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Understory pasture in apple orchard: forage yield, species composition and quality along shade gradients

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ABSTRACT

A study was conducted to investigate if understory pastures in apple orchards differed along a gradient of shade intensities. Species composition, forage yield, quality, and soil fertility were measured from high, medium, and low shade intensities. Species composition of understorey pasture mixture was not affected by shade intensities and soil quality. Shade intensity had significant effect on dry matter (DM) yield and nutritional properties of understorey pasture. DM production under high shade intensity was significantly lower than the DM yield of pasture under medium and low shade intensities. Pasture under high shade had significantly higher CP content than pastures under medium shade. Pastures with high shade also had significantly higher ash content compared to pastures under medium and low shade. DM production of pasture and shade intensities were negatively correlated. Light intensity was positively correlated with forage quality (CP and ash content). The study results suggest that low to medium shade intensities are suited for optimal forage yield and quality of temperate pastures in apple orchards.

INTRODUCTION

Cattle rearing practices have evolved with rapid modernization and growing economic opportunities (Wangchuk et al. 2014). Dairy cattle management is shifting from periodic migration system to sedentary system, leading to adoption of intensive cattle management practices (Tamang and Perkins 2005). Efforts to meet forage demand are often constrained by insufficient land, which is a major limitation to fodder development in Bhutan (RNRRC 1996; Roder 1998). Forage cultivation receives less priority, mainly due to local cattle being less productive with poor responses to better feed (Roder et al. 2001). The annual forage dry matter (DM) shortage in Bhutan in 2008 was estimated at 0.77 million MT (Wangchuk and Dorji 2008) compared to 0.09 million MT in 1993 (Dorji 1993).

Exotic pasture species are preferred as they are high yielding compared to native species. In Bhutan, the common exotic species in temperate pasture mixture are Italian ryegrass (*Lolium multiflorum*), cocksfoot (*Dactylis glomerata*), and white clover (*Trifolium repens*). These species are used in pasture mixture in ratio 17.30: 7.41: 2.47kg ha^{-1} for Italian ryegrass, cocksfoot, and white clover, respectively (NCAN 2014). Temperate pastures are developed mainly in open fields but are also cultivated with fruit crops as understory to optimize land use. Integration of livestock with agricultural crops is an alternative to addressing the issue of limited land. The advantages of livestock integration with tree crops include increased and diversified income, better use of scarce land resources, soil stabilization, potential for higher plantation crop yield through better weed control, nutrient recycling, and nitrogen accretion (Shelton and Stur 1991). Integration of forage production with plantation crops also diversifies production system as it enables proper utilization of space and sunlight by understory crops (Sophanodora 1993).

Agro-pastoral system is one of the alternative land use options to optimize production (Brandt et al. 2012). In such land use system, it is essential to manage tree canopy and sunlight to ensure optimum forage production. In such system, removal of ground biomass enhances tree growth by reducing competition with trees for moisture, nutrients and sunlight (Kundu et al. 2008). However, despite recognizing the importance of managing canopies for shade regulation, little is known of the effects of shade intensity on performance of understory pastures. A proper understanding on the effects of shade intensity on understory pasture would help a farmer to manage tree canopy for optimum forage production. Therefore, a study was conducted to evaluate the effects of different shade intensities on botanical composition, dry matter production, and quality of understory pastures in apple orchards.

MATERIALS AND METHODS

Study site

The study was conducted under temperate climatic conditions in east-central Bhutan. The site selected was Chamkhar under Chhoekhor *gewog* (block) in Bumthang *dzongkhag* (district). The site has improved temperate pasture mixture cultivated in apple orchards. Bumthang *dzongkhag* has a total area of 11.50 ha land under orchard (NSB 2015). Chhoekhor is the biggest *gewog* located in the northern part of Bumthang *dzongkhag*. The *gewog* has total area of approximately 1,533 sq km. The altitude of *gewog* ranges from 2,600 to 5,800 m above sea level. The *gewog* has 39 villages and 661 households with a population of 8,756 (Dzongkhag Administration Bumthang 2015). The average annual rainfall is 677.40 mm and mean maximum and minimum temperature are 18.56 °C and 6.31 °C, respectively (NSB 2015).

Experimental layout

Apple orchards planted with improved temperate pasture mixture as understory vegetation were selected for the study. The orchards were on flat land and some on land with gentle slope of less than five percent. The apple orchards occupied an average area of 0.65 ac. The average age of the selected apple orchards was 14 years. The average age of understorey pasture was over 9 years and the average plant height was about 29 cm. The improved pastures occupied about 71% of apple orchards. The orchards were pruned and fertilized with minimal farm yard manure (FYM) and only 57% of the selected orchards were irrigated.

Experimental design and treatments

Randomized Complete Block (RCB) was the experimental design with three shade treatments. Each treatment was replicated seven times. The amount of light falling on the understory pasture was measured and analyzed with Hemiview software (Conifer Research and Training Partnership [CORET] 2005). Shade was a treatment factor and three different shade intensities were selected. Similar to Eriksen and Whitney (1981), the amount of sunlight falling on understory pasture was classified as heavy shade (15.10–40.00%), moderate shade (40.10% – 65.00%), and light shade (65.10% – 90.00%) (Table 1). Seven samples from each treatment were collected and the total number of samples were 21 samples.

Data collection

The center point of two trees in the orchard was identified for measurements. A single time data was collected in July 2015. Parameters measured were shade intensity, plant height, botanical composition, fodder yield, fodder quality, and soil nutrients. The hemispherical photographs were taken from the center point with Hemiview camera. The photographs were analyzed with Hemiview software (vr. 2.1) to quantify the amount of light falling on the orchard floor. The amount of light falling on the center of a plot was calculated as a proportion of the full amount of sunlight reaching the sample plot. If there were no obstructions to light reaching the point from where the image was taken, then it would receive 100% sunlight, whereas trees intercept light and the value would decrease (CORET 2005). A quadrat of size 1m × 1m was placed at the center point between two trees and 10 pasture plants inside the quadrat were selected randomly. The heights of these plants were measured with the measuring scale to estimate the height of understory pasture mixture.

The point intercept technique was employed for estimating the botanical composition of understory pasture. A distance of 10cm was maintained between intercept points and 10cm between two transect lines. Species were recorded at every 10cm interval along the transect line. Only the first plant species intercepted by the point was identified and recorded. In total, 10 readings were recorded per transect line and 10 lines were laid out per plot. Therefore, the total readings per plot was 100. The process was repeated seven times for each treatment. The biomass inside the quadrat was cut and the fresh matter weight was recorded. The harvested plant materials were thoroughly mixed and a representative sample of about 300gm was collected per plot for estimating forage DM yield and quality. The representative forage samples were analyzed for DM at the National Highland Research and Development Centre (NHRDC), Jakar. Samples were dried in hot air oven at 60°C for 24 hours. The oven dried samples were cooled and weighed. The dried forage samples were processed and analyzed at the College of Natural Resources (CNR) for crude protein (CP), ash, and energy content. The ash content was estimated in muffle furnace through combustion while CP was determined with Kjeldahl method. The energy content of the forage sample was determined with Bomb calorimeter method.

Soil within a depth of 10 to 15 cm was collected with soil auger. Soil samples were collected after harvesting the pasture biomass. Soil samples were bulked and a representative sample of 500 to 1000gm was collected from each plot. Soil samples were collected from the same area where botanical composition and biomass assessments were carried out. Soil samples were air dried at ambient temperature at NHRDC, Jakar, Bumthang. The dried samples were ground into fine powder, packed with proper labels, and sent to the Soil and Plant Analytical Laboratory (SPAL) at Semtokha, Thimphu. Soil samples were analyzed for available nitrogen (N), phosphorus (P), potassium (K), carbon (C), pH, and moisture content.

Data analysis

The dataset was analyzed with the Statistical Package for Social Science (SPSS) version 23. Prior to statistical analysis, the raw data were subjected to Levene's test to check for equal variance. Normal distribution of data was tested with Shapiro-Wilk test. Wherever required, data was logarithmically transformed to meet the assumptions of normality. Differences in forage nutrient content and soil quality parameters between different shade treatments were tested with one-way ANOVA. Species composition was analyzed using Chi-square goodness of fit test for comparing ratios of forage species in understory pasture mixture. The relationship of shade with forage yield and quality was tested with the Pearson's correlation test.

Table 1 Category of shade according to light intensity.

Category	Amount of light
Treatment 1 (Low shade)	65.10% - 90.00%
Treatment 2 (Medium shade)	40.10% - 65.00%
Treatment 3 (High shade)	15.10% - 40.00%

Results and Discussion

Understory pasture and soil in apple orchards

The mean soil nutrient content of the study site is presented in Table 2. Similar to the finding of Roder et al. (2003), the soil was slightly acidic with pH of 5.78 and the texture was sandy loam. The mean soil C content was 2.44% and mean soil N content was 0.18%.

The mean soil phosphorus content was 4.1mg kg^{-1} and mean soil potassium content was 56.92mg kg^{-1}. Phosphorus content was lower than the critical value of 15mg kg^{-1} required for optimum pasture growth (White 2006). Low levels of phosphorus content are probably due to low levels of available phosphate in soils at elevations above 2,000 masl (Roder et al. 2001) and also due to the flow of nutrients to agricultural fields in the form of manure (Roder et al. 2003).

Effects of Shade on botanical composition
The improved temperate pastures in apple orchards were dominated by white clover, followed by Italian ryegrass and cocksfoot (Figure 1). There was no significant difference in botanical composition and plant height of understorey pasture among different shade intensities. The effect of various soil conditions on botanical composition of understorey pasture mixture was not observed among treatments. The weighted mean botanical composition of the understory pasture differed from the normal ratio. According to the recommended seed rate of temperate pasture mixture, a pasture should consist of 63.60% Italian rye, 27.3% cocksfoot and 9.10% white clover (NCAN 2014). Although, the seed rate of white clover constitutes only small percentage in the pasture mixture, the white clover in understorey pasture was greater than expected. It is because of the fast growth and aggressive nature of white clover as compared to other seeds. A positive correlation between white clover and pasture age has been reported (RNRRC Jakar 2008; Wangchuk 2016). *Persiceria* sp., *Rumex nepalensis*, *Cyperus* sp., *Festuca arundinacea*, *Chicory* sp. and bare count were described as ‘Others’ in botanical composition of understory pasture mixture.

Table 2 Soil quality of selected apple orchards with understory pasture mixture.

Soil properties	Mean ± SE	Range	
		Min.	Max.
pH	5.78 ± 0.04	5.40	6.26
Carbon (%)	2.44 ± 0.14	1.70	3.40
Nitrogen (%)	0.18 ± 0.03	0.04	0.41
Phosphorus (mg kg^{-1})	4.12 ± 2.28	0.66	48.7
Potassium (mg kg^{-1})	56.9 ± 10.5	14.4	165.0

Nutrient content and dry matter production
The mean nutrient content of understorey pasture with different shade intensities is presented in Table 3. The mean CP content of understory pasture mixture in apple orchards was 18.09 and mean ash content 11.73%. The average metabolizable energy content of forage sample was 3,282.88Mcal kg^{-1}. Dry matter production was found to be similar in low and medium shade but was very less in high shade intensity. Low DM production in high shade would mean less forage for livestock. The CP content in the fodder under different shade intensities were similar and was above the required CP level for cattle feed. Metabolizable energy content in the pasture is higher than the energy required for body maintenance of a cattle weighing 380kg (Ibrahim and Gyeltshen 2008). Therefore, the result suggests that the cattle maintained solely on understory pasture may not require energy supplements.

Dry matter production and Global Site Factor (GSF)
The amount of sunlight falling on the orchard floor is presented in Figure 2. The average DM production of established pasture mixture in apple orchards was 1.57t ha^{-1} per cut. With three cuts obtained in a year from pasture (Wangchuk and Dorji 2008), the total annual DM production yield amounts to 4.71t ha^{-1} per year. DM yield increased with increase in the level of sunlight falling on understorey pasture. However, the yield decreased as levels of sunlight increased above 75.0% GSF. Similar study carried out by Dorji (1993) also reported DM yield of 4.94t ha^{-1} from understorey pasture in apple orchards. Difference in soil nutrients had no significant effect on DM production. However, there was a significant difference in forage DM yield between shade intensities. The forage production in plots with high shade had significantly lower DM yield as compared to orchards with medium and low shade. However, the DM yield did not differ significantly between medium and low shade. The level of sunlight falling on understory vegetation alters dry matter production. With the increasing amount of sunlight, there is more evaporation of available water, thus, causing lignification of pasture swards leading to high DM production. The microclimate modifies the photosynthetic rate and water relations of herbaceous vegetation (Bergez et al. 1997) and primarily affects the growth

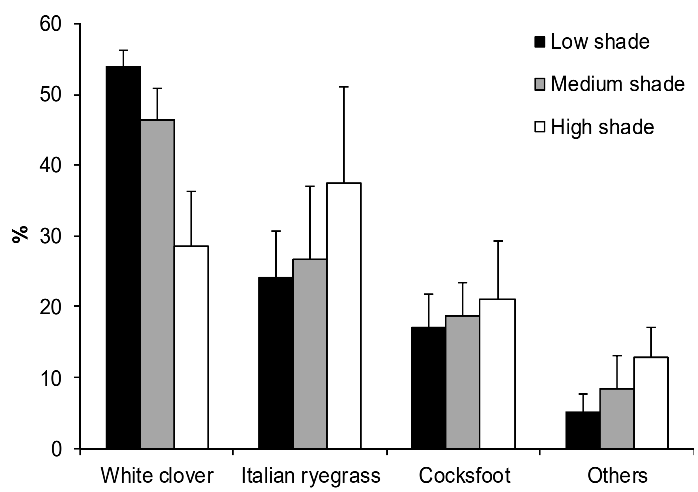

Figure 1 Botanical composition of species in pasture mixture in understory vegetation.

Table 3 Pasture yield under apple orchards with different shade intensity (Mean ± se).

Forage properties	Low shade	Medium shade	High shade	Sig.
Dry matter yield (MT ha^{-1})	5.85 ± 0.51	5.47 ± 0.53	2.77 ± 0.32	***
Ash (%)	9.43 ± 0.42	10.18 ± 0.87	15.59 ± 1.16	***
Crude protein (%)	16.55 ± 0.92	16.92 ± 1.00	20.78 ± 1.40	*
Metabolizable Energy (MJ g^{-1})	14.05 ± 0.30	14.48 ± 1.02	12.70 ± 0.25	ns

*p≤0.05, ***p≤0.001, ns: non-significant of understorey herbaceous vegetation (Braziotis and Papanastasis 1995). Lower DM production under high shade agrees with Wilson and Wild (1991) who reported decrease in herbage yield with increasing shade. Blenkinsop and Dale (1974) described that the decrease in forage yield is possibly due to reduced photosynthetic rate under low light. Hunt (1971) attributes low DM under high shade to leaf death and decomposition as a result of excessive moisture. There was a significant difference in CP and ash content between shade treatments. However, the energy content of understorey pasture did not differ significantly among treatments. Both CP and ash contents of grass species increased as shade level increased (Table 3). The ash content of pasture under high shade was significantly higher than low and medium shaded plots. Similar results were also reported by Kilcher (1981) and Koukoura et al. (2009). However, no significance difference was observed between low and medium shades. There were no clear effects of shade intensity on nutrient content of understory pasture as reported by Norton et al. (1991). The understorey pasture under high shade had significantly higher CP content than pastures under low shade.

Quality of pasture under different shade intensities

Koukoura et al. (2009) reported that the CP content of herbage reduced significantly only under heavy shade (90%), while control (0%) did not differ compared to 50% shade treatment. This could be associated with the age of pasture after cutting (Kyriazopoulos and Nastis 2009). The understory pasture under high shade was significantly younger (Table 4) than the medium and low shaded orchards. The findings are similar to Kilcher (1981) who stated that the CP content of herbaceous plants decreases as they reach maturity. Aganga et al. (2004) also confirmed that the nutrient content or the chemical composition of grass decreases as it matures. The soil properties were similar with no significant difference among shade treatments. Thus, the result indicated that soil quality parameters did not affect the quality of forage grown under different shade intensities.

Interaction between shade intensity and soil properties

The mean soil carbon content is presented in Figure 3. The soil carbon content was significantly different between shade treatments. The average soil carbon of low shade was significantly higher than the high and medium shaded orchards. However, no significant difference was observed between medium and high shaded plots. The available soil potassium (K) content in different shade is presented in Figure 4. The soil K differed significantly among different shade levels. Soil K of high shade was significantly higher than the medium and low shaded orchards. However, no significance difference was observed between medium and low shaded plots. The means of soil N and P also did not differ significantly.

Relationship of shade intensity and soil nutrients with forage nutrients

The relationship between shade intensity and forage quality is presented in Table 5. There was a negative correlation between forage DM production and shade intensity in apple orchards. The result indicated that when shade increases, DM production

Table 4 Average duration of pasture from last date of cutting.

Level of shade	N	Mean (month)	SE
Low	7	2.29	0.10
Medium	7	2.36	0.09
High	7	2.00	0.00

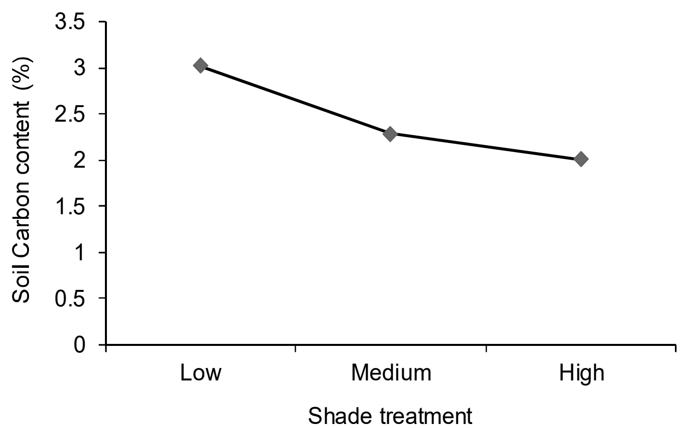

Figure 3 Soil carbon under different shade intensities

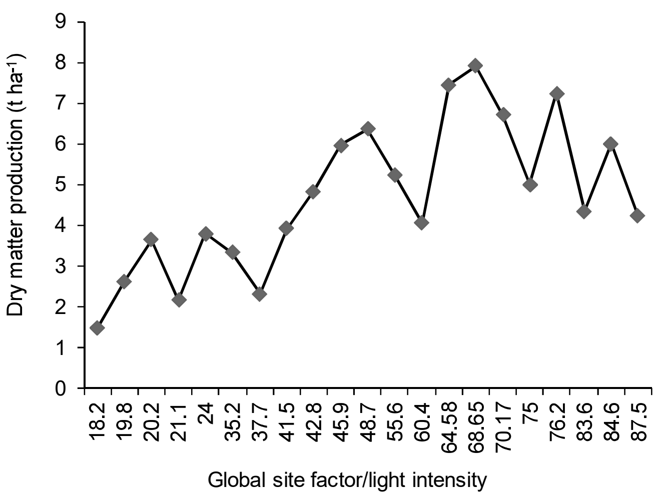

Figure 2 Relationship between dry matter production and light intensity.

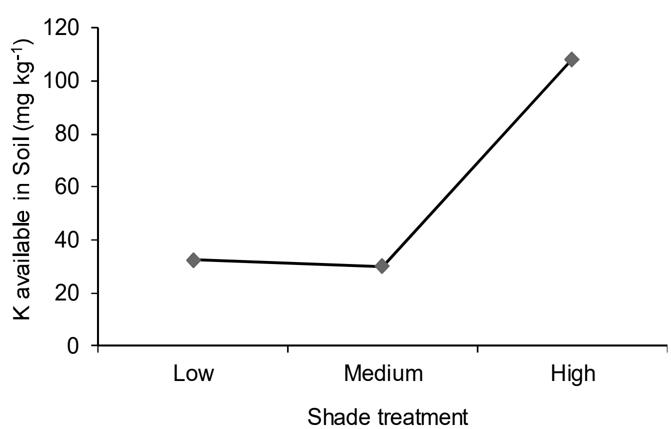

Figure 4 Soil K content under different shade intensities

decreases. This is due to reduced temperature (Albayrak and Camas 2007) of understorey environment. However, there was a positive correlation between level of sunlight and forage quality mainly CP and ash content.

Table 5 Relationship between shade intensity and nutrient content of understorey pasture.

Parameter	Shade intensity
Dry matter	-0.707**
Ash	0.723**
Crude protein	0.515*
Energy	-0.321

CONCLUSIONS

Shade intensity did not alter species composition but influences DM production of understorey pasture. Low shade provides high forage yield. Forage quality did not vary with soil properties but differs significantly between shade intensities. Stage of maturity depends on the duration after cutting as the nutrient content or the chemical composition of grass decreases as it matures. Dry matter production and shade intensity are negatively correlated. Shade intensities do not differ in energy content. Based on study findings, orchard canopy must be maintained to ensure low to medium shade with sunlight of 50.0–75.0% for optimum forage production. Future studies are needed on the adverse effects of understory forage production on yield of tree crops.

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