Pennycress: what's the catch?

In the running as a new biofuels feedstock is field pennycress. The crop is ideal for growing and harvesting in rotation with soyabean and corn and has a high oil yield, but it still hasn't taken off. Rose Hales reports

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As researchers move to find a renewable energy source that may eventually break our ill-fated marriage with fossil fuels, focus has shifted onto pennycress. In March this year the United States Environmental Protection Agency (EPA) completed an analysis of the greenhouse gas (GHG) emissions attributed to the production and transportation of pennycress oil for biofuel production and invited comments on its report.

Thlaspi arvense

Field pennycress, also known as stinkweed or frenchweed, couldn't be called new by any stretch of the imagination and is, in fact, an enthusiastic weed which has been incensing farmers and land owners for centuries. Part of the *brassicaceae* family, related to mustard and canola, the reason for its oversight is, ironically, the same thing that lies behind its possible success – pennycress is not edible, and cannot be used for food production, but grows quickly and easily in reasonably hostile conditions.

A clutch of positive attributes

So why is pennycress being considered for biofuels? Pennycress, like most weeds, is quite an unfussy plant and is happy growing just about anywhere. It doesn't require much work, indeed, the weed-like traits of this plant mean that once the seeds have been sown, no maintenance is required at all until harvest. Its flat, heart-shaped pods contain tiny black seeds with 36% oil – this is double the oil contained in soyabeans and very similar to rape/canola – and is considered to be a high yield. The seeds also contain 32% protein meal, which is a viable animal feed.

In the form of oil, pennycress has attributes which make it a strong contender in the biodiesel market. A United States Department of Agriculture (USDA) study published in 2010 expounded the outcome of research into pennycress' properties. As part of its study, the USDA's Agricultural Research Service (ARS) produced a small amount of biodiesel from pennycress oil and evaluated it. Commenting on the research, it was said: "All diesel-based oils start to gel when it's cold enough. So the cloud point, which is the temperature at which crystals become visible in the fuel, is a crucial factor in both biodiesel and petrodiesel production. Another important property is the pour point, the temperature at which the fuel fails to pour as a result of excessive solidification. The average cloud and pour points for field pennycress biodiesel were 14°F (–10°C) and –0.4°F (–18°C), respectively. These temperatures were well below the cloud and pour points of soyabean oil-based biodiesel." These findings indicate that pennycress-based biodiesel could be utilised in cold climates.

In addition the researchers observed that: "… field pennycress methyl ester characteristics, such as acid value, oxidative stability, cetane number, cold flow properties, viscosity, sulphur content, and phosphorous content, are all satisfactory under ASTM D6751 (Standard Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels)."

Significantly, pennycress is not a food crop. Therefore using it to produce biofuel does not

compete with food use, quashing the food versus fuel debate that has clouded so many potential oilseeds in the past.

The debate is fixed upon the risks of diverting farmland suitable for producing food to biofuel production. However, the EPA's research determined that pennycress "is not expected to have significant indirect land use changes (ILUC)." It is a winter annual that is sown in the early autumn and harvested in late spring, meaning it is not in competition with the rotations of soyabean or corn, and can be grown while the fields would otherwise be empty, as exemplified in Table 1 (*below*). Even better, growing pennycress actually benefits the food crops it is grown in rotation with; it acts as a cover crop, holding nutrients in the soil and preventing erosion.

To produce oil from the seeds, only the traditional and highly available production, logistics and processing equipment is required. Seeds need to be crushed using a cold press – high pressure from an expeller squeezes the oil from the seeds leaving behind a press cake. This process is less complex than soyabean oil extraction or ethanol production. USDA research found that the oil can be converted to fatty acid methyl esters (FAME) using a sodium methoxide catalyst in methanol.

What's the catch?

Even as a consideration for biofuel, the plant is not new. Reports have been appearing for years, quietly evangelising the positive attributes of so-called 'stinkweed'. So what's holding it back? The simplest reason why pennycress is still on the sidelines of the biodiesel industry is cost. Growing the crop is not yet economically viable and thus persuading farmers to cultivate it is difficult. Pennycress is caught in a 'catch 22' – it will only become cost effective once it is grown in large quantities but no one is willing to commit to growing it until it is clear that it can make money.

An answer to this problem is, however, already on its way from a young US biotech firm called Arvegenix. Arvegenix may only be two years old, but it's got experience on its side. Jerry Steiner, the company's founder, is a former Monsanto executive, and many other members of the modest team also bring decades of knowledge to the table. In its 1,000 row nursery near Labadie, Missouri, Arvegenix is studying and investigating pennycress with a view to future cultivation.

An article published in February this year in the *Seattle Times* reports on the company's research. Arvegenix is attempting to domesticate a wild strain of pennycress (just as soyabean was

PHOTO: ARVEGENIX

FIELD PENNYCRESS SEEDS CONTAIN 36% OIL, A HIGH YIELD SIMILAR TO RAPESEED

domesticated in the 1920s). The company is aware of the qualities of pennycress, but it also has a strong understanding of what needs to be done to make a future with pennycress-based biodiesel a reality; it is focusing on "using advanced breeding technology to nudge the plant toward something better than it is today. A plant needs to be more predictable, more consistent and one that produces a higher oil yield." Achieve these simple goals and the crop will have "no trouble attracting the attention of farmers", Dennis Plummer tells the *Seattle Times*. Arvegenix is hoping to achieve domestication of the crop by the end of this decade.

According to a report in the *St. Louis Business Journal* in May this year, Arvegenix have succeeded in raising US$2.5M from a group of investors including Monsanto, Cultivation Capital and BioGenerator to be used to expand the R&D programme, as well as fund regulatory studies and grow operations.

Once a weed, always a weed

The final hurdle facing the large-scale production of pennycress is that it is currently listed on the restricted weed list in nine prospective growing-states of the northern Unites States, including Michigan (where it is also on the invasive species list) and Iowa. The EPA's report on the crop notes that this indicates "limitations on the use of the plant in those [states] and a high probability of impacting production systems such as agriculture, nurseries and forest plantations".

Many farmers may need convincing that pennycress isn't going to become invasive. *Biodiesel Magazine* interviewed Terry Isbell, lead researcher in the new crops and processing technology group at the National Center for Agricultural Utilization Research in Peoria, Illinois, who explained: "Farmers will be concerned that the plant will take over their fields". Corn and soyabean's ordinary herbicide programmes should control the spread of pennycress. However if rotated with other winter annuals, he admits a problem could be created.

Greenhouse gas emissions

Pennycress is clearly becoming an oilseed to watch, and in just a few short years it could be at a stage where planting the winter annual is the more popular choice.

In preparation, Arvens Technology – pennycress developers seeking to produce biofuel and aviation jet fuel from the crop – filed a petition with the EPA, leading it to undertake the previously mentioned analysis of the crop's GHG emissions. The report thoroughly examines the production and transportation of the oil and notes that: "new agricultural sector modelling is not needed to evaluate the lifecycle GHG impacts of using pennycress oil as a biofuel feedstock for purposes of making GHG reduction threshold determinations for the RFS program. This is in part because of the similarities of pennycress oil to soyabean oil and camelina oil, and because pennycress is not expected to have significant land use change impacts. Instead of performing new agricultural sector modelling, EPA relied upon the soyabean oil analysis conducted for the March 2010 rule to assess the relative GHG impacts of growing and transporting pennycress oil for use as a biofuel feedstock."

Additionally the report looks into the future of pennycress cultivation and what could be achieved. As the crop can be rotated with soyabeans the USDA determines "pennycress could be cultivated on 31M acres in Illinois, Iowa, Ohio, and Indiana" – current soyabean growing spaces. "However, industry is also considering cultivating pennycress in other Midwest corn-belt states, and according to their estimates, 40M acres could be cultivated", the report adds.

The report is now closed for comments, which the EPA will review, combining them with its own evaluations of GHG emissions associated with the agricultural use of pennycress oil feedstock and emissions attributed to producers' production processes to "determine whether the proposed pathways satisfy CAA lifecycle GHG emissions reduction requirements for RFS-qualifying renewable fuels." The report concludes that it anticipates biofuel produced from pennycress "could qualify as biomass-based diesel or advanced biofuel (when using typical fuel production processes)." ●

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TABLE 1: EXAMPLE OF SOYABEAN, CORN AND PENNYCRESS ROTATION

	Jan	Feb	March	April	May	June	July	August	September	October	Nov	Dec
Year 1				Corn Planting					Corn harvest / pennycress planting			
Year 2					Pennycress harvest	Soyabean planting				Soyabean harvest		

Indicates fallow months *Indicates growing months*

Compiled by the Environmental Protection Agency