ENERGY USE AND EFFICIENCY IN PERENNIAL RYEGRASS SEED PRODUCTION

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Plants capture solar energy and convert it to chemical energy through photosynthesis. This chemical energy is harvested in the form of seed as well as straw co-products from grass seed fields. To increase the efficiency of solar energy capture and partitioning to harvested products, grass seed growers use various management practices to optimize the size of the biological solar energy collector – the plants, tillers and leaves grown in the field. Examples of these farm management practices include nitrogen fertilizers, plant growth regulators, irrigation and others.

Since high energy costs have been associated with farm management inputs, an examination of energy use and efficiency in perennial ryegrass seed production enterprises under Willamette Valley conditions is needed. In order to answer these questions, field trials were established at Hyslop Farm in 2009, and will continue for the next 2 years.

The field trials were designed to manipulate energy capture and partitioning within the crop in Evening Shade perennial ryegrass through the following management treatments:

1. Spring applied nitrogen (160 lbs/acre)

2. Fall or spring irrigation

3. Trinexapac-ethyl (Palisade) plant growth regulator (PGR)

4. Control (no spring N, no irrigation, no PGR)

Fall irrigation treatments were made in September 2009, but the spring irrigation treatment was not applied in May 2010 as planned because of historic high rainfall in spring 2010. Spring nitrogen was applied in March 2010 by use of an orbit air spreader system and the plant growth regulator treatment [Palisade® (trinexapac-ethyl)] was applied in May 2010 to control lodging. Seed yield components from the various treatments were collected in June 2010, and seed was harvested in July 2010. Since fall irrigation had no effect on seed yield in 2010 and no irrigation was applied in spring, the irrigation factor was not considered in the calculation of the energy budget for this year. Seed yield resulting from the treatments employed in this study was used in calculating an energy budget for perennial ryegrass seed production.

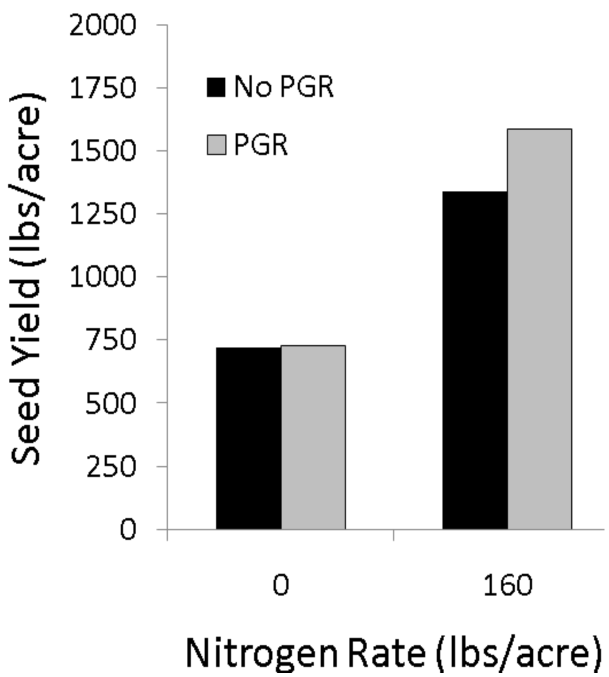
Spring N or the combination of spring N and PGR resulted in large increases in total above-ground dry weight (measured prior to harvest) over the control (Table 1). A similar pattern was observed for the number of fertile tillers; only treatments providing spring N increased the number of fertile tillers over the treatments without spring N. But a different result was observed for seed yield; seed yield was increased by treatments supplying spring N over those without spring N, but unlike fertile tillers, seed yield was further increased by the PGR.

Table 1. Harvest characteristics for a perennial ryegrass seed crop in 2010.

Treatment	Total above-ground dry weight	Fertile tillers	Seed yield
	(lbs/acre)	(no/ft^2)	(lbs/acre)
Spring N + PGR	14,339 b	283 b	1,585 c
Spring N	14,954 b	292 b	1,339 b
PGR	5,731 a	177 a	727 a
Control	5,849 a	181 a	719 a

The relationship of spring N and PGR to seed yield can be better illustrated with the aid of a graph (Figure 1). Application of Palisade PGR with no spring N did not increase seed yield over the no-PGR, no N control. However, applying spring N with no PGR increased seed yield by 620 lbs/acre over the control. But the treatment combination of spring N and PGR increased yield by 865 lbs/acre. The seed yield enhancing benefit of the PGR was not realized without spring N in the system. Nitrogen is required by the plant to build the biological solar energy collector and increases seed yield because the collector size was greater than with no N. Fertile tiller numbers were likewise increased by spring N, but the further increases in seed yield observed with the combination of spring N and PGR were due to the more efficient partitioning of carbon and energy to harvested seed as a result of the PGR.

Figure 1. Effect of spring nitrogen and plant growth regulator (PGR) on seed yield of perennial ryegrass in 2010.



The energy consumption by each of management practice employed in perennial ryegrass seed production in 2010 is outlined in Table 2. Approximately two thirds of all energy used in perennial ryegrass seed production can be attributed to the manufacture, transportation, and application of fertilizers. Since the crop is a perennial plant, the energy used in producing the 2010 seed crop was charged a prorated share of energy costs for stand establishment as based on a 3-year life expectancy for the stand. Lime and lime application costs were also charged to the energy budget on a prorated basis. Fuel and electricity were considered to be a part of the overall energy cost of a farm operation by this analysis, and are not separated from other energy costs. For the purposes of this article, the energy budget is presented in abbreviated summary form without the individual detail for the energy cost associated with each pesticide, fertilizer, tillage operation, planting stock seed, etc. That detail will be published in a future report. All energy values are expressed in mega joules (MJ) on a per acre basis.

Table 2. Energy consumption budget for production of a perennial ryegrass seed crop with both spring N and PGR in 2010.

Management Input	Energy Consumption	% of Total Energy Use
	(MJ/acre)	(%)
Stand Establishment	833	9.9
Fertilizer	5,724	68.1
Lime	490	5.8
Pesticides	782	9.3
PGR	64	0.8
Harvest	243	2.9
Post-harvest	262	3.1
Labor	7	0.1
Total Energy Use	8,404	100.0

Energy efficiency is commonly calculated as the ratio of energy output, in this case energy harvested as seed, to the energy consumed in producing the crop (Table 3). Spring N alone accounts for 52% of the total energy use in perennial ryegrass seed production when applied at the 160 lbs/acre rate used in this study, making spring N the most costly single practice in terms of energy consumption. This energy applied as spring N is consumed by the crop in building the biological solar energy collector in the field – tillers and leaves. With the relatively small addition of 64 MJ/acre of energy in the form of the PGR and its application, more than 2,000 MJ of solar energy was redirected for capture in the seed. This is a very economical seed yield increase from an energy perspective since the resulting gain in seed yield was 3.8 lbs of seed for each additional MJ of energy supplied in the PGR. Conversely, the seed yield increase from spring N without the PGR was only 0.14 lbs of seed for each additional MJ of energy supplied to the crop as 160 lbs N/acre. But the benefits of applying spring N as a management input in perennial ryegrass seed production are undeniable.

Table 3. Effect of spring N and PGR on energy use and efficiency for seed production by a perennial ryegrass seed crop in 2010.

Treatment	Energy Consumed (EC)	Seed Energy Output (SEO)	Net Energy Gain	Energy Efficiency
	(MJ/acre)	(MJ/acre)	(MJ/acre)	(SEO/EC)
Spring N + PGR	8,404	13,362	2,832	1.59
Spring N	8,344	11,288	818	1.35
PGR	3,999	6,129	4	1.53
Control	3,935	6,061	0	1.54

Perennial ryegrass is an energy efficient crop even if the straw co-product is not considered. From the results of this study, the calculated energy efficiency of seed harvested from perennial ryegrass ranged from 1.35 to 1.59. In other words, the harvest of perennial ryegrass seed produced 35% to 59% more energy than it consumed in production of the crop. The net gain in energy by the crop was of course, the result of captured solar energy embodied in the harvested seed. This return on energy investment in perennial ryegrass seed production is comparable to corn grown in the mid-west at 1.67.

When energy from the straw co-product is included along with seed in the calculation of energy efficiency, the values for perennial ryegrass seed crops climbs to ratios ranging from 6.19 to 7.17 (Table 4). The energy captured by the crop and embodied in the straw can be harvested and removed from the field for the production of biofuels or to be consumed in livestock to create meat or milk. The straw energy can also be returned to the soil as chopped straw and the subsequently released nutrients that can be utilized by the plant in the production of future seed crops.

The energy use and efficiency values will be further refined with additional data to be presented in future reports.

Table 4. Effect of spring N and PGR on energy use and efficiency for seed and straw co-product produced by a perennial ryegrass seed crop in 2010.

Treatment	Energy Consumed (EC)	Seed and Straw Energy Output (StEO)	Net Energy Gain	Energy Efficiency
	(MJ/acre)	(MJ/acre)	(MJ/acre)	(StEO/EC)
Spring N + PGR	8,404	59,961	30,420	7.13
Spring N	8,344	59,888	30,407	7.17
PGR	3,999	24,751	-385	6.19
Control	3,935	25,072	0	6.37