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# Performance of Summer Cover Crops Under Limited Irrigation in Northern Nevada: Cowpea, Sunn Hemp, and Millets

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## ABSTRACT

Summer cover crops can be an integral part of soil health. In Northern Nevada, summer cover crop establishment relies on irrigation water that is increasingly limited by drought. As such, it is important to evaluate the adaptation of commercially available warm season cover crops that can establish and provide soil health benefits with reduced water inputs. This three-year study evaluated the performance of cowpea (*Vigna unguiculata*), sunn hemp (*Crotalaria juncea*), and several species of millet in a water limited scenario. Crops were planted in late June and irrigated twice after planting each year. Characteristics evaluated were field emergence, canopy cover, aboveground biomass production, days after planting to 50% flower, and forage quality. Cowpea varieties performed similarly all three years and produced an overall average of 1,553 lb/a of dry matter, sunn hemp failed to establish adequate stands two out of three years and may not be the best option for Northern Nevada, and millets were highly variable by species and variety. Overall, this study identified several warm season cover crop varieties that may be useful in Northern Nevada.

## INTRODUCTION

Summer cover crops can address the principles of a soil health management system. Well adapted cover crops provide diverse benefits including protection against wind and water erosion, increased soil organic matter, and increased soil water holding capacity (Clark, 2007). In Northern Nevada, precipitation falls predominantly in the winter and summer cover crops are typically established and maintained with irrigation. Irrigation water availability depends on the condition of rivers and reservoirs; thus it is climate dependent, highly variable, and predicted to be increasingly stressed (Hall et al., 2023; Shiozawa et al., 2023). Drought years may result in reduced deliveries of irrigation water, while extreme drought may reduce water availability to zero; as experienced by producers in Lovelock, Nevada, in 2021 and 2022 (Nelson, 2022). In addition, ground water sources are increasingly limited as aquifers are overextended (Rothberg, 2023). To gain the soil health benefits of cover cropping in limited water availability scenarios, it is important to consider drought tolerance when choosing cover crops for a given location. Three drought tolerant cover crops available for Nevada include cowpea (*Vigna unguiculata*), sunn hemp (*Crotalaria juncea*) and millets.

### Cowpea

Cowpea is a warm-season annual legume known for rapid growth as well as drought and heat tolerance (Clark, 2007; Sheahan, 2012). Three varieties were chosen for this study, ‘Chinese Red’, Red Ripper, and Iron and Clay. Chinese Red is an early maturing half-bushy half-viny cultivar that originated from Hupeh, China (Piper, 1912). Red Ripper is not a cultivar, but rather a group name applied to closely related cultivars and germplasms with maroon-colored seeds (Morse, 1920; Piper, 1912). The entire group is considered similar, with a very-viny growth form and the main difference being flowering time and seed characteristics. Iron and Clay is a mixture of two formerly separate varieties. ‘Iron’ is a tall, half-bush, that is especially valuable due to its immunity to root-knot nematode. Clay is not a cultivar, but rather a group name for closely related medium-late viny plants with buff-colored seed (Morse, 1920).

## Sunn Hemp

Sunn hemp is a tropical or sub-tropical legume that acts as a warm-season annual when grown in the continental United States (Joy & Peterson, 2006). It is grown as a cover crop for its abundant biomass and nitrogen production, drought tolerance, and ability to suppress nematodes. At least three cultivars have been developed for use as cover crops in the United States: 'Tropic Sun', 'AU Golden', and 'AU Durbin' (Joy & Peterson, 2005; Mosjidis et al., 2013; Rotar & Joy, 1983). Tropic Sunn, the cultivar used in this study, was released in 1983 by the USDA NRCS Hoolehua, Hawaii Plant Materials Center and the University of Hawaii, Hawaii Institute of Tropical Agriculture and Human Resources, Department of Agronomy and Soil Science, for use as a non-toxic green manure cover crop (NRCS, 2021; Rotar & Joy 1983). AU Golden is advertised as a non-toxic improved variety developed by Auburn University (Mosjidis et al., 2013). Unfortunately, AU Golden seed was not commercially available for this study. Desert Sun Marketing, the exclusive seed producer of AU Golden, discontinued production due to an inability to compete commercially with Variety Not Stated (VNS) sunn hemp (M. Malin, personal communication, May 20, 2021). AU Durbin was also not commercially available for this study. VNS sunn hemp is readily available and is often listed at about a third the price of named cultivars. VNS does not mean poor quality, however, the germplasm source is often unknown and performance would likely vary from year to year and vendor to vendor.

## Millet

Millets are warm-season grasses grown for rapid biomass production, nutrient capture, and erosion control. The term "millet" is a poorly defined catch-all term for over 400 species of small-seeded cereals (Wietgrefe, 1989). The majority of millet species originate from semi-arid to arid ecosystems across Eurasia and Africa, thus they are considered well adapted to drought, poor soils, and shorter growing seasons (Fuller, 2017; Riley et al., 1989; Wietgrefe, 1989). The adaptability and tolerance of millets to harsh unpredictable conditions makes them a critical tool for regenerative agriculture (FAO, 2023; Wilson & VanBuren, 2022). Eight varieties of five millet species were evaluated in this study: pearl millet (*Pennisetum glaucum*; varieties: 'Leafy 22', 'Tifleaf 3'), foxtail millet (*Setaria italica*; varieties: 'German', 'White Wonder'), proso millet (*Panicum miliaceum*; varieties: 'Horizon', 'Dove'), VNS Japanese millet (*Echinochloa* sp.), and VNS browntop millet (*Urochloa ramosum*).

Pearl millet is a tall millet (4–8 ft) with a deep root system. It is the most vigorous of the millets, grows well on sandy soils, is extremely drought tolerant, and can regrow if cut or grazed at ~60 days after planting (Hanna et al., 2004; Lee et al., 2012; Sheahan, 2014). Tifleaf 3 pearl millet is a very leafy, semi-dwarf, forage hybrid released by the USDA-ARS and University of Georgia Coastal Plain Experiment Station in April 1995 to provide good grazing for longer periods during the summer (Hanna et al., 1997). It is more rust resistant than 'Tifleaf 2', which in turn was an improvement on 'Tifleaf 1' (Burton, 1980; Hanna et al., 1988). Leafy 22 pearl millet is widely available and is described as having a shorter stature, longer growing season, high biomass, and above average crude protein content (Daniel et al., 1994; Grabowski, 2020; Ogashi et al., 2022; Thomas, 2023; Turner, 2010).

Foxtail millet grows 2–5 ft tall with a shallow root system. It has high salt tolerance, is adapted to sandy to loamy soils in cooler-droughty regions and has one of the highest water use efficiencies of all millets (Myers, 2018; Sheahan, 2014; Vinall, 1924; Williams, 1899). German foxtail millet is a late-maturing cultivar introduced to the United States from France in the early

1860s (Williams, 1899). The original introduction may have been a trade name rather than a certified cultivar as it was described as "…exceedingly variable in appearance and habit of growth. It is very seldom that one sees a field that is uniform in character." (Williams, 1899). German was also sold under the name 'Golden' foxtail millet (Vinall, 1924; Wietgrefe, 1989). Jackson (1950) found nearly all commercial stocks of German to be mixtures of German foxtail and common foxtail, with hybridization making separation by seed characteristic impossible. However, the crops produced from this mixture had consistently large seed heads and provided satisfactory results (Jackson, 1950). White Wonder is a late maturing cultivar, though matures faster than German. It is commonly grown for the dual purpose of grain or hay (Croissant & Shanahan, 1994; Wietgrefe, 1989).

Proso millet grows 1–3.5 ft tall with a very shallow root system at depths of 2–6 in (Baltensperger et al., 1995). It is heat and drought tolerant and has extremely high water use efficiency but does not tolerate high salinity and does not grow well in coarse sandy soils (Martin, 1920; Piper, 1921; Sheahan, 2014; Wietgrefe, 1989). Horizon is a white-seeded proso type released in 2003. It is a short statured early maturing cultivar that has more disease resistance than similar varieties like 'Earlybird' and 'Sunrise' (Baltensperger, 2004; Lyon et al., 2008). The seed source of Dove proso millet originated from the Almora Provinces in India and was developed by the Americus, Georgia Plant Materials Center (GAPMC) and the University of Georgia Agricultural Experiment Stations (Powell et al., 1977). Evaluations occurred at the GAPMC, as well as the Coffeeville, Mississippi Plant Materials Center (PMC) and Brooksville, Florida PMC, where it demonstrated superior growth, early maturation, and abundant seed production. It proved to be highly attractive to doves and was grown mainly to support wildlife (Powell et al., 1977; Surrency & Owsley, 2006).

Japanese millet has been used as a common name for two related species. *E. esculenta* was derived from the domestication of *E. crus-galli* approximately 4,000 years ago in Japan; and *E. frumentacea* was derived from the domestication of *E. colona* in India (Banfi & Galasso, 2021; Doggett, 1989; Hilu, 1994; Sood et al., 2020). They are often confused with each other, but literature that distinguishes between the two species typically list *E. esculenta* as Japanese millet and *E. frumentacea* as Indian millet (Amasiddha et al., 2023; Banfi & Galasso, 2021; Doggett, 1989; Hilu, 1994; Kaur & Sharma, 2020). Both species were widely distributed throughout the United States by the late eighteen hundreds (Williams, 1899) and are used today as forage and waterfowl feed (Mitchell, 1989; NRCS, 2006; Sheahan, 2014). Currently, seed for Japanese millet is widely available on the commercial market, though species designations are rare. The two species are morphologically highly variable, with overlapping characteristics that often make distinguishing between them difficult (Hilu, 1994). Both species are known for maturing rapidly, producing ample biomass, for shallow fibrous roots, and are more frost tolerant relative to other millets. They grow well on marginal lands and are drought tolerant, though not as much as other millets and may not perform as well on sandy soils. They are unique among millets in that they can survive standing water (Renganathan et al., 2020; Sheahan, 2014; Sood et al., 2020).

Browntop millet is a rapidly maturing annual, sometimes perennial, that grows 1–3 ft tall with a 2 ft deep fibrous root system. It is a heat tolerant crop that is more drought tolerant than Japanese millet and is well adapted to semiarid areas. It grows well under shaded conditions, with a shallow water table, and at elevations from sea level to 8,202 ft (Ashoka & Sunitha, 2020; Kingwell-Banham & Fuller, 2014; FAO, 2007; Maitra, 2020; Maitra et al., 2023; Mitchel & Tomlinson, 1989). It was introduced to the United States from India around 1915 to provide food

for game birds and is generally grown in the Southern United States (Kingwell-Banham & Fuller, 2014; Mitchel & Tomlinson, 1989; Sheahan 2014).

The purpose of this study is to evaluate the performance and adaptation of commercially available warm season cover crop varieties to Northern Nevada.

## MATERIALS AND METHODS

This study was conducted in the summer of 2021 (Y1), 2022 (Y2), and 2023 (Y3) at the Great Basin Plant Materials Center (GBPMC) in Fallon, Nevada (39.4563 N, −118.77966 W). Species were planted on a pure live seed basis (PLS; table 1) and legumes were inoculated with appropriate rhizobia before planting. No fertilizer was used in any year of the study. Mechanical and chemical methods were used to control weeds.

A firm, weed free seedbed was prepared each year by disking and cultipacking, followed by a single irrigation to encourage weed seed germination. All germinated weeds were controlled with herbicide prior to planting. The plantings were established in Sagouspe loamy sand soil with a modified Great Plains no-till drill with cone seeder mount in a randomized block design with four replications. Plots were 15 ft long by 6 ft wide with a two-foot buffer between plots and 6-in row spacing. The field was flood irrigated with three inches of water twice after planting. Plots were moved to new field locations each year to avoid contamination from previous years.

Table 1: Species, variety, and seeding rates in pounds of Pure Live Seed per acre used in the warm season cover crop trial evaluations at the Great Basin Plant Materials Center, 2021–2023.

| Species | Scientific Name | Variety | Pounds Pure Live Seed per acre |
|---|---|---|---|
| Cowpea | *Vigna unguiculata* | 'Chinese Red' | 50 |
| Cowpea | *Vigna unguiculata* | Red Ripper | 50 |
| Cowpea | *Vigna unguiculata* | Iron and Clay | 50 |
| Sunn Hemp | *Crotalaria juncea* | 'Tropic Sun' | 45 |
| Japanese Millet | *Echinochloa* sp. | VNS* | 20 |
| Proso Millet | *Panicum miliaceum* | 'Horizon' | 20 |
| Proso Millet | *Panicum miliaceum* | 'Dove' | 20 |
| Browntop Millet | *Urochloa ramosum* | VNS* | 20 |
| Pearl Millet | *Pennisetum glaucum* | 'Leafy 22' | 20 |
| Pearl Millet | *Pennisetum glaucum* | 'Tifleaf 3' | 20 |
| Foxtail Millet | *Setaria italica* | 'White Wonder' | 20 |
| Foxtail Millet | *Setaria italica* | 'German' | 20 |

*VNS = Variety Not Stated

Climate data was collected from a Pacific Northwest Cooperative Agricultural Weather Network (AgriMet) weather station located on the GBPMC (39.4575 N, −118.77388 W; Palmer, 2011). Daily maximum and minimum temperature and daily precipitation was recorded. Growing degree day (GDD) was calculated for each day using the equation (McMaster & Wilhelm, 1997):

$$GDD = \frac{Tmax + Tmin}{2} - Tbase$$

Where Tmax is the day's maximum temperature or the target plant's maximum temperature for growth (whichever was lower), Tmin is the day's minimum temperature, and Tbase is the target plant's baseline temperature required for growth. If GDD was negative for the day, then zero was recorded instead. For this study, sorghum baseline and max temperatures were used to calculate GDD (Tbase: 46.6°F; Physiological Tmax=93.2°F; Ritchie & Alagarswamy, 1989).

Data was collected using the application Field Book (Rife & Poland, 2014) on a Galaxy SM-T390 tablet. Evaluation protocol included germination and field emergence, canopy cover, 50% bloom date, plant height at 50% bloom, biomass production at 50% bloom, and forage quality samples. Germination and field emergence was recorded at 7, 14, 21, and 28 DAP by ocular estimate on 1–5 point scale then given a descriptive rank; with 0–20% = Poor, 21–40% = Fair, 41–60% = Moderate, 61–80% = Good, 81–100% = Excellent. Canopy cover was estimated with the application Canopeo (Patrignani & Ochsner, 2015). Photos were taken near the center of the plot at approximately 4 feet above the canopy every 30 DAP until plots reached 100% cover or 50% bloom. Bloom date was recorded when half of the plants in a plot reached 50% bloom or anthesis. Height was collected from three plants and measured from base of the plant to the highest part of the plant. If the inflorescence had a bend, then the measurement was to the highest part of the bend rather than straightening out the plant. Biomass was collected at the 50% bloom date, or at 90 DAP should the plot not reach 50% bloom. A 1.64 ft square frame was placed on a representative sample of the plot, and all above ground biomass rooted in the frame was clipped to ground level and bagged; removing weeds and other contaminants if any. The wet weight was recorded, and the bag was left in a warehouse until air dried for the dry weight.

Emergence, cover, height, biomass, and DAP to 50% flower was analyzed with Statistix 10 (Statistix, 2013) utilizing Friedman Two-Way ANOVA and Dunn's All Pairwise Comparison to rank differences. For forage quality, a subsample from the biomass of each plot was clipped and mixed by cultivar. The 12 samples were sent to Sierra Testing Service and their partner Dairyland Laboratories for nutrition analysis and nitrate concentration. Sierra testing service utilized a FOSS NIR Systems 5000 for the nutrition analysis.

## RESULTS AND DISCUSSION

The climate was similar throughout the study. The cumulative Growing Degree Days (fig. 1) was calculated for 90 DAP for all three years. By 90 DAP, 2022 accumulated the most GDD (2379), followed by 2021 (2301) and 2023 (2158). In contrast to the similar temperatures, summer precipitation varied dramatically (table 2), with 2023 receiving the most (1.56 in) followed by 2022 (1.22 in) and 2021 (0.28 in). Despite this difference, total summer rain was minimal and insufficient to support a typical crop without additional irrigation. In general, all three summers could be described as hot and dry (table 2 and 3).

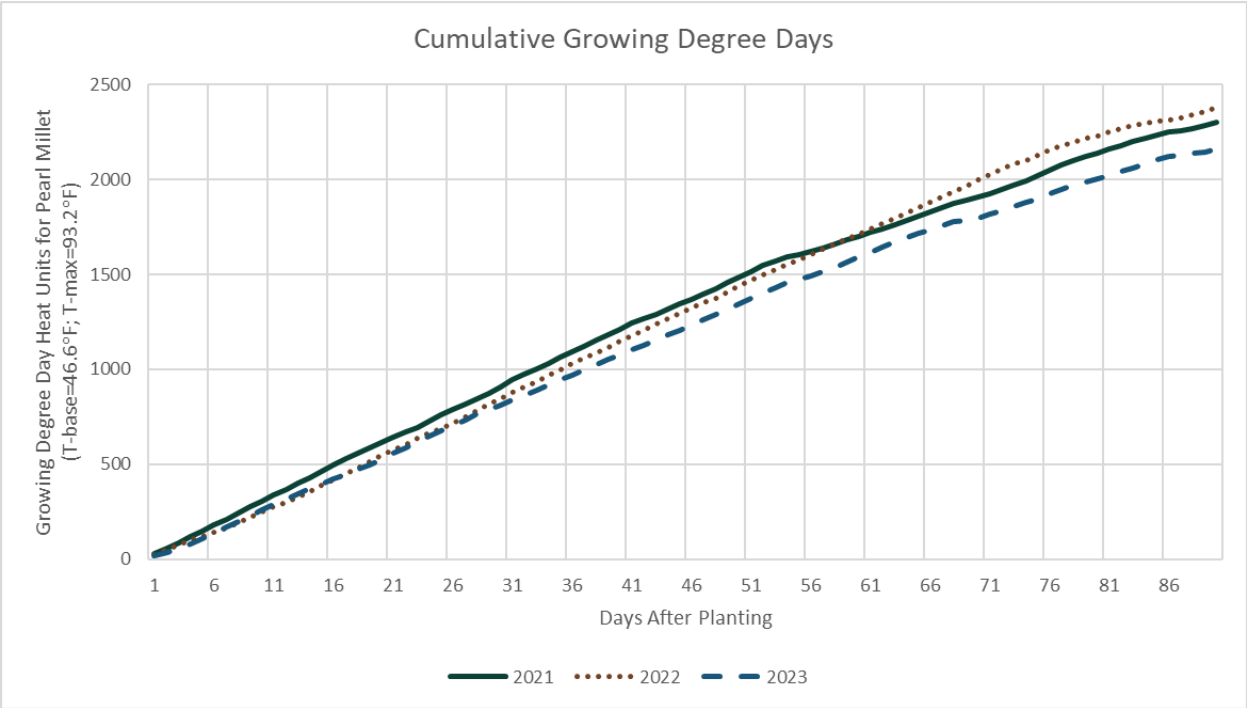


Figure 1: Cumulative Growing Degree Days for 2021, 2022, and 2023 from day 1 of the planting till 90 days after planting in the warm season cover crop trial evaluations at the Great Basin Plant Materials Center.

Table 2: Monthly temperatures per year measured for the warm season cover crop trial evaluations at the Great Basin Plant Materials Center, 2021–2023.

| Climate | 2021 Average Monthly Max Temp (°F) | 2022 Average Monthly Max Temp (°F) | 2023 Average Monthly Max Temp (°F) |
|---|---|---|---|
| June* | 97 | 89 | 81 |
| July | 98 | 98 | 96 |
| Aug | 92 | 96 | 90 |
| Sept | 87 | 88 | 82 |

*June average temperature is from June 15–June 30 for all years.

Table 3: Monthly precipitation per year measured for the warm season cover crop trial evaluations at the Great Basin Plant Materials Center, 2021–2023.

| Climate | 2021 Precipitation (in) | 2022 Precipitation (in) | 2023 Precipitation (in) |
|---|---|---|---|
| June* | 0.01 | 0.00 | 0.00 |
| July | 0.26 | 0.00 | 0.04 |
| August | 0.00 | 0.92 | 1.20 |
| September | 0.01 | 0.30 | 0.32 |
| Total | 0.28 | 1.22 | 1.56 |

*June average precipitation is from June 15–June 30 for all years.

## Cowpea

Cowpea varieties (fig. 2) performed similarly throughout this study. Emergence was rapid, with Chinese Red and Iron and Clay having >90% emergence by 7 DAP for all three years, and Red Ripper having >90% by 7 DAP for year two and three. Red Ripper emergence was slower in

year one, reaching >90% emergence by 14 DAP (62% at 7 DAP). There was no significant difference in canopy cover at 30 DAP between varieties and years (no canopy data collected Y3). Average canopy cover at 30 DAP for all varieties was 38%. Canopy cover ranged from 27–41% in Y1 and 24–37% in Y2 for Chinese Red; 44–61% in Y1 and 20–54% in Y2 for Iron and Clay; and 24–65% in Y1 and 21–65% in Y2 for red ripper (table 4). Height at 90 DAP was somewhat variable by year and cultivar. Iron and Clay had greater height than Chinese Red and Red Ripper in Y1, there was no difference in height between varieties in Y2, and Iron and Clay was greater than Chinese Red Y3. Chinese Red height in Y1 and Y2 were both greater than Y3, and there was no within variety height difference for Iron and Clay and Red Ripper for any year. Biomass differences were minimal. There was no difference between varieties for any year. There was no difference in biomass between years within cultivars, except for Iron and Clay where Y1 and Y3 were greater than Y2 (table 4).

Figure 2: A cowpea plot at 90 days after planting in Year 3 of the warm season cover crop trial evaluations at the Great Basin Plant Materials Center, 2021-2023.

Cowpea nutrient analysis found similar percent crude protein and nitrogen content for all three years (table 5). Nitrate levels were high in Y1, with trace amounts detected in Y2 and Y3.

Table 4: Three years of emergence data at 7 and 14 days after planting (DAP), canopy cover at 30 DAP, height at 90 DAP, and biomass production for cowpeas in the warm season cover crop trial evaluations at the Great Basin Plant Materials Center, 2021–2023.

| Variety | Year | 7 DAP Emergence[1] | 14 DAP Emergence[1] | 30 DAP Canopy | Average Height at 90 DAP (in) | Biomass[2] (lb/a) |
|---|---|---|---|---|---|---|
| Chinese Red | 1 | Excellent | Excellent | 32% | 21 | 1,454 |
| Chinese Red | 2 | Excellent | Excellent | 30% | 22 | 1,535 |
| Chinese Red | 3 | Excellent | Excellent | NA | 14 | 1,401 |
| Iron & Clay | 1 | Excellent | Excellent | 54% | 27 | 2,391 |
| Iron & Clay | 2 | Excellent | Excellent | 37% | 24 | 749 |
| Iron & Clay | 3 | Excellent | Excellent | NA | 27 | 2,659 |
| Red Ripper | 1 | Good | Excellent | 40% | 17 | 1,169 |
| Red Ripper | 2 | Excellent | Excellent | 41% | 18 | 1,124 |
| Red Ripper | 3 | Excellent | Excellent | NA | 17 | 1,499 |
| Total Average | | Excellent | Excellent | 38% | 21 | 1,553 |

[1]Good =61–80%; Excellent = 81–100%

[2]Biomass collected at 50% bloom, or at 90 DAP if the plot never reached 50% bloom.

Table 5: Nutrient Analysis of three varieties of cowpeas in the warm season cover crop trial evaluations at the Great Basin Plant Materials Center, 2021–2023.

| Variety | Year | %Crude Protein | %P | %K | %N | %Nitrate | N (lb/a) |
|---|---|---|---|---|---|---|---|
| Chinese Red | 1 | 23.7 | 0.41 | 1.02 | 3.79 | 0.91 | 49.6 |
| Chinese Red | 2 | 18.5 | 0.35 | 1.17 | 3.00 | <0.13 | 40.9 |
| Chinese Red | 3 | 13.2 | 0.31 | 1.45 | 2.11 | <0.13 | 26.6 |
| Iron & Clay | 1 | 20.3 | 0.45 | 1.60 | 3.25 | 1.40 | 69.9 |
| Iron & Clay | 2 | 19.1 | 0.35 | 0.72 | 3.10 | <0.13 | 20.6 |
| Iron & Clay | 3 | 19.4 | 0.37 | 1.08 | 3.10 | <0.13 | 74.3 |
| Red Ripper | 1 | 19.8 | 0.39 | 1.82 | 3.17 | 0.53 | 33.3 |
| Red Ripper | 2 | 16.5 | 0.35 | 1.56 | 2.60 | <0.13 | 26.7 |
| Red Ripper | 3 | 18.6 | 0.40 | 2.62 | 2.98 | <0.13 | 40.1 |

## Sunn Hemp

Sunn hemp (fig. 3) performance was inconsistent, with good performance in Y1 and very poor performance by the end of Y2 and Y3 (table 6). Emergence was rapid in Y2 (>90% at 7 DAP), and significantly faster than Y1 at 7 DAP (68%) and 14 DAP (85%). By 21 DAP there was no longer a difference in emergence. Canopy cover at 30 DAP was greater in Y1 (58%) than Y2 (28%), and height varied considerably by year and plot. Y1 height averaged 58 in (range: 47–80 in) and was significantly taller than Y2 (average: 21 in; range: 10–38 in) and Y3 (average: 24 in; range: 16–33 in). Biomass also varied considerably by year and plot. Y1 biomass averaged 4,229 lb/a (range: 2,320–6,424 lb/a) and was significantly greater than Y2 (average: 339 lb/a; range: 71–784 lb/a) and Y3 (average: 687; range: 321–1,249 lb/a). Y1 reached 50% flower by 88 DAP, while both Y2 and Y3 desiccated and never flowered.

Figure 3: A sunn hemp plot at 50% flower in the warm season cover crop trial evaluations at the Great Basin Plant Materials Center, 2021-2023. Foreground is 'Horizon' proso millet.

Table 6: Three years of emergence data at 7 and 14 days after planting (DAP), canopy cover at 30 DAP, height at 90 DAP, and biomass production for sunn hemp in the warm season cover crop trial evaluations at the Great Basin Plant Materials Center, 2021–2023.

| Variety | Year | 7 DAP Emergence[1] | 14 DAP Emergence[1] | 30 DAP Canopy | Average Height (in) | DAP to 50% Flower |
|---|---|---|---|---|---|---|
| Tropic Sunn | 1 | Good | Excellent | 58% | 58 | 88 |
| Tropic Sunn | 2 | Excellent | Excellent | 28% | 21 | x |
| Tropic Sunn | 3 | Excellent | Excellent | NA | 24 | x |

[1]Good =61–80%; Excellent = 81–100%

X: No plot reached 50% flower

Sunn hemp nutrient analysis found that Y1 had much higher percent crude protein and nitrogen content than Y2 and Y3 (table 7). Y2 and Y3 had crude protein percentages more reminiscent of a grass than legume, suggesting a possible issue with nodulation in both years. Only trace amounts of nitrate was found in all three years.

Table 7: Sunn hemp nutrient analysis in the warm season cover crop trial evaluations at the Great Basin Plant Materials Center, 2021–2023.

| Variety | Year | %Crude Protein | %P | %K | %N | %Nitrate | Biomass (lb/a) | N (lb/a) |
|---|---|---|---|---|---|---|---|---|
| Tropic Sunn | 1 | 24.19 | 0.21 | 1.62 | 3.87 | <0.13 | 4,229 | 147.3 |
| Tropic Sunn | 2 | 9.97 | 0.33 | 1.77 | 1.60 | <0.13 | 339 | 4.9 |
| Tropic Sunn | 3 | 9.40 | 0.40 | 1.90 | 1.50 | <0.13 | 687 | 9.3 |

## Millet

Emergence was rapid, with all millets except White Wonder foxtail (50%|Y3) and Japanese (55%|Y3) having >90% emergence by 7 DAP for all years, and all millets had >90% emergence by 14 DAP for all years (table 8). Cover, Height, DAP to 50% flower, and biomass were highly variable per species and per variety, which limits additional generalizations. However, Y1 was significantly greater than Y2 and Y3 for end-of-season height and biomass across most varieties. Exceptions include Tifleaf 3 pearl millet, which had no difference in height or biomass for all three years, and Dove proso millet, which had no difference in height for the three years. Nutrient analysis found high concentrations of Nitrates for Y1 for all millets, but only trace amounts in Y2 and Y3 (table 9).

Table 8: Three years of emergence data at 7 and 14 days after planting (DAP), canopy cover at 30 DAP, height at 90 DAP, and biomass production for millets in the warm season cover crop trial evaluations at the Great Basin Plant Materials Center, 2021–2023.

| Variety | Year | 7 DAP Emergence[1] | 14 DAP Emergence[1] | 30 DAP Canopy | Average Height at 90 DAP (in) | DAP to 50% Flower |
|---|---|---|---|---|---|---|
| VNS Japanese | 1 | Excellent | Excellent | 95% | 35 | 88 |
| VNS Japanese | 2 | Excellent | Excellent | 40% | 18 | x |
| VNS Japanese | 3 | Moderate | Excellent | NA | 21 | x |
| Horizon Proso | 1 | Excellent | Excellent | 94% | 32 | 38 |
| Horizon Proso | 2 | Excellent | Excellent | 37% | 17 | 48 |
| Horizon Proso | 3 | Excellent | Excellent | NA | 19 | 50 |
| Dove Proso | 1 | Excellent | Excellent | 93% | 55 | 67 |
| Dove Proso | 2 | Excellent | Excellent | 53% | 43 | 73 |
| Dove Proso | 3 | Excellent | Excellent | NA | 38 | 67 |
| VNS Browntop | 1 | Excellent | Excellent | 92% | 39 | 59 |
| VNS Browntop | 2 | Excellent | Excellent | 29% | 25 | 73 |
| VNS Browntop | 3 | Good | Excellent | NA | 26 | 59 |
| Leafy 22 Pearl | 1 | Excellent | Excellent | 94% | 46 | x |
| Leafy 22 Pearl | 2 | Excellent | Excellent | 41% | 33 | x |
| Leafy 22 Pearl | 3 | Excellent | Excellent | NA | 32 | x |

| Variety | Year | 7 DAP Emergence[1] | 14 DAP Emergence[1] | 30 DAP Canopy | Average Height at 90 DAP (in) | DAP to 50% Flower |
|---|---|---|---|---|---|---|
| Tifleaf 3 Pearl | 1 | Excellent | Excellent | 94% | 41 | x |
| Tifleaf 3 Pearl | 2 | Excellent | Excellent | 45% | 38 | x |
| Tifleaf 3 Pearl | 3 | Excellent | Excellent | NA | 33 | x |
| White Wonder Foxtail | 1 | Excellent | Excellent | 93% | 42 | 73 |
| White Wonder Foxtail | 2 | Excellent | Excellent | 33% | 23 | 87 |
| White Wonder Foxtail | 3 | Moderate | Excellent | NA | 23 | x |
| German Foxtail | 1 | Excellent | Excellent | 89% | 38 | 88 |
| German Foxtail | 2 | Excellent | Excellent | 52% | 24 | 88 |
| German Foxtail | 3 | Excellent | Excellent | NA | 23 | x |

[1]Good =61–80%; Moderate = 41–60%; Excellent = 81–100%

x: No plot reached 50% flower

Pearl millet (fig. 4) had no difference between cultivars for end-of-season height and biomass for each year; with one exception. In Y2 Tifleaf 3 pearl millet had greater height (38 in) than Leafy 22 (33 in). While some individual plants in some plots did flower, no plot for either variety reached 50% flower for any year. Within cultivar differences by year was minimal. Both cultivars had greater cover at 30 DAP in Y1 (94% for both) than Y2 (Leafy 22 at 41%; Tifleaf 3 at 45%), and Leafy 22 had greater height in Y1 than Y2 and Y3. Crude protein was similar, but Tifleaf 3 had a slightly higher average over the three years than Leafy 22 (11.6% vs. 10.8%).

Figure 4: Left, pearl millet at 90 Days after planting. Center, 'White Wonder' Foxtail at 50% flower. Right, 'German' Foxtail at 50% flower. Photos all taken during year 1 in the warm season cover crop trial evaluations at the Great Basin Plant Materials Center, 2021–2023.

Foxtail millet (fig. 4) had no differences between varieties for end-of-season height and biomass for each year. Within variety differences by year were more pronounced. White wonder had greater cover in Y1 (93%) than Y2 (33%), greater height in Y1 (42 in) than Y2 (23 in) and Y3 (23 in), and greater biomass in Y1 (9,466 lb/a) than Y2 (2,543 lb/a) and Y3 (2,721 lb/a). German also had greater cover in Y1 (89%) than Y2 (52%), greater height in Y1 (38 in) than Y2 (24 in) and Y3 (23 in), and biomass was greater in Y1 (7,450 lb/a) than Y2 (3,283 lb/a) and Y3 (2,891 lb/a). There were no between variety or within variety differences for DAP to 50% flower for

any year. However, White Wonder did trend towards slightly earlier maturity, with 6 out of 12 plots reaching 50% flower; the earliest plot doing so at 59 DAP in Y1. In Contrast, German had 2 out of 12 plots reach 50% flower; the earliest plot at 81 DAP in Y1.

Proso millet (fig. 5) had both within and between variety differences all three years. For between variety differences: Dove was taller than Horizon for all three years (Y1: 55 in vs. 32 in; Y2: 43 in vs. 17 in; Y3: 38 in vs. 19 in), but only produced more biomass in Y1 (9,957 lb/a vs. 4,853 lb/a) and Y2 (5,380 lb/a vs. 2,659 lb/a). For within variety differences: Dove height was similar for the three years, but produced more biomass in Y1 than Y3 (9,957 lb/a vs. 3,872 lb/a) while Horizon was taller and produced more biomass in Y1 than Y2 and Y3 (Height: 32 in vs. 17 in and 19 in; Biomass: 4,853 lb/a vs. 2,649 lb/a and 2,427 lb/a). Both varieties consistently reached 50% flower for the three years. Horizon matured the fastest, reaching 50% flower at 38 DAP in Y1, 48 DAP in Y2 and 50 DAP in Y3. Dove averaged 50% flower at 67 DAP in Y1, 73 DAP in Y2, and 67 DAP in Y3.

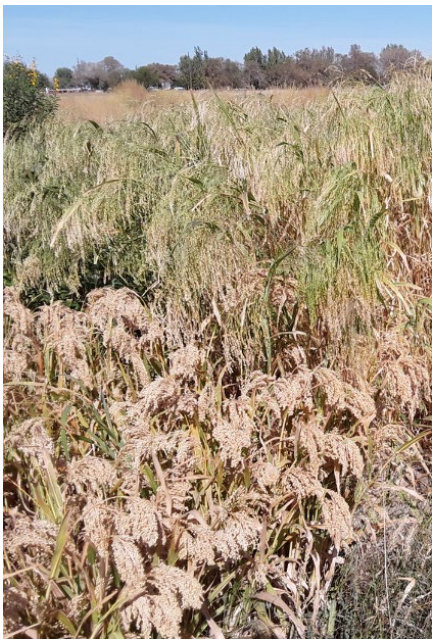

Figure 5: Two adjacent proso plots at 90 days after planting in the warm season cover crop trial evaluations at the Great Basin Plant Materials Center, 2021-2023. Foreground is 'Horizon' Prozo and background is 'Dove' Proso.

Japanese millet (fig. 6) performance was inconsistent for the three years. In Y1 production was high, heights averaged 35 in and biomass ranged from 4,853 lb/a to 8,458 lb/a. In contrast, Y2 and Y3 were weed infested and had partial stand failures; heights were 18 in and 21 in respectively, and

Figure 6: Left, Japanese millet. Right, browntop millet. Both photos taken at 50% flower in year 1 in the warm season cover crop trial evaluations at the Great Basin Plant Materials Center, 2021-2023.

biomass ranged from 428 lb/a to 3,033 lb/a. All plots had some individual plants flower prior to termination, but only one plot in Y1 reached 50% flower. Y1 also had a lodging problem that was not apparent in Y2 or Y3.

Browntop millet (fig 6) performance was variable for the three years. Heights in Y1 were greater than Y2 and Y3 (39 in vs. 25 in and 26 in), biomass was greater in Y1 than Y2 and Y3 (9,279 lb/a vs. 4,211 lb/a and 3,569 lb/a), and Y1 cover was greater than Y2 (92% vs. 29%). All three years reached 50% flower prior to the end of the study, with Y1 and Y3 both reaching it at 59 DAP, and Y2 being 14 days slower at 73 DAP.

Table 9: Millet nutrient analysis results in the warm season cover crop trial evaluations at the Great Basin Plant Materials Center, 2021–2023.

| Variety | Year | %Crude Protein | %P | %K | %N | % Nitrate | Biomass (lb/a) | N (lb/a) |
|---|---|---|---|---|---|---|---|---|
| VNS Japanese | 1 | 11.1 | 0.25 | 2.31 | 1.8 | 1.15 | 6,450 | 104.5 |
| VNS Japanese | 2 | 8.8 | 0.23 | 2.74 | 1.4 | <0.13 | 1,436 | 18.1 |
| VNS Japanese | 3 | 9.1 | 0.20 | 2.30 | 1.5 | <0.13 | 1,713 | 23.1 |
| Horizon Proso | 1 | 17.7 | 0.32 | 3.23 | 2.8 | 1.70 | 4,853 | 122.3 |
| Horizon Proso | 2 | 9.8 | 0.29 | 2.26 | 1.6 | <0.13 | 2,659 | 38.3 |
| Horizon Proso | 3 | 11.0 | 0.30 | 2.43 | 1.5 | <0.13 | 2,427 | 39.3 |
| Dove Proso | 1 | 10.9 | 0.21 | 2.31 | 1.7 | 0.96 | 9,957 | 152.3 |
| Dove Proso | 2 | 10.1 | 0.25 | 2.27 | 1.6 | <0.13 | 5,380 | 77.5 |
| Dove Proso | 3 | 10.3 | 0.22 | 2.38 | 1.7 | <0.13 | 3,872 | 59.2 |
| VNS Browntop | 1 | 9.6 | 0.22 | 2.56 | 1.8 | 0.84 | 9,279 | 125.3 |
| VNS Browntop | 2 | 9.7 | 0.25 | 2.25 | 1.6 | <0.13 | 4,211 | 60.6 |
| VNS Browntop | 3 | 6.8 | 0.20 | 2.30 | 1.1 | <0.13 | 3,569 | 35.3 |
| Leafy 22 Pearl | 1 | 11.1 | 0.26 | 2.78 | 1.8 | 1.40 | 9,332 | 151.2 |
| Leafy 22 Pearl | 2 | 12.5 | 0.30 | 3.04 | 2.0 | <0.13 | 4,059 | 73.1 |
| Leafy 22 Pearl | 3 | 8.8 | 0.30 | 2.50 | 1.4 | <0.13 | 4,461 | 56.2 |
| Tifleaf 3 Pearl | 1 | 16.7 | 0.34 | 3.51 | 2.7 | 1.49 | 8,235 | 200.1 |
| Tifleaf 3 Pearl | 2 | 9.9 | 0.28 | 2.67 | 1.6 | <0.13 | 4,987 | 71.8 |
| Tifleaf 3 Pearl | 3 | 8.2 | 0.25 | 2.49 | 1.4 | <0.13 | 6,459 | 75.6 |
| White Wonder Foxtail | 1 | 9.8 | 0.26 | 2.67 | 1.6 | 1.08 | 9,466 | 136.3 |
| White Wonder Foxtail | 2 | 7.9 | 0.26 | 2.48 | 1.3 | <0.13 | 2,543 | 29.8 |
| White Wonder Foxtail | 3 | 7.9 | 0.26 | 2.44 | 1.3 | <0.13 | 2,721 | 31.8 |
| German Foxtail | 1 | 11.1 | 0.27 | 2.83 | 1.8 | 0.61 | 7,450 | 120.7 |
| German Foxtail | 2 | 11.0 | 0.32 | 3.14 | 1.8 | <0.13 | 3,283 | 53.2 |
| German Foxtail | 3 | 7.0 | 0.25 | 2.64 | 1.1 | <0.13 | 2,891 | 28.6 |

## CONCLUSION

This three-year study demonstrated that there are suitable summer cover crop options for northern Nevada when irrigation is limited. The three cowpea varieties, Chinese Red, Iron and Clay, and Red Ripper, all established quickly and produced decent biomass. Biomass differences between varieties per year were not significant, and only one variety had a difference between years (Iron and Clay: Y1 and Y3 > Y2). Forage nutrient content was similar for all varieties, and carbon-to-nitrogen ratio of the biomass was relatively low. Nitrate content varied by year with

Y1 concentrations potentially toxic, but only trace concentrations in Y2 and Y3. Standard precautions for nitrate toxicity may be warranted if using the biomass as livestock forage. In general, the three varieties performed similarly, and all three would likely be useful for a summer cover crop. It may be interesting to evaluate late maturing forage cowpea varieties in future studies.

The Tropic sun sunn hemp establishment was relatively slow, suitable biomass was only produced in Y1 (4,229 lb/a vs 339 lb/a and 687 lb/a for Y2 and Y3 respectively), and percent nitrogen content was highly variable between years. Sunn hemp also appeared to poorly compete against weeds, which may have contributed to the poor performance in Y2 and Y3. Past evaluations of sunn hemp at the GBPMC has had mixed results, but at times demonstrated great potential. A 2009 study recorded full emergence at 6 DAP, 699 lb/a at 30 DAP, and 10,729 lb/a at 90 DAP (Eldredge & Humphrey, 2012). Sunn hemp is described as extremely drought tolerant (Joy & Peterson, 2005), but it may require more frequent irrigation for establishment than was provided in this study.

Millet performance was variable and depended on species and variety. In general, all millets established rapidly and produced ample biomass, making them all useful for erosion control and for increasing organic soil carbon. One exception was Japanese millet, which had a lodging problem in Y1 and low biomass production and some stand failure in Y2 and Y3. There were significant height and biomass differences between species and within varieties per year, which can be viewed in table 8 and 9. These differences are noteworthy as they provide options to producers as they choose the best cover to meet their resource concerns.

DAP to 50% flower is worth stressing, as plant maturity may determine the timing and type of termination strategies considered. Crops that do not flower may be terminated by the first frost in late September or October, while earlier maturing plants may need alternative termination strategies. Horizon proso, dove proso, and browntop millet all reached 50% flower prior to the end of the study and would likely require additional termination strategies to prevent contamination or volunteers in subsequent crops. German foxtail, White Wonder foxtail, and Japanese millet had some plots reach 50% flower and most plots flowered to some extent despite not reaching 50%. These would likely require careful observation near the end of the growing season to determine what termination strategies are warranted. It is also likely that, had irrigation continued throughout the summer, these millets would have reached 50% flower. Both pearl millet varieties were the only millets that did not flower by the end of the study.

Nitrates levels were variable. In Y1 nitrates were high and a potential problem for all species except sunn hemp, while Y2 and Y3 found only trace amounts of nitrate for all species (table 5, 7, and 9). Nitrate concentration can vary as a plant matures, as it experiences stress, and the type of tissue tested (Stem vs. leaf). High nitrate concentrations may require adaptive management strategies such as diversity of diet, slow acclimation of animals to the higher nitrate feed, supplements that reduce the nitrates effect, and/or avoiding forage when plants are stressed.

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