Christoph Stephan, Bonn

Energy balance of resource-saving sugar beet cultivation methods

Energy balances represent a valuable basis for decisions on which to base strategies for the optimising of more environment-relevant and location-oriented production methods. The cultivation methods of conventional drilling, minimum cultivation or mulch drilling with secondary soil cultivations, minimum cultivation drilling without secondary soil cultivations and conventional drilling and compost, and their differing energy balances, were compared and discussed. The diesel fuel consumption, which serves as a basis for the current energy balances in sugar beet production systems, was determined in field trials. The energy balances were calculated for a model farm.

Dr. Christoph Stephan is specialist with the Federal Association of German Plant Breeders e.V. (BDP), Kaufmann Str. 71-73, 53115 Bonn; e-mail: *cstephan@bdp-online.de.* From 1993 to 1996 he was a member of the scientific staff at the Chair for Agricultural Engineering (director: Prof. Dr.-Ing. K.-H. Kromer).

Keywords

Energy balance, energy yield, energy input

The finiteness of fossil fuels was made clear by the energy crises of 1973/74 and 1978/79. Fuel shortages and resultant price rises forced farmers, as well as others, to reduce energy consumption. The general public has become so sensitive about the resultant pollutant gases emitted when burning fossil fuels that its members have involved themselves to an increasing extent in pressuring for a reduction in energy consumption and thus protection of earth atmosphere and environment. Environmental pollution through burning fossil fuel is developing into a still greater problem than that represented by the supply limitations of fossil fuels and is once again encouraging considerations regarding energy balances [1, 2, 3, 4, 5, 9, 10, 16].

Material and methods

Conservation cultivations offer a way of reducing energy consumption. For this reason, the production systems conventional drilling (CD), mulch drilling with secondary cultivations (MDSC), mulch drilling without secondary cultivations (MDWSC) and conventional drilling with compost application (CDC) were compared and discussed.

For quantifying the energy streams involved each sugar beet cultivation method must be clearly described and determined with relation to area, time and energy [15]:

Area limits

Used to determine the area limits was a representative model farm of 60 ha with the following rotation:

- 20 ha sugar beet
- 20 ha winter wheat
- 15.2 ha winter barley
- 4.8 ha phacilia.

Beet yield and fuel consumption in the operations within the four cultivation methods were determined through field (loamy silt) trials.

Time limits

Beet yield was measured in the trial years 1993 and 1994. The cultivation system was described through a production cycle which covered the time from „harvest of previous crop" to „beet harvest" with dumping the roots in a pile

Energy limits

The energy limit was represented by the defoliated beet as marketable harvest product based on average yield over the two years of the field trials.

All final energy carriers were converted to primary energy carriers.

All inputs directly or indirectly applied in the observed beet cultivation methods, and their energy requirements, were recorded. Work input from humans and animals was not taken account of. The applied energy which could not be precisely related to beet, such as the preparation and maintenance of farm buildings, was not taken account of.

With cultivation method CDC 6.65 t compost moist matter/ha was applied from an average-sized partly-roofed compost plant managed according to a central concept.

The energy factors taken from current specialist literature are shown in *table 1*.

Results and discussion

Energy yield

Applied as energy yield were the different beet yields from the individual methods. (Yield average from 1993 and 1994; CD: 67.4 t/ha; MDSC: 64.6 t/ha; MDWSC: 59.9

Table 1: Energy factors (in each case with preliminary inputs) of applied direct and indirect energy carriers and gross energy factor sugar beet

Energy carrier	Energy factors
Diesel	47,53 MJ/kg [11]
Lubricants	54,00 MJ/kg [8]
Machinery and equipment	70,00 MJ/kg [7]
Mineral fertiliser	49,10 MJ/kg N
	17,70 MJ/kg P_2O_5
	10,50 MJ/kg K_2O
	2,39 MJ/kg CaO [12]
Seed	250,00 MJ/U [9]
Plant protection spray	236,00 MJ/kg Active substance [13]
Compost	1,87 MJ/kg FM [14]
Harvest product	**Gross energy factor**
Sugar beet	17,30 MJ/kg FM [6]

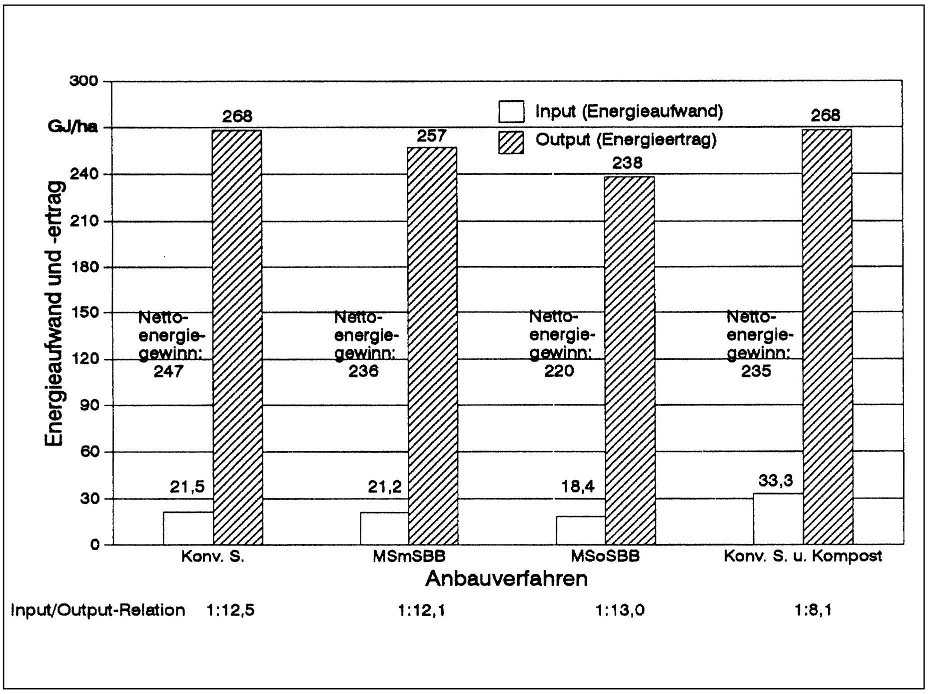

Fig. 1: Energy balance for different sugar beet cultivation methods

t/ha; corrected yield: CDC: 67.4 t/ha.) CD with and without compost achieved the highest output (*fig. 1*) with in each case 268 GJ/ha; the MDSC achieved a lesser yield with 257 GJ/ha, whilst the MDWSC was markedly lower with only 238 GJ/ha.

Net energy surplus

The net energy surplus, i.e. the measurement of the real amount of energy yielded from the area, was highest with CD. The low energy surplus of MDWSC at 220 GJ/ha was because the energy requirement was only 3.1 GJ/ha lower than that of CD and thus the 30 GJ/ha lesser surplus of energy could not be compensated for. The cultivation method MDWSC used less energy compared with CD and, at the same time, less energy was established in the plants. In this comparison, beet output was in direct relationship to energy yield. This result also applied to MDSC.

Input/output relationship

For evaluation of energy productivity in sugar beet production, the results must be seen in an input/output relationship. These lie closely together, i.e. with an MDWSC efficiency of 1:13.0; CD 1:12.5; and MDSC 1:12.1. Lowest input/output relationship of the four cultivation methods was CDC with 1:8.1. Because of the similar yields from methods CD and CDC, the 55% extra energy application required for the CDC method had naturally an extreme effect of the efficiency.

Applied energy

Figure 2 shows the applied energy in relationship to beet cultivation methods using the unit MJ/ha. The MDWSC required the least energy with 18402 MJ/ha. MDSC and CD were both clearly over the MDWSC value with 21180 and 21498 MJ/ha respectively. The highest applied energy of the four methods with 33268 was the CDC method.

The difference in applied energy between the various methods was caused by the differing energy consumptions through fuel and lubricants and through that in machinery manufacture. It is additionally decisive whether or not compost is applied.

Where compost is applied, then the factor application for the energy carriers phosphor, potassium and calcium alters only marginally. The factor application for energy carrier nitrogen remains constant.

With an energy application of 12451 MJ/ha, the compost had the highest share of all directly or indirectly applied energy carriers. The energy applied appears at first sight as very high, however one must take into account the fact that the material was applied at 6.65 t/ha. The second important parameter was the energy factor of the compost because, in comparison with a decentred concept with many small unroofed plants in an area (650 t composted raw material per plant and year) and the chosen averaged size of partly-roofed composting plant (9000 t compost raw material/y) with a central concept, it was indicated that the energy factor for a tonne of compost from the decentred concept was able to be reduced by 63%.

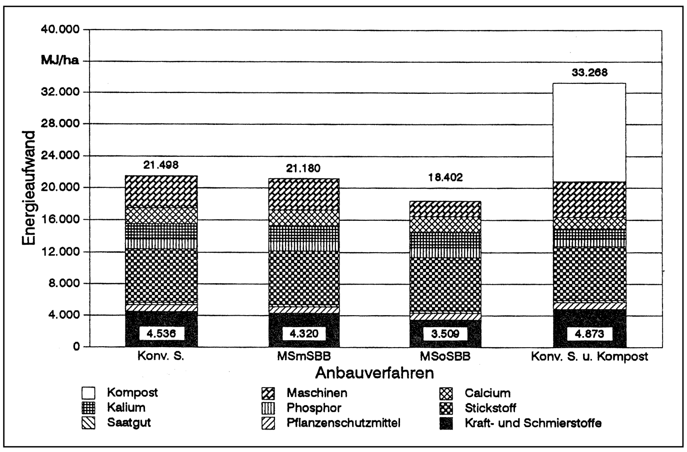

Fig. 2: Composition of the energy requirements for different sugar beet cultivation methods.

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