Relative importance of topography, climate, species composition, and phenology in affecting forage yield and quality in alpine summer pastures

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Introduction: High quality and healthy food demands have continuously increased in Europe over the last years (Grunert 2013). Grasslands play a crucial role in providing milk, meat and other edible products in large areas around the world (Huyghe et al. 2014). The extensive long permanent grasslands hold a high plant species diversity and often support the provision of valuable forage sources (Ravetto Enri et al. 2016). Particularly, the forage produced by mountain summer pastures is generally the only feed for grazing livestock. The main issue in alpine pasture management is the optimal exploitation of the available forage resource in relation to seasonal advancement, altitude and vegetation composition. However, little is still known about forage yield of species-rich alpine pastures and related chemical composition. In this work, we aim at characterizing forage quantity and quality (i.e., digestibility and proximate composition) exploring the relationships with topographic, climatic and vegetation variables along the growing season. We focused on six grassland types in the western Italian Alps, characterized by contrasting environmental conditions and vegetation compositions.

Materials and methods: The study was carried out in an alpine valley of the Gran Paradiso National Park, in the south-western Italian Alps. We selected six grassland types within two altitudinal (lower: 2300 m a.s.l.; higher: 2750 m a.s.l.) and three fertility (oligotrophic, mesotrophic and eutrophic) levels. Each grassland type was surveyed five times (three replicates) during summer 2019 and 2020, for a total of 162 vegetation surveys. Once plant species composition was assessed, the relative percentage covers of different functional species pools (i.e., broadleaf grasses, narrow-leaved grasses, sedges and rushes, legumes, other species) were computed. A grass sample was harvested at each survey using a portable lawn-mower (cutting height 1 cm), then air-dried, weighed and analysed with near infrared reflectance spectroscopy (NIRS) technique for proximate composition and digestibility. Topographic variables (i.e., elevation, slope) were recorded in the field. Temperatures and precipitations were measured throughout the trial and combined in a synthetic eco-climatic variable (ΔPrET) calculated as the difference between the total precipitation and the potential evapotranspiration (according to the Hargreaves equation) from the day of snowmelt. Plant phenology as well was recorded according to the Lambertin scale (Lambertin 1990). Data were analysed with Generalized Linear Mixed Models to assess the relative importance of topographic (altitude, slope and southness) and climatic (ΔPrET and mean temperatures between surveying period) variables, plant phenology and functional species pool covers in explaining forage yield and quality (in terms of digestibility, crude protein, NDF, ADF, ADL, soluble sugars).

Results: Herbage quality (except for soluble carbohydrates) was negatively affected by ΔPrET, with a larger relative importance compared to the other explanatory variables (digestibility: ΔPrET $\beta = 0.18$, $p < 0.001$; Phenology $\beta = -0.11$, $p < 0.001$; sedges and rushes $\beta = -0.04$, $p < 0.01$). Plant phenology showed a remarkable role in explaining also crude protein and fibre contents (i.e., NDF, ADF, and ADL). More specifically, a decrease in crude protein and an increase in fibre fractions was observed at advanced phenophases, thus resulting in a reduced digestibility. The cover of broadleaf grasses primarily promoted biomass production, which was in turn lowered by increasing elevation and slope. On the other hand, a minor effect on forage yield was observed for increasing cover of sedges and rushes and mean temperatures, respectively (biomass: elevation $\beta = -0.58$, $p < 0.001$; broadleaf grasses $\beta = 0.42$, $p < 0.001$; slope $\beta = -0.38$, $p < 0.05$; sedges and rushes $\beta = 0.18$, $p < 0.001$; mean temperatures $\beta = 0.15$, $p < 0.01$). At increasing cover of legumes, NDF declined and digestibility increased consequently.

Conclusion: Eco-climatic variables as water stress (i.e., ΔPrET) and phenology were the main degrading factors of forage quality in the study area. Nevertheless, the abundance of high-quality forage species (i.e., broadleaf grasses and legumes) can counterbalance these negative processes. Pastoral management in the alpine environment should therefore aim to maintain and enhance these functional species pools, especially to face the ever more frequent summer droughts and heat waves.

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