AN 11-YEAR HISTORY OF CROP ROTATION INTO NEW PERENNIAL RYEGRASS AND TALL FESCUE

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Introduction

Grass seed production in western Oregon is maturing from an older emphasis on how quickly it was possible to rotate from one grass seed crop to the next to a newer one in which rotational crops themselves are expected to be profitable and provide long-term benefits for future grass seed crops. Benefits from crop rotations may include disruption of the life cycle of pests such as slugs, weeds, diseases, insects, and rodents, along with improved soil fertility, health, and physical properties.

Researchers, advisors, and growers currently have more questions than answers regarding the long-term benefits of specific crop rotation sequences and associated management practices. One approach for improving this situation is to develop an industry-wide census of current crop rotations and then study the relationships between those practices and factors of interest, such as reliability of attempts to establish new grass seed stands, duration of those stands, and prevalence of particular pests before and after rotations from one grass seed crop to the next. We converted an 11-year-long remote-sensing-based record of western Oregon crops into knowledge of complete crop rotation cycles from old grass seed stands to new ones with varying years of intervening crops. The challenges in developing such data have been presented elsewhere (Mueller-Warrant et al., 2015, 2016a, 2016b).

This report focuses on crop rotation patterns in fields transitioning from previous grass seed crops to new stands of perennial ryegrass or tall fescue. Our primary objectives were to: (1) measure the distribution of years spent growing rotational crops or fallow between successive grass seed stands, and (2) identify the primary rotational sequences used during each period.

Materials and Methods

Through ground-truth, drive-by surveys of several thousand fields per year, we identified crop kind and establishment status and were able to convert satellite imagery and aerial photographs into classifications of 19 annually disturbed crops, 20 established perennial crops, 13 forest types, and 5 urban development levels. Tests for consistency of year-to-year transitions from 2004 to 2014 refined land-use classification during conversion of 11 individual-year data sets into stand duration measurements and crop rotation sequences. The most typical error was omission of fields that should have been recognized as intervening rotational crops grown between older and newer grass seed stands.

Results and Discussion

Length of crop rotation cycles

The length of crop rotations was measured from the final year of a previous grass seed crop to the first harvest of a fully established new stand of perennial ryegrass (not the harvest 9 months after fall planting). The most common length was 3 years, with the second, third, fourth, and fifth most common intervals being 6+, 4, 2, and 5 years (Table 1). Rotational periods of

Table 1. General properties of crop rotations from final year of previous grass seed crop to first fully established year of new perennial ryegrass.

Years from final harvest of previous grass seed crop to established stand of perennial ryegrass	Estimated number of fields	Total area	Years available for intervening crops	Number of most common rotations needed to cover one-half of fields
		(acres)		
2	187	12,543	0	1.16
3	287	20,037	1	2.45
4	228	14,941	2	6.86
5	70	4,760	3	19.0
≥6	284	18,834	4+	21.3
All cases	1,056	71,114	—	—

either 3 years or 6+ years were each approximately four times as common as those of 5 years. Fields with only 2 years from established old stands to established new stands represented replanting of the same variety. New perennial ryegrass stands were fall planted an average of 8.6 times as often as they were spring planted. The total area that underwent full crop rotation from one grass seed stand to the next was 71,114 acres, equaling 54% of the average area reported in perennial ryegrass seed production over the period from 2004 to 2014 (Anderson and Young, 2014). There were large changes in area devoted to perennial ryegrass seed production over this period, with the 91,531-acre minimum in 2010 being only 47% of the 192,867-acre maximum in 2005.

The most common length of time for crop rotations into fully established new stands of tall fescue was 6+ years, with the second, third, fourth, and fifth most common intervals being 4, 3, 2, and 5 years (Table 2). Rotational periods of 3, 4, or 6+ years were each approximately 2.2 times as common as those of 5 years. New tall fescue stands were spring planted an average of 1.4 times as often as they were fall planted. Total area identified as undergoing full crop rotation cycles from one grass seed stand to the next was 69,543 acres, equaling 49% of the average area reported in tall fescue seed production. There were large changes in area devoted to tall fescue over these years, with the 106,474-acre minimum in 2011 being only 61% of the 174,506-acre maximum in 2008.

Crop rotation distribution patterns

One way to simultaneously examine crop rotation length, numbers of unique crop rotations present in each length rotation, and varying area associated with each rotation was to calculate how many different types of the most common rotations would be needed to cover one-half of the field area present in each of those rotation periods (Table 1). For the shortest possible rotation (immediate planting back to perennial ryegrass with no time for intervening non-grass seed crops), it would take only 1.16 unique rotations to cover 50% of the field area present within all of the 2-year rotations (the single most common rotation plus 16% of fields with the second most common rotation). Crop rotations became more complicated as the number of years for growing intervening crops increased. The exponential increase in the number of rotations necessary to cover half of the field area (on average 2.2 times as many for each additional year of rotation length over a regression base of 1.25 rotations) is a way of expressing this factor.

Several aspects of crop rotation distribution patterns for tall fescue stood out as differing from those for perennial ryegrass (Table 2). For the shortest possible rotation (immediate planting back to tall fescue, with no time for intervening non-grass seed crops), it took 1.81 unique rotations to cover 50% of the field area present within all of the 2-year rotations. The number of required rotations increased an average of 1.8 times over a 2.64 base for each additional year.

The number of rotations required to cover half of the field area for the three shortest crop rotation lengths was higher for tall fescue than for perennial ryegrass, underscoring the greater complexity of challenges facing growers of tall fescue, a slower-to-establish crop that often fails to produce harvestable amounts of seed even when fall planted. A partial list of such challenges includes: (1) competition from summer annual weeds (e.g., sharppoint fluvellin), which may weaken seedling stands of spring-planted tall fescue and force growers to reseed, (2) financial constraints imposed by the

Table 2. General properties of crop rotations from final year of previous grass seed crop to first fully established year of new tall fescue.

Years from final harvest of previous grass seed crop to established stand of tall fescue	Estimated number of fields	Total area	Years available for intervening crops	Number of most common rotations needed to cover one-half of fields
		(acres)		
2	177	11,318	0	1.81
3	249	16,949	1	4.89
4	252	16,534	2	15.0
5	116	7,902	3	22.0
≥6	258	16,838	4+	16.5
All cases	1,052	69,543	—	—

additional year without a harvestable seed crop for spring versus fall planting, (3) greater susceptibility to yield loss when "salvage treatments" of glufosinate are applied to tall fescue compared to perennial ryegrass, and (4) constraints on choice of rotational crops following prior stands of tall fescue due to the use of higher rates of soil-residual herbicides in tall fescue than in perennial ryegrass.

Crop rotations with 2-year periods

Four major crop rotation sequences accounted for 93.9% of the area in which only 2 years elapsed from the last crop of the previous stand to the first fully established (non-seeding year) crop of a new perennial ryegrass stand (Table 3). The most common rotation (2004–2012) was final crop of the old perennial ryegrass stand–fall-planted perennial ryegrass–first

Table 3. Rotations lasting 2 to 4 years from any previous grass seed crop to new stands of established perennial ryegrass.

Crop rotation (Read moving forward in time from left to right)[1]	----- Area covered -----	
	(acres)	(%)
2-year-long rotations ending in fully established perennial ryegrass (EST PR)		
EST PR–fall plant PR–EST PR	5,916	47.2
EST FF–fall plant PR–EST PR	3,505	27.9
AR–fall plant PR–EST PR	1,502	12.0
EST PR–spring plant GS or UNK–EST PR	857	6.8
All other 2-year rotations	766	6.1
3-year-long rotations ending in fully established perennial ryegrass (EST PR)		
EST PR–WW–fall plant PR–EST PR	4,844	24.2
EST PR–winter fallow/UNK summer–fall plant PR–EST PR	4,411	22.0
EST PR–beans–fall plant PR–EST PR	1,899	9.5
EST FF–WW–fall plant PR–EST PR	1,067	5.3
EST TF–WW–fall plant PR–EST PR	867	4.3
EST TF–winter fallow/UNK summer–fall plant PR–EST PR	637	3.2
EST PR–winter fallow/UNK summer–spring plant GS–EST PR	516	2.6
EST bentgrass–winter fallow/UNK summer–fall plant PR–EST PR	462	2.3
EST PR–winter/summer fallow–fall plant PR–EST PR	432	2.2
EST PR–winter/summer fallow–spring plant GS–EST PR	422	2.1
All other 3-year rotations	4,481	22.2
4-year-long rotations ending in fully established perennial ryegrass (EST PR)		
EST PR–WW–WW–fall plant PR–EST PR	2,107	14.1
EST PR–winter fallow/UNK summer–winter fallow/UNK summer–fall plant PR–EST PR	1,843	12.3
EST PR–beans–winter fallow/UNK summer–fall plant PR–EST PR	768	5.1
EST PR–winter fallow/UNK summer–WW–fall plant PR–EST PR	978	6.5
EST TF–WW–WW–fall plant PR–EST PR	746	5.0
EST PR–WW–winter fallow/UNK summer–fall plant PR–EST PR	585	3.9
AR–fall plant clover–EST clover–fall plant PR–EST PR	504	3.4
EST PR–winter fallow/UNK summer–beans–fall plant PR–EST PR	494	3.3
EST PR–winter fallow/UNK summer–winter fallow/UNK summer–spring plant GS–EST PR	393	2.6
EST FF–WW–spring plant PR–fall plant PR–EST PR	343	2.3
EST PR–fall plant clover–EST clover–fall plant PR–EST PR	331	2.2
EST FF–WW–WW–fall plant PR–EST PR	309	2.1
All other 4-year rotations	5,543	37.1

[1]AR = annual ryegrass; EST = established; FF = fine fescue; GS = grass seed; PR = perennial ryegrass; UNK = unknown crop; WW = winter wheat

post-establishment crop of the new perennial ryegrass stand. This rotation accounted for 47.2% of the area and corresponded to seed certification rules for planting fields back to the same variety previously grown. The second most common rotation, used on 27.9% of the area, was established fine fescue–fall-plant perennial ryegrass–established stand of perennial ryegrass. Two general traits of fine fescue enhance the feasibility of a rapid transition from established fine fescue to perennial ryegrass: (1) tillage is highly effective in destroying fine fescue plants, and (2) seedling fine fescue generally fails to flower the first spring after fall planting and so would not contaminate the first seed harvest of a new perennial ryegrass planting.

Five major crop rotation sequences accounted for 89.2% of the area in which only 2 years elapsed from the last crop of the previous stand to the first fully established crop of a new tall fescue stand (Table 4). The most common rotation was final crop of the old tall fescue stand–spring-planted grass seed–first post-establishment seed crop of the new tall fescue stand (harvested in 2006 to 2014). This rotation accounted for 29.2% of the area. The second most common rotation, used on 22.5% of the area, was old tall fescue–fall-planted tall fescue–established new tall fescue. This rotation was similar to the first one, differing mainly in the existence of a modest chance of producing harvestable seed the first summer after planting.

Crop rotations with 3-year periods

The next longer rotations were defined by the presence of a single intervening (non-grass seed) crop prior to planting of perennial ryegrass. When 3-year rotations from any kind of grass seed crop to established stands of perennial ryegrass were examined, the 10 most common ways to make these transitions accounted for 77.8% of the area (Table 3). The single most common rotation, covering 24.2% of the area, was established perennial ryegrass–winter wheat/fall-planted perennial ryegrass–established perennial ryegrass. Winter wheat was used as the first crop following termination of grass seed stands on 34.8% of the area. The winter fallow/unknown summer crop class was used as an intervening crop in five rotations covering 31.7% of the area. The winter fallow/unknown summer crop category was a diverse class that included multiple crops. Its primary common feature was the openness of the ground during the preceding winter. This category likely included some irrigated annual crops, other dryland crops, and some perennials whose winter growth was limited. This class possessed a strong tendency to overlap with established clover, fall-planted clover, beans, flowers, field peas, and new planting alfalfa. Only two of the 21 most common rotations used spring planting instead of fall planting for establishment of new perennial ryegrass stands, for a total of 18.9 times as much fall planting as spring planting.

When 3-year rotations from any kind of grass seed crop into new stands of tall fescue were examined, the 12 most common ways to make these transitions accounted for 76.3% of the area (Table 4). Spring planting was used 2.61 times as often as fall planting in establishing the new stands of tall fescue in 3-year-long rotations. The single most common rotation, present on 14.1% of the area, was annual ryegrass–winter fallow/unknown summer crop–spring-planted grass seed–established tall fescue. Winter wheat was used as the intervening crop on a total of 17.5% of the area when transitioning to new tall fescue stands in 3-year-long rotations. This was roughly half of its use in similar-length rotations into perennial ryegrass. Interestingly, only 26% of the area with a winter wheat intervening crop used spring planting of the new tall fescue crop, in contrast to 78% of the area over all of the 3-year-long rotations.

Crop rotations with 4-year or longer periods

The 4-year rotations into perennial ryegrass with 2 years for alternatives to grass seed were more diverse than the 3-year rotations. The 12 most common 4-year rotations accounted for only 62.9% of the area (Table 3). Winter wheat was grown for 2 years in rotations between grass seed crops on 21.1% of the area. It was also grown as just the first or second intervening crop on 9% and 6.5% of the area, respectively. Grower preferences for winter wheat as first, second, or both intervening crops in 4-year rotations may indicate varying needs to improve control of grass weeds through selection of clover, beans, unknown summer crops, or fallow rather than winter wheat. Fall-planted perennial ryegrass was used twice in a row in two rotations on a total of 3.9% of the area, representing the all-too-common experience of failing in first attempts to establish new perennial ryegrass stands.

The 10 most common of the 4-year rotations into tall fescue accounted for only 40.0% of the area (Table 4). Established tall fescue, established perennial ryegrass, and annual ryegrass occurred as starting crops on 28.4%, 14.6%, and 11.7% of the area, respectively. Multiple rotations featured two consecutive attempts to establish tall fescue, implying failure on the first try.

Table 4. Rotations lasting 2 to 4 years from any previous grass seed crop to new stands of established tall fescue.

Crop rotation (Read moving forward in time from left to right)[1]	---- Area covered ----	
	(acres)	(%)
2-year-long rotations ending in fully established tall fescue (EST TF)		
EST TF–spring plant GS–EST TF	3,300	29.2
EST TF–fall plant TF–EST TF	2,547	22.5
AR–fall plant TF–EST TF	2,238	19.8
AR–spring plant GS–EST TF	1,465	12.9
EST PR–spring plant GS–EST TF	543	4.8
All other 2-year rotations	1,230	10.8
3-year-long rotations ending in fully established TF (EST TF)		
AR–winter fallow/UNK summer–spring plant GS–EST TF	2396	14.1
EST TF–winter fallow/UNK summer–spring plant GS–EST TF	1949	11.5
EST TF–WW–fall plant TF–EST TF	1704	10.1
EST PR–winter fallow/UNK summer–spring plant GS–EST TF	1460	8.6
AR–winter/summer fallow–spring plant GS–EST TF	1623	9.6
EST TF–winter fallow/UNK summer–fall plant TF–EST TF	862	5.1
EST TF–WW–spring plant GS–EST TF	773	4.6
EST PR–winter fallow/UNK summer–fall plant TF–EST TF	499	2.9
EST PR–WW–fall plant TF–EST TF	482	2.8
EST TF–winter/summer fallow–spring plant GS–EST TF	474	2.8
EST TF–fall plant TF–spring plant GS–EST TF	351	2.1
EST PR–winter/summer fallow–spring plant GS–EST TF	343	2.0
All other 3-year rotations	4,034	23.7
4-year-long rotations ending in fully established TF (EST TF)		
EST TF–WW–winter fallow/UNK summer–spring plant GS–EST TF	1,440	8.7
AR–winter fallow/UNK summer–winter fallow/UNK summer–spring plant GS–EST TF	946	5.7
EST PR–winter fallow/UNK summer–winter fallow/UNK summer–spring plant GS–EST TF	995	6.0
EST TF–winter fallow/UNK summer–WW–fall plant TF–EST TF	805	4.9
EST PR–WW–winter fallow/UNK summer–spring plant GS–EST TF	487	2.9
AR–WW–winter fallow/UNK summer–spring plant GS–EST TF	467	2.8
EST PR–winter/summer fallow–winter fallow/UNK summer–spring plant GS–EST TF	462	2.8
EST TF–winter/summer fallow–spring plant GS–spring plant GS–EST TF	403	2.4
EST TF–WW–WW–fall plant TF–EST TF	390	2.4
EST TF–winter fallow/UNK summer–winter fallow/UNK summer–spring plant GS–EST TF	373	2.3
All other 4-year rotations	9,769	60.0

[1]AR = annual ryegrass; EST = established; FF = fine fescue; GS = grass seed; PR = perennial ryegrass; UNK = unknown crop; WW = winter wheat

Winter wheat was the single most common intervening crop in 5-year-long rotations leading into new stands of both perennial ryegrass and tall fescue. Included in the longer rotations were numerous cases in which attempts to establish new stands of perennial ryegrass or tall fescue apparently failed in one year and were repeated in the next year. The diversity of cropping sequences present in the longer period rotations likely indicates that growers have yet to decide on the best sequences.

Summary

Growers choose intervening rotational crops non-randomly, presumably anticipating a mixture of benefits ranging from income to reduced populations of troublesome pests.

Fall planting dominated new perennial ryegrass stands regardless of the length of rotation period out of grass seed production. For tall fescue, spring planting was preferred in general over fall planting. However, rotations using winter wheat as the final intervening crop deviated from this pattern, showing a modest preference for fall planting.

Winter wheat was the most common intervening crop in rotations into new stands of perennial ryegrass. In rotations into new stands of tall fescue, unknown summer annuals were the most common intervening crop when either 1 or 4+ years were available for production of intervening crops. Winter wheat was the most common intervening crop when either 2 or 3 years were available.

The full set of crop rotation patterns available for each specific length of time between consecutive grass seed stands rapidly increased in complexity with the number of intervening years. In crop rotations ranging in length from 2 to 5 years, there would be at least 2, 3, 7, and 19 cropping sequences of greatest importance for rotations into new perennial ryegrass, and 2, 5, 15, and 22 sequences going into tall fescue.

References

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