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Fertilizer and irrigation effects on forage protein and energy production under semi-arid conditions of Pakistan

Sami Ul-Allah[a], Asif Ali Khan[b], Thomas Fricke[a], Andreas Buerkert[c], Michael Wachendorf[a,*]

[a] Grassland Science and Renewable Plant Resources, Universität Kassel, Steinstrasse 19, 37213 Witzenhausen, Germany
[b] Plant Breeding and Genetics, University of Agriculture Faisalabad, Pakistan
[c] Organic Plant Production and Agro-ecosystems Research in the Tropics and Subtropics, Universität Kassel, Steinstrasse 19, 37213 Witzenhausen, Germany

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ABSTRACT

Fertilizer and irrigation water are major inputs for forage production in semi-arid areas, and to ensure sustainability, nutrient and water efficient crop species should be used. The major objectives of the present study were to (i) evaluate the effect of crop species, fertilizer and irrigation on nutritive value and (ii) determine irrigation water use efficiency (IWUE) in terms of crude protein (CP) and metabolizeable energy (ME) production per unit of land. A two-year field experiment was conducted in Faisalabad, Pakistan, with a four times replicated completely randomized design in a split-plot arrangement of a combination of fertilizer treatment (control, farm yard manure (FYM) and mineral fertilizer (MIN)) and irrigation (recommended irrigation (RI), half recommended irrigation (HRI)) as main-plots. Sub-plots were assigned to two cropping systems Egyptian clover (*Trifolium alexandrinum* L.) followed by corn (*Zea mays* L.) (common cropping system, CCS) and the drought-adopted cropping system (DACS) oat (*Avena sativa* L.) followed by sudangrass (*Andropogon sorghum* subsp. *drummondii*). Crude protein concentration and IWUE of CP production per unit of land in CCS was 44 and 13% higher than in DACS, whereas ME contents and IWUE of ME production in DACS was 9.5 and 38% higher than in CCS. In view of ME as the major limiting nutritive property in roughages for feeding dairy cows, it is concluded that the tested DACS may be more suitable for sustainable forage production under water and nutrient limited conditions in semi-arid areas of Pakistan.

1. Introduction

Livestock production is the most important component of Pakistan's agriculture, contributing more than 50% in value added and green forage is the basic feed for livestock, especially in peri-urban areas. Declining water availability is a big threat to sustainable production in many semi-arid regions of the world where crop production depends on supplementary irrigation (Marsalis et al., 2010), and it is predicted that availability of irrigation water may decline in the near future which may influence the price of irrigation water (World Water Assessment Program, 2009). Fertilizer is another important factor influencing Pakistan's fodder production, whereby import and prices of fertilizer in Pakistan increased by 34 and 320%, respectively, in the past decade (Farooq, 2013). There are many commercial and semi-commercial livestock farms in Pakistan. Dung is frequently used by women to produce dung cakes (Fafchamps and Quisumbing, 1999; Hassan et al., 2007) for burning in private households which is related to substantial losses of nutrients. These nutrients can potentially be used as a source of fertilizer and might be important by-products of livestock production when they are effectively managed and utilized for field crop production.

Most lactating cows are fed concentrates to compensate for quality deficits in roughage especially in terms of crude protein and energy (Sarwar et al., 2002; Younas and Yaqoob, 2005) jeopardizing the profitability of dairy farming. Fulkerson et al. (2007) and Vuuren (1993) identified metabolizable energy (ME) as a major factor limiting the performance of dairy cows. There is ample knowledge on the effects of fertilizer and irrigation on fodder

Abbreviations: ADF, acid detergent fiber; CCS, common cropping system; CL, crude lipid; CP, crude protein; CS, cropping system; DACS, drought adopted cropping system; DAS, days after sowing; DMY, dry matter yield; ESOM, enzyme soluble organic matter; F, fertilizer; FYM, farm yard manure; HRI, half recommended irrigation; I, irrigation; IWUE.CP, irrigation water use efficiency for crude protein; IWUE.ME, irrigation water use efficiency for metabolizeable energy; ME, metabolizeable energy; MIN, mineral fertilizer; NDF, neutral detergent fiber; NIRS, near infrared spectroscopy; RI, recommended irrigation.

* Corresponding author. Tel.: +49 05542981334.
E-mail address: mwach@uni-kassel.de (M. Wachendorf).

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quality of specific crops. Philipp et al. (2005) reported an increase in ME and a decrease in fiber concentrations with reduced irrigation in three bluestem grass species (*Bothriochloa caucasica*, *ischaemum*, and *bladhii*). Islam et al. (2012) investigated the effect of irrigation (0–480 mm) and fertilizer (0–158 kg N ha^{-1}) on corn forage and found that the increase in forage yield with increased fertilizer and irrigation was accompanied by decreased nutritive value. Yosef et al. (2009) reported a decrease in crude protein (CP) and water soluble carbohydrates with reduced irrigation. Simsek et al. (2011) detected a yield reduction in corn with reduced irrigation (0–75%), but nutritive value remained unaffected. Significant effects of nitrogen fertilizer on crude protein and fiber contents of corn (Carpici et al., 2010), bermudagrass (Kering et al., 2011) and oat (Iqbal et al., 2013; Collins et al., 1990) have also been shown.

Among the many forage crops grown in Pakistan, sorghum (*Sorghum bicolor* L.), corn (*Zea mays* L.) and Egyptian clover (*Trifolium alexandrinum* L.) are major crops for irrigated areas (Dost, 2003). Egyptian clover and corn require high amounts of water to produce adequate yields. Recent research showed that by growing oat (*Avena sativa* L.) and sudangrass, 12 and 22% higher dry matter yields could be produced than with Egyptian clover and corn, respectively, when irrigation was reduced by half (Ul-Allah et al., 2013).

Multiple cropping systems, which include more than one crop over the whole year, can be more water and nutrient efficient than cropping systems based on a single crop only. Newton et al. (2003) reported that forage with a high nutritive value can be produced using multiple cropping systems with manure fertilizer and that nutrient recovery in multiple cropping systems is higher than in single cropping systems. Macoon et al. (2002) assigned a stronger effect to cropping system than to nitrogen fertilizer (450–900 kg N ha^{-1} year^{-1}) on forage quality over a full year in semi-arid conditions. Up to now, little data is available on the quality of fodder grown in cropping systems with two succeeding crops over a full year under semi-arid conditions of Pakistan. Major objectives of this study therefore were (1) to investigate the effect of fertilizer and irrigation on the nutritive value of different forage crops and cropping systems and (2) to evaluate the different cropping systems regarding the irrigation water use efficiency of CP and ME production per unit of land.

2. Materials and methods

2.1. Experimental site and treatments

The experiment was conducted at a research station of the University of Agriculture Faisalabad, Pakistan (73–74° E and 30–31.5° N; 184 m above sea level) for two consecutive years, 2010 and 2011. The area is located in a sub-tropical semi-arid climate with cool winters and hot summers and a long-term average annual rainfall of 375 mm (Rasul and Mahmood, 2009). Rainfall and temperature data for the experimental period were taken from the meteorological station of the University of Agriculture Faisalabad, located 500 m away from the experimental site (Fig. 1). The soil was a sandy loam and had been classified as an Aridisol (USDA, 1998) derived from alluvial river deposit sand.

The experimental design for each year was a three factorial completely randomized split-plot arrangement with four replications. The factors comprised (i) fertilizer type (farm yard manure (FYM), mineral fertilizer (MIN) and an unfertilized control (C)), (ii) irrigation level (recommended irrigation (RI) and half recommended irrigation (HRI)), as main-plot factors and (iii) cropping system (common cropping system (CCS)) Egyptian clover followed by corn and drought-adopted cropping system (DACS) oat followed by sudangrass as subplot factors. Main plots had an area of 51.9 m^2 with four sub-plot of 11.7 m^2 area each, out of which only two were considered in this study.

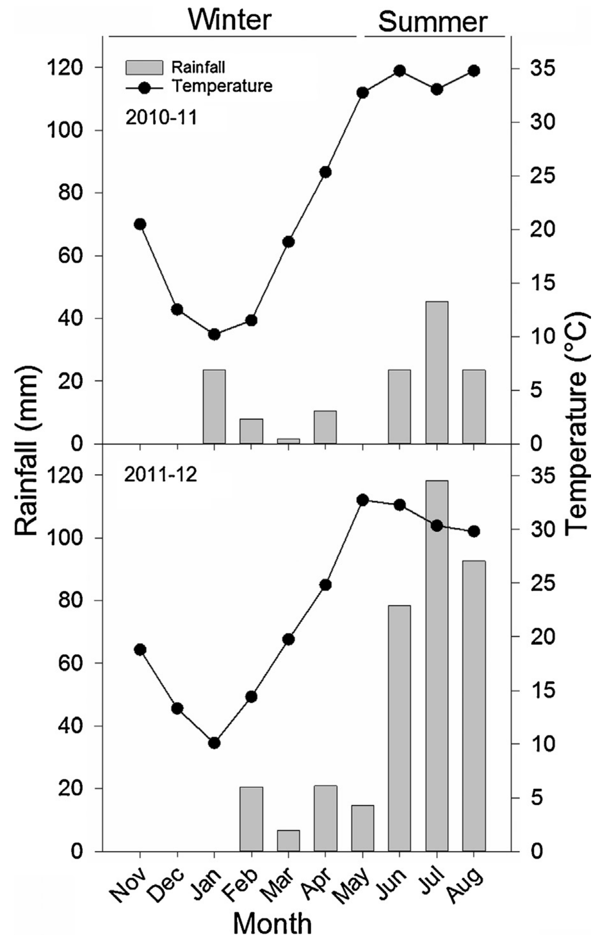

Fig. 1. Monthly total rainfall and average temperature in Faisalabad during 2010–12.

Crops were grown in two consecutive growing periods within one year, i.e. winter (November–April) and summer (May–August). Winter crops (Egyptian clover and oat) were sown on the 24 and 26 November in 2010 and on 22 and 21 November in 2011, respectively, while summer crops (corn and sudangrass) were sown on 30 May 2011 and 23 and 27 May in 2012, respectively. Both FYM and MIN (Urea and di-ammonium phosphate) were applied with 107 kg N ha^{-1} and 26 kg phosphorus (P) ha^{-1}. Whole FYM and P were applied at the time of each sowing, whereas N was applied in split, half at the time of sowing and half with the second irrigation. Potassium (K) was not applied, as the soil was rich in K prior to the experiment and K did not decline during the two experimental years. The official recommendation for irrigation in the area is at 600–800 mm per season (Critchley and Siegert, 1991). Actual total irrigation applied for Egyptian clover, oat, corn and sudangrass under RI was 840, 729, 689 and 689, respectively. Irrigation water was applied through water channels between the sub-plots, releasing 70–75 mm per irrigation event. A 90 cm cutthroat flume meter with an 20 cm wide throat was installed at the entry point of the water to measure the amount of irrigation water applied (Siddiqui et al., 1996). To accomplish RI, irrigation interval was kept two weeks in winter and one week in summer. Half recommended irrigation was done by doubling the irrigation interval. Thus, HRI refers to an amount of half the total seasonal applied irrigation.