1}) increased corn forage yield by 74 and 42% under full and low irrigation regimes, respectively. The forage yield increased by 121 and 69% in the corn–pigweed mixture for comparable treatments. In corn monoculture, the minimum required forage protein (90 g kg^{-1}) occurred only where forage yields were lower than 10 t ha^{-1}, whereas in the corn–pigweed mixture, all the treatments with 90 g kg^{-1} protein produced yield more than 11 t ha^{-1}. N enhancement (0–450 kg ha^{-1}) increased nitrate leaching loss (NLL) by 158 and 107 kg ha^{-1} in corn monoculture and 100 and 55 kg ha^{-1} in the corn–pigweed mixture under full and low irrigation regimes, respectively. However, an alteration in the NLL trend in response to N application grew in both forage types, but the NLL severity was reduced in the corn pigweed mixture. The integration of redroot pigweed (a major weed species on summer crop farms) with corn, rather than its removal, could be recommended to ensure an acceptable forage yield/quality in a poor sandy soil while also reducing N leaching.

1. Introduction

Corn forage is an important feed for many dairy and beef operations. The value of forage corn is a function of both its yield and quality. Corn forage is a high-yielding, palatable forage with high energy density (Armstrong and Albrecht, 2008). Among the many agronomic factors that may affect corn forage yield and quality, the application of water and N are considered to be the most important. Forage or grain corn reportedly has a high irrigation requirement (Payero et al., 2006; Farre and Faci, 2009). Additionally, water availability can affect not only crop forage yields but also forage quality. Islam et al. (2012) stated that water availability has profound effects on the growth and chemical composition of corn forage as a consequence of effects on plant maturity, leaf to stem ratios and senescence rate.

While it follows the importance of water, N has a significant role in realizing the maximum potential of forage crops. Nitrogen fertilization increases corn dry matter yield by influencing leaf area development, leaf area duration and leaf photosynthesis efficiency (Cox and Charney, 2005). Additionally, many investigators have reported that N fertilization increases corn forage quality, including crude protein and nutritive value (Lawrence et al., 2008; Ferri et al., 2004). Because N is a mobile nutrient in soil and when it is combined with water during excessive application (which often occurs, especially in sandy soils), high levels of ground water N are predictable. Several studies have investigated the effects of water and N on corn grain and forage yield (Sexton et al., 1996; Al-Kaisi and Yin, 2003; Islam et al., 2012). In general, evaluating the response of corn to

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combination of irrigation and N may help to identify an appropriate application of water and N to maximize profit and reduce ground water pollution.

In addition to water and N, weeds are a major limitation in corn production. Weeds can reduce corn dry matter and grain yields by 35–70% in different soil and climatic conditions (Mohammadi, 2007). One of the most aggressive weed species in corn fields is redroot pigweed (*Amaranthus retroflexus* L.). This plant is a small-seeded, broadleaf weed distributed throughout Iran and other areas of the world. Redroot pigweed is annual and can be difficult to manage in agronomic crops because of high seed production, long seed viability, extended germination times and relatively fast growth (Sellers et al., 2003). Another reason that it is successful weed is its history of developing herbicide-resistance biotypes to commonly used herbicides in row crops. Biotypes of redroot pigweed have developed resistance to different herbicide modes of action that once effectively controlled these weeds in row crops (Heap, 2006). For example, pigweed biotypes with resistance to triazine or acetolactate synthase-inhibiting herbicides have been reported for redroot pigweed in the USA (Bensch et al., 2003). Additionally, in many developing countries such as Iran, farmer access to effective herbicides for controlling these weeds is limited and other weed control methods including mechanical or biological control have been used to little effect, so weeds are present throughout the crop growth period. Furthermore, in developed countries such as the USA where attention is being given to organic and low input agriculture systems (Zoschke and Quadranti, 2002), herbicide applications are limited, which results in the presence of weeds in corn and other crops. Therefore, in recent years redroot pigweed frequency and severity have increased and corn producers are often confronted with infestation levels of this weed species. For the first time, this study has assessed the possibility of integrating redroot pigweed (a common and dormant weed species in summer crop farms) with corn, rather than weed removal, to produce forage. According to our literature review, there is no actual information on the effects of water and N on corn and corn–redroot pigweed forage yield and quality, N and water use efficiency, N leaching loss or economic evaluations of these practices. Because these crucial traits have never been measured in a single experiment, especially in sandy soils, these experiments were conducted to evaluate the yield and quality of corn–redroot pigweed mixture forage and to compare it with the yield and quality of forage corn.

2. Materials and methods

2.1. Experimental location and general methodology

The experiment was conducted in the 2010 and 2011 growing seasons at the research farm of Tarbiat Modares University, Tehran, Iran (35°41′ N, 51°19′ E and 1215 masl). The region is characterized as semi-arid with a mean annual precipitation of 298 mm, which mostly falls during the autumn and winter months. Daily meteorological data on precipitation and air temperature (see supplementary file, Table S1) were obtained from the nearest weather station (500 m from the experimental site). Several soil samples were taken before planting at depths of 0–30 and 30–60 cm, and composite samples were collected, air-dried, crushed, and tested for physical and chemical properties (see supplementary file, Table S2). The soil texture was sandy loam based on the texture triangle classification (Gee and Bauder, 1986).

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.agee.2013.08.016.

2.2. Land preparation and treatment

Corn was planted in different sections of the field each year following canola (*Brassica napus* L.) in 2010 and wheat (*Triticum aestivum* L.) in 2011. The field, with 1–2% slope, was prepared by shallow plowing followed by disking in late May. Each experimental unit was 8 m long and consisted of 7 rows spaced 0.75 m apart. There were 2.5 m gaps between the blocks, and a 1.5 m alley was established between each plot to prevent lateral water movement and other interference. A polyethylene pipeline and a flowmeter were installed to control irrigation. The experiment was conducted using a randomized complete block design with a split factorial arrangement of treatments in four replications (see supplementary file, Figure S1). The main plots were subjected to irrigation regimes, which were defined with respect to water shortages as follows: L, irrigation was initiated after using 80% of the available water (low irrigation); and F, irrigation was initiated after using 40% of the available water (full irrigation). The subplots consisted of a factorial combination of four N levels (0, 150, 300, and 450 kg N ha^{-1}) and two forage mixtures, namely a corn monoculture and corn–redroot pigweed mixture. These N rates reflect feasible inputs (below average, average or conventional and high average) currently used in Iran. The conventional N treatment (300 kg N ha^{-1}) represents a typical farmer's practice for similar soils in the region.

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The corn cultivar (hybrid SC 604) was sown by hand at depths of 4–5 cm on 28 May 2010 and 26 May 2011. To ensure good emergence, the experimental plots were overseeded and then thinned (to 17 cm spacing in row) to achieve the recommended plant density of 78,000 plants ha^{-1} at the two-leaf stage (V2, corn growth stage identified according to Ritchie et al. (1997)). At the same time the corn was seeded, all weedy plot rows were seeded with redroot pigweed at depths of 1 cm in a 14 cm band over the corn rows. Redroot pigweed seeds were collected locally, and their viability was verified in germination tests each year before planting. Redroot pigweed seeds were planted in excess and thinned to population densities of 12 plants m^{-2} at the two-leaf stage. The weed population for the experiment had a widespread density similar to what was observed at infested corn farms (Knezevic et al., 1994; Aguyoh and Masiunas, 2003). The soil was irrigated immediately after sowing and the irrigation cycle of each plot was closed to avoid runoff. Irrigation was applied by furrow method and irrigation scheduling was determined according to daily changes in the soil water content (ΔSW) at the depth of root development. A deficit approach was used to estimate irrigation requirements, and the soil water content at field capacity (FC) was defined as no water deficit. Available water was determined by taking the difference between the water content at field capacity and permanent wilting point (PWP). Until the corn two-leaf stage (V2), all plots were irrigated in a similar manner in which 40% of available water was consumed at the depth of root development. N fertilizer (from urea [$(NH_2)_2CO$] source) was applied by top dressing at the three- to four-leaf stage (1/2 of N treatment) and seven- to eight-leaf stage (1/2 of the remaining N). Potassium and P were not applied because the soil had adequate amounts of these minerals (see supplementary file, Table S2). All weeds other than redroot pigweed were removed throughout the growing season with hand hoes.

Time-domain reflectometry (TDR) probes with tube access (TRIME-FM, England) were used to measure soil water content (θv) in the experimental plots (4 points in each plot) at a soil depth of 0–80 cm (at 20 cm intervals). Data on soil volumetric water content were collected daily during the growing season. Prior to seed sowing and at the same time of TDR tube access probe installation, soil water sampler tubes (Model 1900, Soil Moisture Equipment Co.) were inserted into vertical holes (with a diameter of 5–6 cm and