ISSN 1068-3674, Russian Agricultural Sciences, 2011, Vol. 37, No. 2, pp. 130–134. © Allerton Press, Inc., 2011.
Original Russian Text © N.N. Dubenok, A.P. Nesvat, A.A. Mushinskii, 2011, published in Doklady Rossiiskoi Akademii Sel'skokhozyaistvennykh Nauk, 2011, No. 2, pp. 24–27.

FODDER PRODUCTION

# Efficiency of Growing Annual Sweetclover and Its Mixtures under Irrigation

**N. N. Dubenok[a], A. P. Nesvat[b], and A. A. Mushinskii[c]**

[a]*Russian State University–Timiryazev Agricultural Academy, Moscow, 127550 Russia*
[b]*Orenburg State Agrarian University, Orenburg, 460000 Russia*
[c]*Orenburg Agricultural Research Institute, Orenburg 460051 Russia*
*e-mail: san2127@yandex.ru*

Received March 3, 2010

**Abstract**—The agrobiological characteristics of the formation of agrocenoses of annual sweetclover in single-species and mixed crops with Sudan grass and millet with different densities and sowing methods under irrigation in the steppe zone of the Southern Urals are examined. The maximum green mass yield and digestible protein content per feed unit are obtained in a single-species sweetclover crop with a sowing rate of 4 million germinable seeds per hectare and 3 million in a mixture with Sudan grass.

*Keywords*: annual sweetclover, mixed crops, digestible protein, feeding value

**DOI:** 10.3103/S1068367411020078

In the steppe zone of the Southern Urals, most feeds don't contain a sufficient amount of digestible protein. In winter rations, which are based on corn and sunflower silage, barley concentrates, straw, and wheatgrass hay, there is not more than 70–80 g of digestible protein per feed unit instead of the 105–110 g according to the physiological standards of animal requirements [1]. It's not expedient to increase the area of growing leguminous grasses by reducing the sowing of cereal, silage, and other crops. However, there are ways to increase the production of feeds. One of them is the more efficient use of irrigated lands with an increase on them of the proportion of leguminous crops and their mixtures.

The purpose of our investigations was to study individual methods and technologies of growing annual sweetclover and its mixtures with Sudan grass and millet for producing the maximum amount of feed balanced with respect to the main nutrient elements.

## METHOD

The experiments were conducted over the course of 4 years at AO Samorodovo (Orenburg), subsequently renamed ZAO Promyshlennaya. The soil of the experiment plot and adjacent land was southern, terrace, average humus, average deep, deeply solonetzic, sandy clay and clay loam chernozem on ancient Quaternary pale yellow brown calcareous alluvium. The humus content in the plow horizon was 4.8%, thickness 0.47–0.56 m, and characterized by average availability of mobile forms of nitrogen (6.95 mg/100 g soil), low of phosphorus (2.63–3.96 mg/100 g soil), and high of exchangeable potassium (30–40 mg/100 g soil).

The hydrophysical properties of soil in the 0–1.00 m layer were represented by the following indices: field capacity 23.8%, maximum hygroscopicity 8.3%, and permanent wilting point 12.5% dry soil weight. The density of the meter layer was 1.29 t/m$^3$.

In a three-factor experiment we studied single-species and mixed crops of annual sweetclover with Sudan grass and millet (factor A) with an interrow width in four variants of 0.15, 0.30, 0.45, and 0.60 m (factor B) and sowing rates of annual sweetclover of 4, 3, and 2 million germinable seeds per hectare (factor C). The sowing rate of the component of the mixture in all variants of the experiment was constant (3 million germinable seeds per hectare for Sudan grass and 2.5 million for millet). The variant with single-species sowing of Sudan grass served as the control.

The preirrigation soil moisture threshold in all experimental variants was maintained not lower than 75% FC in the 0.3 m layer up to the start of branching stage of annual sweetclover with a subsequent increase of the active layer to 0.7 m.

The experiments were established according to the split plot method in threefold replication according to B.A. Dospekhov [2] and the Vil'yams All-Russian Fodder Research Institute [3]. Phenological observations and recording the density of the plant stand and main indices of photosynthetic activity of the plants were carried out according to the appropriate methods. The soil hydrophysical properties were determined according to the methods of A.A. Rode [4] and

N.A. Kachinskii [5]; the irrigation dose and total water requirement were calculated by A.N Kostyakov's formulas [6]. The yield was recorded weekly.

Economic and energy efficiency was determined by the method developed at the Samara State Agricultural Academy [7].

## RESULTS AND DISCUSSION

Not only the soil water and nutrient regimes but also the air temperature regime during the growth period have a significant effect on the dynamics of growth and development of annual sweetclover under irrigation conditions. Observations showed that, depending on temperature conditions developing in the spring and summer, the seedling–branching interstage period of sweetclover lasts from 36 to 40 days. In this case, an increase of heat availability in the growth period shortened the length of the interstage periods. Depending on the weather conditions in different years, 63–73 days with a sum of active temperatures of 1050–1100°C was required for the formation of the first harvest and 69–75 days with a sum of temperatures of 1350–1400°C for the second. Consequently, a sum of temperatures of 2400–2500°C is necessary for the formation of two harvests of annual sweetclover.

By the time of the first harvest in mixed crops at the start of the flowering stage of annual sweetclover, Sudan grass was in the full flowering stage and millet in the start of flowering stage. At the time of the second harvest, both Sudan grass and millet were in the start of flowering stage.

The interrow width affected the dynamics of annual sweetclover growth. Its most intensive growth in single-species crops was observed with its increase from 0.15 to 0.60 m. In a single-species crop, the maximum plant height (0.96 m) was obtained with a sowing rate of 3 million germinable seeds/ha and in the mixture with a rate of 4 million (0.97 m) and 0.60-m interrow width.

The daily increment of green mass of the studied plants in mixed crops went slowly up to the branching stage of annual sweetclover. It reached maximum values in the branching–budding interstage period. The proportion of daily increment of green mass of sweetclover in a mixture with Sudan grass and millet on average during the years of investigation in the variant with a sweetclover sowing rate of 4 million germinable seeds/ha and 0.15-m interrow width from seedlings to branching was respectively 50 and 46%, from branching to budding 55 and 56%, and from budding to the start of flowering 36 and 62%. The slow growth of plants at the start of vegetation is due to the biological characteristics of annual sweetclover, Sudan grass, and millet. In the variant with a sweetclover sowing rate of 4 million seeds/ha, its suppression in mixed crops was not observed; however, with a reduction of the sowing rate to 2 million/ha, its daily increment and green mass accumulation in the mixture slowed considerably.

Maximum rates of green mass accumulation in the single-species and two-component mixtures of annual sweetclover with Sudan grass and millet were noted in the variant with a 0.15-m interrow width and sowing rate of 4 million germinable sweetclover seeds. By the harvest ripeness stage, their yield reached respectively 22.5, 27.0, and 24.9 t/ha. The proportion of annual sweetclover in the green mass in the mixture with millet on average for the 4-year investigation in the sweetclover branching stage was 49%, in the budding stage 53%, and in the start of flowering stage 55%, and in the mixture with Sudan grass, respectively 51, 46, and 51%. The maximum sweetclover leaf surface area in the single-species crop reached 38160–38230 $m^2$/ha and formed on the row crop with a sowing rate of 4 million germinable seeds. In the mixed crops it was slightly higher owing to the layer arrangement of the leaves and was 45580–45690 $m^2$/ha (Table 1). The photosynthetic potential reached maximum values by the start of flowering stage of sweetclover in variants with the greatest increase of leaf surface area. In mixed crops it was 5–18% greater than in the single-species crop and varied from 0.71 million $m^2$/day/ha (sweetclover + millet) to 1.26 million $m^2$/day/ha in the variant of sowing sweetclover in a mixture with Sudan grass (Table 2).

According to A.A. Nichiporovich's data [8], the net photosynthetic productivity indices decreased with increasing area of leaves owing to their increasing mutual shading in crops. In our experiment, this regularity was noted in variants of the single-species annual sweetclover crop. In crops of mixtures, their mutual shading weakened owing to the difference of gramineous and leguminous plant leaves in size, configuration, arrangement on stems, and orientation in space. Net photosynthetic productivity reached a maximum value of 5.83 g/$m^2$/day in crops of a mixture of sweetclover with Sudan grass with its sowing rate of 4 million seeds and 0.15-m interrow width.

During the investigation, every year all variants of single-species and mixed crops were harvested twice with a yield distribution of 69–77% in the first and 23–31% in the second harvest of the total green mass yield. The maximum yield of green and dry mass on average for the two harvests was obtained in the variant of single-species Sudan grass crop, respectively 39.4 and 9.7 t/ha. The maximum yield of the mixture was noted on row crops of sweetclover with Sudan grass with its sowing rate of 3 million germinable seeds/ha. For the two harvests it was 37.1 t/ha green mass and 9.5 t/ha dry mass (Table 3). The maximum yield for the two harvests—32.1 t/ha green mass and 9.0 t/ha dry mass in single-species annual sweetclover crops—was noted in the variant with a sowing rate of 4 million seeds/ha and 0.15-m interrow width. The mixture of annual sweetclover with millet insignificantly (by 5–

**Table 1.** Dynamics and increase of leaf area of annual sweetclover and its components in the first harvest, thousand $m^2$/ha (4-year average)

| Crop | Interrow width, m | Sweetclover sowing rate, million seeds/ha | | | | | |
|---|---|---|---|---|---|---|---|
| | | 4 | | | 2 | | |
| | | sweetclover development stage | | | | | |
| | | branching | budding | flowering | branching | budding | flowering |
| Sweetclover | 0.15 | 19.11 | 31.94 | 38.16 | 17.37 | 28.40 | 37.04 |
| | 0.30 | 20.20 | 29.93 | 38.23 | 16.48 | 28.87 | 37.21 |
| | 0.45 | 16.80 | 28.90 | 35.74 | 14.61 | 25.97 | 33.66 |
| | 0.60 | 16.06 | 27.73 | 34.73 | 14.33 | 23.02 | 30.26 |
| Sweetclover + Sudan grass | 0.15 | 19.96 | 39.74 | 45.58 | 22.10 | 39.29 | 45.08 |
| | 0.30 | 20.01 | 38.81 | 45.69 | 21.07 | 38.07 | 45.11 |
| | 0.45 | 19.84 | 38.69 | 44.03 | 19.31 | 37.50 | 43.26 |
| | 0.60 | 21.91 | 36.45 | 43.24 | 20.59 | 36.84 | 42.41 |
| Sudan grass | | 25.01 | 48.07 | 58.47 | – | – | – |

**Table 2.** Photosynthetic potential and average net photosynthetic productivity during growth period of annual sweetclover in single-species and mixed crops in first harvest (4-year average)

| Crop | Interrow width | Sweetclover sowing rate, million seeds/ha | | | |
|---|---|---|---|---|---|
| | | 4 | | 2 | |
| | | photosynthetic potential, million $m^2$/day/ha | net photosynthetic productivity, g/$m^2$/day | photosynthetic potential, million $m^2$/day/ha | net photosynthetic productivity, g/$m^2$/day |
| Sweetclover | 0.15 | 1.11 | 5.28 | 0.84 | 4.88 |
| | 0.30 | 0.96 | 5.09 | 0.79 | 4.70 |
| | 0.45 | 0.87 | 4.96 | 0.71 | 4.69 |
| | 0.60 | 0.74 | 4.84 | 0.66 | 4.65 |
| Sweetclover + Sudan grass | 0.15 | 1.26 | 5.83 | 1.02 | 5.08 |
| | 0.30 | 1.17 | 5.54 | 0.95 | 4.99 |
| | 0.45 | 0.95 | 5.20 | 0.80 | 4.80 |
| | 0.60 | 0.80 | 5.08 | 0.75 | 4.65 |
| Sweetclover + millet | 0.15 | 1.17 | 5.31 | 0.89 | 5.12 |
| | 0.30 | 0.99 | 5.22 | 0.73 | 5.02 |
| | 0.45 | 0.76 | 5.01 | 0.63 | 4.72 |
| | 0.60 | 0.71 | 4.87 | 0.59 | 4.63 |

28%) surpassed annual sweetclover in yield with respect to green and dry mass.

According to the data [9], rations balanced in protein and other nutrients increase the productivity of poultry and cattle by 25–30%. The maximum harvest yield of digestible protein in our experiments was noted in the single-species annual sweetclover crop (1.25 t/ha) and the minimum in the single-species Sudan grass crop (0.60 t/ha for two harvests) (Table 4).

The content of digestible protein in the fodder mixtures depended on the presence of the leguminous component in them. It was maximum (0.75 t/ha) in crops of a mixture of sweetclover with millet with a sweetclover sowing rate of 4 million seeds/ha.

The maximum yield of feed units (FU), 5760/ha for two harvests, was obtained in the variant with single-species Sudan grass crop. It was 4.98 t/ha in the single-species annual sweetclover crop. The maximum content of digestible protein, 253.2 g/FU, was noted in the first harvest in the single-species annual sweetclover crop with a sowing rate of 4 million germinable seeds/ha and row sowing method, which was 2.4 times

**Table 3.** Productivity of annual sweetclover in single-species and mixed crops for two harvests, t/ha (4-year average)

| Crop | Interrow width, m | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0.60 | | | | 0.15 | | | |
| | green mass | dry mass | feed units | digestible protein | green mass | dry mass | feed units | digestible protein |
| Sweetclover sowing rate 4 million seeds/ha | | | | | | | | |
| Sweetclover | 21.0 | 5.6 | 3.03 | 0.77 | 32.1 | 9.0 | 4.98 | 1.25 |
| Sweetclover + Sudan grass | 28.4 | 7.3 | 3.95 | 0.54 | 36.0 | 9.2 | 5.04 | 0.72 |
| Sweetgrass + millet | 23.4 | 6.3 | 3.55 | 0.51 | 32.3 | 8.8 | 5.00 | 0.75 |
| Sweetclover sowing rate 3 million seeds/ha | | | | | | | | |
| Sweetclover | 19.3 | 5.1 | 2.81 | 0.69 | 31.3 | 8.8 | 4.79 | 1.20 |
| Sweetclover + Sudan grass | 30.2 | 7.7 | 4.22 | 0.51 | 37.1 | 9.5 | 5.18 | 0.68 |
| Sweetgrass + millet | 24.6 | 6.8 | 3.81 | 0.52 | 31.5 | 8.7 | 4.87 | 0.70 |
| Sweetclover sowing rate 2 million seeds/ha | | | | | | | | |
| Sweetclover | 16.9 | 4.5 | 2.43 | 0.62 | 26.4 | 7.4 | 4.04 | 1.04 |
| Sweetclover + Sudan grass | 27.9 | 7.2 | 3.93 | 0.48 | 32.7 | 8.4 | 4.60 | 0.67 |
| Sweetgrass + millet | 21.3 | 5.9 | 3.27 | 0.44 | 31.2 | 8.6 | 4.87 | 0.68 |
| Sudan grass | – | – | – | – | 39.4 | 9.7 | 5.76 | 0.60 |

**Table 4.** Feed and energy value of annual sweetclover in single-species and mixed crops, row sowing method (4-year average)

| Crop | First harvest | | | | Second harvest | | | |
|---|---|---|---|---|---|---|---|---|
| | content per kg DM | | | content of digestible protein per FU, g | content per kg DM | | | content of digestible protein per FU, g |
| | feed units | metabolizable energy, MJ | digestible protein, g | | feed units | metabolizable energy, MJ | digestible protein, g | |
| Sweetclover sowing rate 4 million seeds/ha | | | | | | | | |
| Sweetclover | 0.55 | 7.61 | 139.3 | 253.2 | 0.55 | 7.61 | 136.1 | 247.4 |
| Sweetclover + Sudan grass | 0.55 | 7.12 | 79.4 | 144.3 | 0.55 | 7.12 | 75.9 | 138.0 |
| Sweetclover + millet | 0.57 | 7.41 | 86.0 | 150.9 | 0.57 | 7.41 | 85.8 | 150.5 |
| Sweetclover sowing rate 3 million seeds/ha | | | | | | | | |
| Sweetclover | 0.54 | 7.48 | 135.1 | 250.2 | 0.54 | 7.48 | 136.1 | 252.1 |
| Sweetclover + Sudan grass | 0.54 | 7.01 | 71.8 | 133.0 | 0.54 | 7.01 | 70.3 | 130.2 |
| Sweetclover + millet | 0.56 | 7.26 | 80.8 | 144.3 | 0.56 | 7.26 | 82.8 | 147.9 |
| Sweetclover sowing rate 2 million seeds/ha | | | | | | | | |
| Sweetclover | 0.54 | 7.49 | 138.0 | 249.6 | 0.54 | 7.49 | 133.7 | 247.7 |
| Sweetclover + Sudan grass | 0.54 | 7.01 | 67.6 | 125.2 | 0.54 | 7.01 | 67.8 | 125.6 |
| Sweetclover + millet | 0.57 | 7.35 | 77.1 | 135.3 | 0.57 | 7.35 | 79.8 | 140.1 |
| Sudan grass | 0.59 | 7.02 | 62.0 | 105.1 | 0.59 | 7.02 | 60.2 | 102.1 |

higher than in the single-species Sudan grass crop. Mixture of annual sweetclover with Sudan grass and millet surpassed single-species Sudan grass crop in digestible protein content per feed unit by 26–29%, but was inferior to the maximum index in the single-species annual sweetclover crop by 13–42%.

The maximum digestible protein content and metabolizable energy yield per kilogram dry matter in the first harvest was respectively 139.3 g and 7.61 MJ. The maximum content per kilogram dry matter of feed units, 0.59, was observed in the single-species Sudan grass crop.

Soil moisture, depending on the depth of moistening and meteorological characteristics of the year, was maintained by irrigation at a dose of 200 $m^3$/ha for a depth of moistening of 0.3 m and 600 $m^3$/ha with its increase to 0.7 m. In acutely dry 1998 and 1999, during the growth period it was necessary to irrigate 9–

8 times with an irrigation requirement of 3380 and 2960 $m^3$/ha. The total water requirement of the annual sweetclover crops in those years was 4870 and 4830 $m^3$/ha. The minimum number of irrigations was four in 1997 with an irrigation requirement of 1660 $m^3$/ha. The main income item of the water balance in that year was precipitation, the proportion of which in total water requirement of sweetclover was 46.2%, and in 1998, 1999, and 2000, the irrigation requirement was respectively 69.4, 61.3, and 43.7%.

Economic and energy estimates showed that the maximum level of profitability, 128.3%, was observed in the variant with a single-species annual sweetclover crop with its sowing rate of 4 million germinable seeds/ha and row sowing method. The maximum energy yield, 68.2 GJ/ha, and net energy income, 39.6 GJ/ha, were obtained in the given variant. Variants with single-species Sudan grass crop as well as mixtures of annual sweetclover with Sudan grass and millet were somewhat inferior in economic and energy indices. This is related mainly to an increase of production costs per hectare, particularly the cost of seed material and large consumption of fuels and lubricants.

Thus, to produce 37 t/ha of green mass enriched with 253 g digestible protein/FU, it is necessary to sow annual sweetclover on irrigated lands at a rate of 4 million germinable seeds/ha and in a mixture with Sudan grass, up to 3 million. It is necessary to maintain a moisture content of the active layer of soil in the crops not below 75% FC in the 0.3 m layer up to the start of the flowering stage of annual sweetclover with a subsequent increase of the active layer to 0.7 m.

## REFERENCES

1. Vavilov, P.P. *Bobovye kul'tury i problema rastitel'nogo belka* (Leguminous Crops and Problem of Plant Protein), Vavilov, P.P. and Posypanov, G.S., Moscow: Rossel'khozizdat, 1983.
2. Dospekhov, B.A., *Metodika polevogo opytov* (Field Experiment Methods), Dospekhov, B.A., Moscow: Agropromizdat, 1985.
3. *Metodika polevykh opytov s kormovymi kul'turami* (Field Experiment Methods with Fodder Crops), Moscow, 1981.
4. Rode, A.A., *Osnovy ucheniya o pochvennoi vlage* (Fundamentals of a Study of Soil Moisture), Rode, A.A., Leningrad: Gidrometeoizdat, 1965.
5. Kachinskii, N.A., *Fizika pochvy* (Soil Physics), Kachinskii, N.A., Moscow: Vyssh. Shk., 1970.
6. Kostyakov, A.N., *Osnovy melioratsii* (Principles of Amelioration), Kostyakov, A.N., Moscow: Sel'khozgiz, 1960.
7. Vasin, V.G., *Agroenergeticheskaya otsenka vozdelyvaniya polevykh kul'tur v Srednem Povol'zhe* (Agroenergy Assessment of Cultivating Field Crops in the Middle Volga Region), Vasin, V.G. and Zorin, A.V., Samara, 1998.
8. Nichiporovich, A.A., *Fotosintez i produktsionnyi protsess* (Photosynthesis and the Production Process), Nichiporovich, A.A., Moscow: Nauka, 1998.
9. Tyutyunnikov, A.I., *Povyshenie kachestva kormovogo belka* (Improvement of Fodder Protein Quality), Tyutyunnikov, A.I. and Fadeev, V.M., Moscow: Rossel'khozizdat, 1984.