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Are Chilean Pasture Seed End-Users Adopting New Species? Trends and Joinpoint Regression Analysis of the Last 19 Years of Seed Imports

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Abstract: Pastures are important for the agricultural sector as forage, recreational and sports systems. The Chilean pasture seed market is highly dependent on introduced genetics; however, the effect of climate change and market conditions can modify pasture options. The objective of this study was to quantify changes of the pasture seeds sown by Chilean end-users, as metric tons (Mt) or proportion of the total (PT), based on 19 years of imported seed. The Mann–Kendall test and joinpoint regression analysis were used to estimate the overall trends and the average annual percent change (AAPC) for the whole period, respectively. The total imported Mt had an increasing trend and AAPC (+5.7%), wherein a large PT corresponded to ryegrasses (*Lolium* spp.) (0.681), with increasing trends for Mt and PT. Clovers (*Trifolium* spp.) had decreasing trends and AAPC (−2.9% for Mt and −9.6% for PT). For PT, the main species was perennial ryegrass (*L. perenne* L.) (0.357), with increasing trends for Mt. As Mt, a positive AAPC was found for plantain (*P. lanceolata* L.) (+17.4%) and chicory (*C. intybus* L.) (+63.2%). Over a period of 19 years, based on Mt but not PT, Chilean end-users have been adopting new pasture species with a decreasing use of *Trifolium* spp.

Keywords: forage; grass; legumes; herbs; turfgrass; imports

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1. Introduction

Grassland systems are one of the most important ecosystems in terms of providing feed to ruminants for milk and beef production [1]. It is estimated that at the global level, grasslands account for nearly 50% of feed use in livestock systems [2], 80% of the world's cow milk production and 70% of the world´s beef and veal produced in temperate grasslands [3]. In addition to the importance of temperate pastures in bovine diets, some species are highly adapted to close cutting because they have a high recuperative growth capacity after damage and biomass removal, making them suitable for lawns and sports fields [4]. In this usage, the pasture surface is called turfgrass and has many attributes; it can be used as an ideal playing, walking and seating surface and also helps to prevent erosion of the soil by water and wind [5]. Both sectors (animal production and recreational sports) use pasture seeds to reach some of their objectives.

At the global level, the pasture and forage seed market has increased by 50% to 60% in volume since 1990, mainly due to the increased demand of seed for turf [6]. According to [7], the forage and turf world seed production of 19 selected species was 846,573 metric tons (Mt), composed of 30.4% perennial ryegrass (*Lolium perenne* L.), 20.5% Italian and Westerwolths ryegrasses (*Lolium multiflorum* Lam.) and 19.3% tall fescue (*Festuca arundinacea* Schreb.). Indeed, 10 years of data from the European Union (EU-27) indicate that grasses account for 92% of pasture seed production [8].

Ryegrasses (*Lolium* spp.) are recognized as the most important species in temperate climates where grazed pastures are the base for animal production [3,9], because of high yields, digestibility and adaptation to a range of production practices [10]. Within this genus, *L. perenne* is the most important species, with seed production for forage and turf accounting for 47% in the EU-27 [8] and 80% of the seed production area in New Zealand [11]. In terms of forage use, in the Republic of Ireland, *L. perenne* accounts for 95% of grass seed usage [12] and, in Northern Ireland, between 78% and 86% of seed sales in a 25-year survey [13].

Fescues (*Festuca* spp.) are the second-most important pasture grass worldwide, and *F. arundinacea* is one of the most important species in this genus [6]. These species have a broad range of suitability in zones with water scarcity, hot summers and low temperatures during the winter months. Due to these characteristics and the effect of climate change, the use of species in this genus may increase [14].

In contrast, forage legumes have a small place in seed production [7]. The three most important species in temperate regions are *Medicago sativa* L., *Trifolium repens* L. and *Trifolium pratense* L., and as forage legumes, they have a strategic role in safeguarding the agricultural value in less favorable environments [15]. Forage legumes are a pillar for sustainable production systems due to their natural capacity to fix atmospheric N, having the potential to reduce the detrimental effects of livestock on the environment [16,17], but improvement in seed production to meet market requirements is a prerequisite [18].

In Chile, permanent and temporary pastureland areas cover 14.1 million hectares, with only 3.6% corresponding to sown pastures, an increase of 10.9% in the main zones for beef and dairy farming (Los Ríos and Los Lagos Regions), where *L. multiflorum* and *L. perenne* are the most important species in terms of sown hectares [19]. These data are only from one census, and there is a lack of historical data for the pasture seed use. The only study published gives data from two years (1998–1999) of imports and exports of clovers and ryegrasses seed [20]. The study highlights the importance of ryegrass imports, but the analysis was performed in a short time period. For the turfgrass seed market, perennial ryegrass and tall fescue are the main cool season grasses [21].

Taking into consideration the effects of climate change, central and southern Chile has experienced a decrease in precipitations [22], and projections indicate an increase in minimum and maximum temperatures [23]. A change in the use of pasture species to other species with better characteristics to cope with higher temperatures and/or less available water is expected. Increasing the diversity of forage species could enhance grassland productivity in the temperate [24] and Nordic and Mediterranean regions [25]. However, not only is diversity important but also factors such as storage time, temperature and light requirements may be considered an adaptation strategy for the optimal seed germination and seedling emergence [26], and soil temperature measurement, a need in order to predict field emergence [27]. Based on these, the objective of the present study is to quantify trends and changes over time in the pasture seeds sown by Chilean end-users, as metric tons and proportion of the total, based on 19 years of imported seed, and how this may impact some agricultural policies.

2. Materials and Methods

2.1. Data Source, Criteria Selection and Classification

Raw data of imported forage seed between 2001 and 2019 were requested from the Office of Agricultural Studies and Policies (ODEPA), a branch of the Ministry of Agriculture of Chile, with information from the National Customs Services. These raw data sets consist of monthly and yearly information of imports of seed, in metric tons, of different genera, species and blends.

Records (n = 5029) for a 19-year period of forages, turfgrasses, forage legumes, forage herbs, brassicas, cereals and other minor species were collected. These records were analyzed individually to find, delete or correct errors in identity and classification. The selection criteria were based on pastures and related turfgrass species that are used under grazing or turfgrass regimes. The authors use the term *related turfgrass* to include some species of the genera *Lolium* and *Festuca* spp. that are recognized as having a dual purpose: forage and amenity [28,29]. Brassicas, cereals, lupine, vicia, sorghum and specific turf-type species were not the focus of this article. Verified import data were first classified into six groups: *Lolium* spp., *Festuca* spp., *Trifolium* spp., *Medicago* spp., other pastures and the not determined (ND) group. The ND group was reported without a clear classification, such as seed blends of different species or inconsistency in their names, but related to the above groups.

Each of the six groups described were subdivided further. The genus *Lolium* spp. was divided into perennial ryegrass (*Lolium perenne* L.), Italian and Westerwolths ryegrasses (*Lolium multiflorum* Lam.), hybrid ryegrasses (*Lolium x hybridum* Hausskn.) and Wimmera ryegrass (*Lolium rigidum* Gaudin). *Festuca* spp. was composed only of tall fescue (*Festuca arundinacea* Schreb.). The genus *Medicago* spp. was subdivided into alfalfa/lucerne (*Medicago sativa* L.), burr medic (*Medicago polymorpha* L.), and barrel medic (*Medicago truncatula* Gaertn.). *Trifolium* spp. was subdivided into white clover (*Trifolium repens* L.), subterranean clover (*Trifolium subterraneum* L.), berseem clover (*Trifolium alexandrinum* L.), red clover (*Trifolium pratense* L.), strawberry clover (*Trifolium fragiferum* L.), balansa clover (*Trifolium michelianum* Savi.), arrowleaf clover (*Trifolium vesiculosum* Savi.), crimson clover (*Trifolium incarnatum* L.), and kura clover (*Trifolium ambiguum* M. Bieb.). The other pastures group was composed of *Dactylis glomerata* L., *x Festulolium* Asch. & Graebn., *Phalaris* spp., *Plantago lanceolata* L., *Cichorium intybus* L., *Lotus* spp., *Bromus* spp. and *Phleum pratense* L. If within any single group the species description was confusing or not detailed, data were classified as ND.

2.2. Statistical Analysis

A descriptive analysis of the proportion of mean annual imports of the 19-year period was performed, and the proportion of pastures related to the total seed imports was calculated.

Two analyses were performed to study trends in the Chilean pasture seed market. Firstly, we examined the trend over the 19-year period by means of the Mann–Kendall test for non-autocorrelated data, or the modified Mann–Kendall test for autocorrelated data [30]. As these tests identify only monotonic trends (increasing, decreasing or no trend), and not the changes over time, the data were analyzed using a joinpoint (turning-point) regression analysis [31]. Joinpoint regression has been used to analyze trends in environmental issues [32], sales trends [33], ecological risk assessment [34], bibliometric analysis [35], but mainly in cancer surveillance [36]. This analysis determines when a significant change in trends is present, assessing the annual percent change (APC) between trend points and the year when a change in the trend is produced. A number of joinpoints are selected using the Bonferroni correction for multiple testing, and the tests of significance use a Monte Carlo permutation method [37]. For each group and species, the average annual percent change (AAPC) is calculated for the whole period. If no change in trends is observed in the joinpoint analysis, the AAPC value is identical to the APC.

Both Mann–Kendall tests and joinpoint regression analyses were used in two data sets, imported seed in metric tons (Mt) and the proportion of each group/species in relation to the total imported seed (PT). A p-value < 0.05 was considered statistically significant. For years with no import data, the time-point was omitted [38]. For Mann–Kendall tests, R [39] and PAST [40] software were used. For APC and AAPC, the Joinpoint Regression software was used [37].

3. Results

3.1. Total Imported Seed

Expressed as a proportion of the 19-year period mean (2698 Mt), the change in total imported seed between 2001 and 2015 ranged from −0.51 to +1.00, with positive proportions in year 2008 and from year 2010 onwards. After the peak in year 2015, the proportion of the mean annual imports decreased to nearly zero (+0.05) in 2019 (Figure 1). In terms of imported Mt of pastures (Table 1), an increasing trend was observed over the 19-year period and a significant AAPC of +5.7% (Table 2). Despite this, the joinpoint regression analysis for the total imported seed (Figure 2a) indicates a change in trend in year 2015, with a significant APC (+10.6%) from year 2001 to 2015, decreasing afterwards.

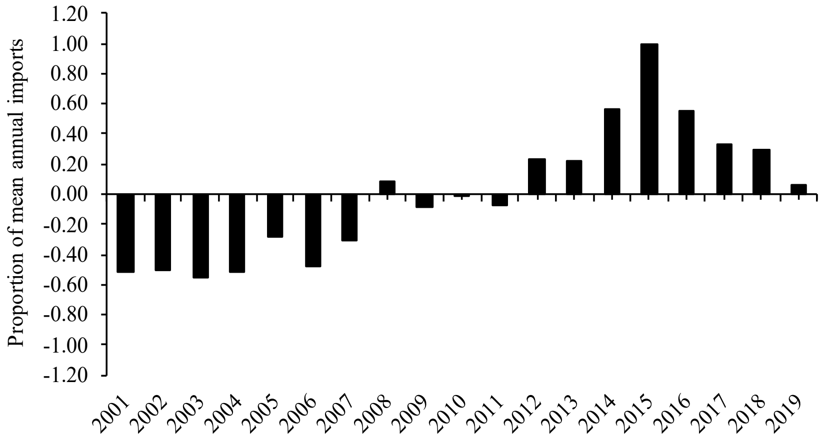

Figure 1. Comparison of imports of pastures and related turfgrass seed expressed as a proportion of the mean of the 19-year period (2698 Mt).

3.2. Genus and Group Trends and Changes

In the 19-year period, a large PT corresponded to the genus *Lolium* spp. (0.681) followed by *Festuca* spp. (0.119), *Medicago* spp. (0.086), *Trifolium* spp. (0.059), other pastures (0.049) and the ND group (0.006), with means of 1837 Mt, 320 Mt, 232 Mt, 161 Mt, 133 Mt and 15 Mt, respectively (Table 1).

In the period as a whole for Mt, *Lolium* spp., *Festuca* spp., and the other pastures group showed an increasing trend, but the latter had only a significant AAPC of +6.1% (Table 2). *Lolium* and *Festuca* spp. have had an increasing trend as a PT over the years, and *Festuca* spp. only, a significant AAPC of +2.4% (Table 2). The remaining genera have no trends for Mt and PT as in the genus *Medicago* spp., or a decreasing trend in Mt and PT as in the genus *Trifolium* spp. (Table 2). Both legumes have a significant AAPC as PT, −4.4% and −9.6%, respectively (Table 2).

Within the period for Mt, a change in trend was observed for *Lolium* spp., with joinpoints in 2003 and 2015. For this genus, a significant APC (+14.9%) was observed between 2003 and 2015 (Figure 2a). For *Festuca* spp., joinpoints in the years 2008 and 2011 were detected (Figure 2a), and in the period between 2001 to 2008 and 2011 to 2015, a significant APC was observed (+5.0% and +4.7%, respectively). The APC were less pronounced than *Lolium* spp. (+14.9%), but *Festuca* spp. was continuously increasing and did not show a decrease from 2015 as *Lolium* spp. did (Figure 2a). In terms of PT, the only genus with joinpoints was *Lolium* spp., in years 2003 and 2015, but only the period between 2003 and 2015 had a significant APC of +3.0% (Figure 2c).

Table 1. Total pasture and related turfgrass seed imported (Mt) by group from 2001 to 2019.

Group	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
	Metric tons (Mt)																		
Lolium spp. [1]	872	879	594	709	1148	836	975	1994	1563	1816	1680	2249	2263	3135	4293	3152	2291	2417	2033
Festuca spp. [1]	109	157	128	179	178	128	203	197	191	360	356	417	397	489	480	540	577	504	496
Medicago spp.	170	51	133	162	234	220	334	388	468	153	118	300	365	253	221	159	275	261	145
Trifolium spp.	124	187	240	158	253	154	177	200	147	153	183	174	128	152	146	105	149	167	60
Other pastures [2]	33	67	111	73	104	64	153	156	81	178	153	177	112	185	194	167	293	108	114
Not determined [3]		1	1	16	14		22	3		30	18	20	20		59	63		21	
Total	1308	1342	1207	1296	1930	1402	1865	2937	2450	2690	2507	3337	3284	4214	5393	4186	3585	3478	2848

[1] Some species of this genus (*L. perenne* and *F. arundinacea*) can be used under forage or turf situations. [2] Including *D. glomerata*, *x Festulolium*, *Phalaris* spp., *P. lanceolata*, *C. intybus*, *Lotus* spp., *Bromus* spp. and *P. pratense*. [3] Seed blends and data not classifiable between groups. Spaces with no data indicate no imported material in that year.

Table 2. Trends (Mann–Kendall) and joinpoints (AAPC and number) of imported seed from 2001 to 2019.

Group/Species	Metric tons (Mt)				Proportion of the Total (PT)			
	Mann–Kendall *p*-Value	Mann–Kendall Trend	AAPC [3] %	Joinpoints *n*	Mann–Kendall *p*-Value	Mann–Kendall Trend	AAPC [3] %	Joinpoints *n*
Total	<0.001	Increasing [2]	5.7 [4]	2				
Lolium spp.	<0.001	Increasing [2]	4.3	3	0.001	Increasing	−0.2	3
L. perenne	<0.001	Increasing [2]	4.7	2	0.726	No trend	−1.1	2
L. multiflorum	<0.001	Increasing [2]	6.9	3	<0.001	Increasing	2.9	3
L. x hybridum	0.001	Increasing [2]	17.2	3	0.363	No trend	11.8	3
Not determined [1]	0.007	Increasing	7.9 [4]	0	0.833	No trend	0.4	0
Festuca spp.	<0.001	Increasing [2]	4.3	3	0.025	Increasing	2.4 [4]	0
F. arundinacea	<0.001	Increasing [2]	7.1	3	0.003	Increasing	2.6 [4]	0
Not determined [1]	0.024	Increasing	8.7 [4]	0	0.994	No trend	1.3	0
Medicago spp.	0.441	No trend	2.6	0	0.074	No trend	−4.4 [4]	0
M. polymorpha	0.242	No trend			0.431	No trend		
M. sativa	0.441	No trend	2.6	0	0.050	Decreasing	−6.1	0
Trifolium spp.	0.021	Decreasing	−2.9 [4]	0	<0.001	Decreasing	−9.6 [4]	0
T. repens	0.150	No trend	5.1	2	0.003	Decreasing	−1.3	3
T. subterraneum	0.383	No trend	5.1	0	0.001	Decreasing	−8.5 [4]	0
T. alexandrinum	0.061	No trend	−15.6 [4]	0	0.001	Decreasing	−22.5 [4]	0
T. pratense	0.456	No trend	7.4	0	0.901	No trend	0.1	0
T. fragiferum	0.029	Decreasing	−9.6	0	0.001	Decreasing	−16.6	0
T. michelianum	0.837	No trend	−4.8	0	0.372	No trend	−14.4	0
T. vesiculosum	0.360	No trend			0.592	No trend		
Not determined [1]	0.276	No trend	2.1	0	0.154	No trend		
Other pastures	0.003	Increasing	6.1 [4]	0	0.233	No trend	−1.2	0
D. glomerata	0.009	Increasing	6.6 [4]	0	0.441	No trend	−1.3	0
x Festulolium	0.392	No trend	4.9	0	0.752	No trend	−2.7	0
Phalaris spp.	0.011	Decreasing	−12.9 [4]	0	0.001	Decreasing	−21.8 [4]	0
P. lanceolata	0.096	No trend	17.4 [4]	0	0.372	No trend	7.2	0
C. intybus	0.064	No trend	63.2 [4]	0	0.046	Increasing	24.1	0
Lotus spp.	0.386	No trend			0.500	No trend		
Bromus spp.	0.080	No trend			0.386	No trend		
Not determined [1]	0.212	No trend	27.7 [4]	0	0.996	No trend	−0.4	0

[1] Data not classifiable within a group or species. [2] Modified Mann–Kendall test used. [3] Average annual percent change. [4] Significantly different from zero at alpha = 0.05. The species *L. rigidum*, *M. truncatula*, *T. incarnatum*, *T. ambiguum* and *P. pratense*, as well as spaces with no data indicate no sufficient data to perform the analysis.

3.3. Species Trends and Changes

For PT, the main reported species over the period was *L. perenne* (0.357), accounting for more than one-third of all documented species, representing 52.4% of the genus *Lolium* spp., followed by *L. multiflorum* (0.132), *F. arundinacea* (0.107), and the legumes *M. sativa* (0.085), *T. repens* (0.036) and *T. subterraneum* (0.011) (Table 3). In addition, there was an important proportion of ND seeds belonging to the genus *Lolium* spp. (0.121). As a percentage, the ND data within *Lolium* and *Festuca* spp. accounts for 17.9% and 9.6%, respectively. This contrasts with the low proportion of data not determined that was found between groups: only 0.006 (Table 3). In the other pastures group, the most important species were *D. glomerata* and *x Festulolium*, which represent a PT of 0.030 and 0.014, respectively (Table 3). Other pasture species appear intermittently and represent <0.001 of the total, such as *L. rigidum*, *M. truncatula*, *T. vesiculosum*, *T. incarnatum*, *T. ambiguum*, *P. pratense*, *Bromus* spp. and *Lotus* spp., with no imported material of the last two in the last 6 and 11 years, respectively (Table 3).

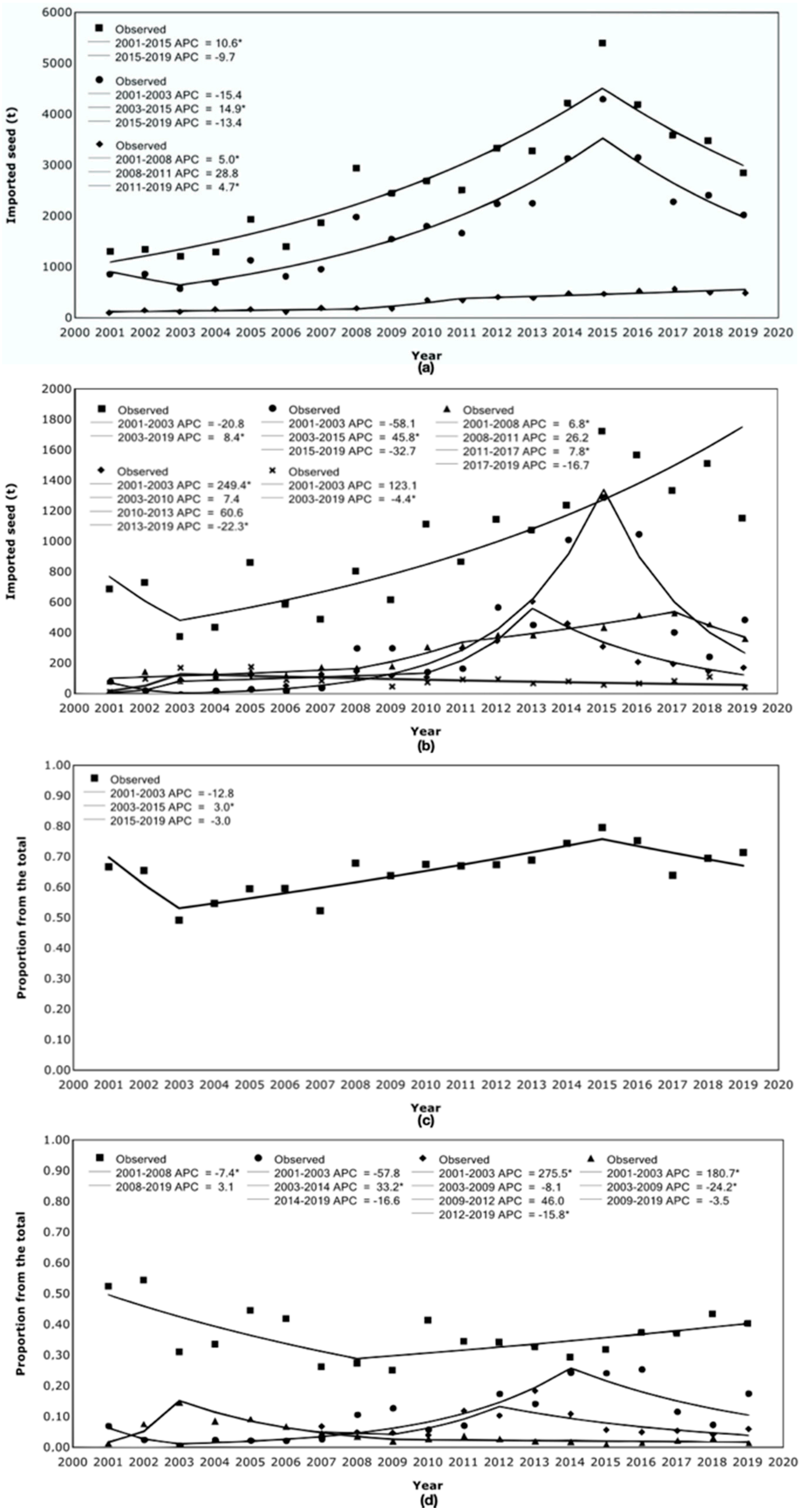

Figure 2. Joinpoint regressions (APC) for imported seed in terms of (**a**) metric tons for the total (■), *Lolium* spp. (●) and *Festuca* spp. (⧫); (**b**) metric tons for the species *L. perenne* (■), *L. multiflorum* (●), *L. x hybridum* (⧫), *F. arundinacea* (▲) and *T. repens* (x); (**c**) proportion of the total for *Lolium* spp. (■); (**d**) proportion of the total for the species *L. perenne* (■), L. *multiflorum* (●), *L. x hybridum* (⧫) and *T. repens* (▲).

Table 3. Proportion of the total seed imports (PT) of species of pasture and related turfgrass by group from 2001 to 2019.

Group/Species	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Lolium spp.																			
L. perenne	0.525	0.544	0.310	0.336	0.446	0.418	0.263	0.274	0.251	0.414	0.346	0.343	0.327	0.294	0.319	0.374	0.372	0.435	0.404
L. multiflorum	0.069	0.024	0.005	0.024	0.021	0.020	0.026	0.105	0.126	0.057	0.070	0.172	0.140	0.240	0.239	0.251	0.114	0.072	0.173
L. x hybridum	0.007	0.012	0.075	0.081	0.062	0.036	0.067	0.049	0.047	0.040	0.117	0.102	0.182	0.108	0.057	0.049	0.054	0.042	0.059
L. rigidum				0.006	0.008														
Not determined [1]	0.067	0.075	0.101	0.101	0.057	0.121	0.167	0.252	0.214	0.165	0.137	0.057	0.041	0.102	0.181	0.079	0.099	0.147	0.078
Festuca spp.																			
F. arundinacea	0.068	0.113	0.076	0.118	0.079	0.090	0.097	0.060	0.076	0.116	0.127	0.118	0.119	0.107	0.082	0.124	0.149	0.133	0.129
Not determined [1]	0.015	0.004	0.030	0.020	0.013	0.001	0.012	0.006	0.002	0.018	0.015	0.007	0.002	0.010	0.008	0.005	0.012	0.012	0.044
Medicago spp.																			
M. polymorpha						0.001	0.002	0.003		<0.001	0.002	0.002	0.002	0.002			<0.001	0.002	
M. sativa	0.130	0.038	0.110	0.125	0.121	0.156	0.177	0.130	0.191	0.056	0.045	0.088	0.109	0.058	0.041	0.038	0.076	0.072	0.051
M. truncatula												<0.001				<0.001		0.001	
Trifolium spp.																			
T. repens	0.016	0.079	0.148	0.087	0.096	0.071	0.050	0.038	0.023	0.031	0.041	0.031	0.024	0.021	0.012	0.018	0.026	0.034	0.018
T. subterraneum		0.037	0.016	0.025	0.026	0.018	0.028	0.010	0.009	0.012	0.004	0.015	0.010	0.008	0.001	0.003	0.014	0.009	0.003
T. alexandrinum	0.022	0.011	0.033			0.018		0.007	0.008	0.006						0.001	<0.001	0.002	
T. pratense			<0.001	0.002	0.002	0.001	<0.001	<0.001	0.008	<0.001	<0.001	<0.001	<0.001	0.001	0.013	0.002	<0.001	0.001	<0.001
T. fragiferum	0.004	0.003			0.003	0.003	0.001	0.001	0.009	0.001	<0.001	0.002	0.001	<0.001	<0.001			<0.001	0.001
T. michelianum			0.001	0.001	0.003		0.002	0.004		0.003		0.001	0.001	0.001	<0.001		0.001	0.001	
T. vesiculosum							<0.001	0.001				<0.001	0.001	0.001			<0.001		
T. incarnatum												<0.001	<0.001						
T. ambiguum			<0.001				<0.001												
Not determined [1]	0.054	0.001	<0.001	0.007	0.002		0.013	0.007	0.003	0.004	0.028	0.003	0.002	0.004	0.001				
Other pastures																			
D. glomerata	0.013	0.027	0.067	0.033	0.049	0.035	0.043	0.023	0.018	0.032	0.037	0.035	0.023	0.027	0.019	0.018	0.060	0.025	0.027
x Festulolium			0.011	0.008		0.008	0.030	0.028	0.016	0.033	0.021	0.007	0.008	0.012	0.015	0.022	0.022	0.003	0.010
Phalaris spp.	0.008	0.019	0.012	0.009	0.005	0.001	0.005	0.002				0.007	0.002	0.002	<0.001	<0.001		0.001	
P. lanceolata		<0.001		0.001					<0.001	0.001	0.001	<0.001	<0.001	0.002	0.001	<0.001		0.001	0.001
C. intybus			<0.001			<0.001	<0.001		<0.001		0.001	0.001	<0.001	0.001	<0.001	<0.001		0.001	0.001
Lotus spp.	0.004	0.003	0.003	0.004			0.004	0.002											
Bromus spp.	0.001			<0.001		0.001				0.001	0.001	0.001	0.001						
P. pratense															<0.001				
Not determined [1]		0.001	0.001	0.012	0.007		0.012	0.001		0.011	0.007	0.006	0.006		0.011	0.015		0.006	

[1] Data not classifiable within a group or species. Spaces with no data indicate no imported material in that year.

In the entire period, the species *L. perenne*, *L. multiflorum*, *L. x hybridum* and *F. arundinacea* have an increasing trend in Mt but none with a significant AAPC (Table 2). Only the species *L. multiflorum* and *F. arundinacea* showed an increasing trend as PT over this period, and the latter a significant APC of +2.6% (Table 2). In relation to legume species, *M. sativa* is the most important forage legume as Mt and PT (Table 3), representing 99.0% of all species within the genus. No trend for Mt was found, but a decreasing trend for PT was found (Table 2). The AAPC for Mt and for PT were not significant. The second-most important legume species in terms of seed imports was *T. repens*, representing 59.5% of *Trifolium* spp. For *T. repens*, no trend as imported Mt, but a decreasing trend as a PT was found in the 19-year period. Neither Mt or PT had a significant AAPC (Table 2). Similarly, *T. subterraneum* and *T. alexandrinum* had decreasing trends and a significant AAPC (−8.5% and −22.5%, respectively) as PT. The species *T. fragiferum* had a decreasing trend in Mt and PT, and the rest of the *Trifolium* spp. species have no trends in both types of analysis performed (Table 2). From the other pastures group, only *D. glomerata* showed an increase in terms of Mt, with a significant AAPC of +6.6% (Table 2). The forage herbs *P. lanceolata* and *C. intybus* have no trends but a significant AAPC (+17.4% and +63.2%, respectively) as Mt, and only *C. intybus* had an increasing trend as PT (Table 2).

When Mt import data were analyzed within the period, the joinpoint regression analysis indicates changes in the trends for *L. perenne*, *L. multiflorum*, *L. x hybridum*, *F. arundinacea* and *T. repens* (Figure 2b). The species *L. perenne* had one joinpoint in year 2003, and from that year onwards the APC was significant (+8.4%). *L. multiflorum* had two joinpoints for the years 2003 and 2015, the period between those years only had a significant APC (+45.8%). *F. arundinacea* had three joinpoints, in 2008, 2011 and 2017, and a significant APC from 2001 to 2008 (+6.8%) and from 2011 to 2017 (+7.8%). *L. x hybridum* had three joinpoints, in the years 2003, 2010 and 2013 and from 2001 to 2003 and from 2013 to 2019, a significant APC (+249.4% and −22.3%, respectively). The only legume with a joinpoint was *T. repens*, in year 2003. Following that year, a significant APC was observed (−4.4%). Analyzing the PT (Figure 2d), the same species except for *F. arundinacea* demonstrated at least one joinpoint. There was a significant APC of −7.4% for *L. perenne* between 2001 and 2008, and an APC of +33.2% for *L. multiflorum* from 2003 to 2014. There was an APC of +275.5% for *L. x hybridum* from 2001 to 2003, and an APC of −15.8% from 2012 to 2019. There was an APC of +180.7% for *T. repens* between the years 2001 and 2003, and an APC of −24.2% from 2003 to 2009 (Figure 2d).

4. Discussion

4.1. Overview of the Genus and Species Imported

In Chile, the amount of pasture seed use is small compared to worldwide usage. The pasture seed imported in 2007 represents less than 0.5% of the total world seed production [7]. Despite this, in Chile the pasture seed market has been dynamic in terms of imports with an increase of over 4000 Mt in the first 15 years of the period from 2001 to 2015. Mainly due to *Lolium* and *Festuca* spp. importations, both reflecting the increasing market as a component of forage and turf fields [28,29]. This overall figure is similar to the world seed production data [7], with a greater importance of grasses over legumes, and *Lolium* spp. over other genera [6].

Tendencies in imports of forage seed depend on multiple factors including the demand of seed by farmers, climatic factors that generate the need to sow pastures (drought, cold winters and others), and/or a high price of the animal products, mainly milk, leading to a higher investment in pasture establishment. If the US dollar exchange rate is favorable, the cost of imports is lower, seed production in Chile is less economically attractive and imports increase. International forage seed prices, alternative use of land, and profitability of cereals, all affect land use for Chilean forage seed production.

The import peak in the year 2015 could be due to higher pasture establishment due to the extreme drought event between January and March (Figure S1). This, coupled with the high mean air temperature (Figure S2), leads to an increase in the importations

(Tables 1 and 2). The accumulated precipitation in those months was only 22 mm, extremely low compared with the 40-year mean rainfall of 142 mm. Another reason may be the low US dollar exchange rate that year, high international wheat prices and the national area sown with cereals (mainly wheat and oat) that reached a peak between the years 2014 and 2016, which all contributed to making import of pasture and turfgrass seed more attractive than producing it in Chile [41]. The increase from 2001 to 2015 was mainly in the *Lolium* spp. group followed by *Festuca* spp. (Table 1, Figure 2a). The species *L. multiflorum* showed the biggest increase in the years 2014 to 2016 (Table 3, Figure 2b) and this was due to the availability of seed for this species and the lower price (personal communication of seed industry).

The CIF prices (nominal values) over the years for the imports of the genera *Lolium* and *Festuca* spp. had the lowest values compared to *Medicago* spp., *Trifolium* spp. and the other pastures group (Figure S3), making them more available in terms of price for end-users.

The increasing trend of ND seed (as Mt) within *Lolium* and *Festuca* spp., and their significant AAPC (+7.9% and +8.7%, respectively), diminish the option to have a more specific value of the real amount of seed. Unfortunately, within *Lolium* and *Festuca* spp. data, there is not enough detail in terms of cultivars or use. A more detailed classification system is needed in order to have clear information about the intrinsic characteristics of each species, farmer reseeding activity and the intended use of the seed. For example, in a 10-year period in the Republic of Ireland, overall imports of grass seed increased to over 5000 t, but mainly due to a doubling of amenity grass seed imports, with seed usage of grasses and clovers in agriculture between 3000 and 3500 t [12]. This reflects the importance of a more detailed data collection to neither underestimate nor overestimate the real use of the seed, to calculate the surface that is (theoretically) reseeding each year and to identify how pasture end-users are facing the constant challenge in growing and maintaining pastures. This valuable information allowed the quantification of the decline in reseeding activity in a nearly 30-year study in Northern Ireland [12], a decline in the use of early maturing cultivars and a steady increase in tetraploid perennial ryegrasses in a 25-year survey [13].

Legume species have great potential for production in the Mediterranean region of central Chile, because of plant survival under low rainfall conditions and the possibility to extend the growing period [42,43], but the higher CIF prices (nominal values) compared with ryegrasses and fescues could affect the adoption of these legumes by farmers (Figure S3). For instance, *M. sativa* is more tolerant of growth under limited water availability than a range of grasses, legumes and forage herbs species [44], and the persistence remains unchanged under different defoliation regimes [45]. This particular species has a strong Chilean seed production company that supplies an important amount of seed to farmers, masking the real use of this forage legume. Secondly, *M. polymorpha* does not show any trend (Table 2) and the PT is very low (Table 3). This species has good agronomic characteristics for Mediterranean conditions, and some cultivars were developed for sub-humid and humid Mediterranean zones [46].

For the *Trifolium* spp., the amount of seed imported may be a concern. It is the only group that showed a decrease in all parameters: Mt, PT and AAPC (−2.9% and −9.6% respectively). The species *T. repens* is by far the clover species with the largest amount of seed imports (Table 3). In 1999, data indicated that the clover import was approximately 271 Mt [20], but in the period from 2001 to 2019 the mean was 161 Mt (Table 1), with a continuous and significant decrease in importation (Table 2). From a grazing perspective, forage legumes have greater importance because of their high nutritional value in the ruminant diet and the ability to reduce N leaching by reducing the use of N fertilizers [17,47]. In terms of yield, there is an economically important advantage of the perennial ryegrass–white clover mixture in high N treatments (225–325 kg N ha^{-1} $year^{-1}$), as summarized in a series of multisite-year research [48]. Grass and white clover mixtures have the potential to increase milk production per cow and similar levels of overall milk production than only grass systems, but with less fertilizer inputs [49].

A focus on better grazing management to improve the persistency, yield and use of the *Trifolium* spp. species should be considered, and the benefits of reseeding white clover or red clover in an existing permanent pasture can be considerable in terms of dry matter and crude protein yield [50].

Other forage legumes in temperate regions are less used [15] and have only a small place in the Chilean market. The evaluation in terms of yield and persistence is used to improve the animal production systems both in the Mediterranean production areas [43,51] and temperate ecosystems [17], characterized globally by a low adoption of annual legumes by farmers [52]. The successful development, particularly in Australia, of mainly annual legumes [53] and the new phenological stage scales developed for *T. subterraneum* and *T. alexandrinum* could help improve agronomical practices and increase the use of these less adopted species [54]. To increase the forage legume options, the *T. pratense* breeding program of the Instituto de Investigaciones Agropecuarias (INIA-Chile) has been working in the last three decades to improve persistence and forage yield, releasing new improved cultivars [55].

In the other pastures group, *D. glomerata* was the most important. This species could see a systematic improvement after a complete phylogenetic analysis of the genus *Dactylis* spp. [56]. Another option for farmers is the use of the hybrid *x Festulolium*, which has appeared continuously since 2006, but without any trend. This hybrid is an alternative to those species that lack the quality and resilience of *x Festulolium* to biotic and abiotic stresses [57].

The characteristics of *P. lanceolata* and *C. intybus* of increased productivity during summer months [58] and the tolerance of hot and dry conditions over other common species [59] are desired features that farmers need in order to extend the grazing period, helping to increase the persistence of sown species and reducing weed ingress when forage herbs are included in the pasture mixture on sheep and beef systems [60] and increasing milk production as a part of multispecies swards [61]. The forage herb *C. intybus* is suggested as a potential alternative to *F. arundinacea*, *D. glomerata* and *L. perenne* under frequent heat and drought stress [62].

4.2. Chances of Adopting New Species

There is a world tendency towards the use of specialized and proprietary cultivars [6], but market prices and volumes are the primary factors that determine the success of a new cultivar [63]. The development of cultivars adapted to abiotic stress is necessary, and is one of the issues that the seed industry must address with the climate change conditions [64].

Chile has a free market-oriented economy, and is usually in line with the world market. The Chilean market depends on international prices and quantities available on the market and internal dynamics such as prices of animal products and climatic conditions affecting the demand for forage seed. Moreover, the Chilean market is very dynamic in terms of available cultivars due to the few legal requirements when introducing a new variety into the market. In fact, the Chilean legal system allows the introduction of new cultivars of known species to the market without the requirement of performing a prior agronomic evaluation. This has at least three consequences. First, from the market standpoint there is a rapid change in available cultivars with less emphasis on its agronomic value and more on the seed price. Second, from the production point of view, there are no official data available regarding the agronomic value of the cultivars, so farmers have no possibility of choosing the cultivars better adapted to their environment [55]. Third, it is difficult for national breeding programs to compete in a market that works like a commodity market rather than as a specialized one.

Chile has good soil and climatic conditions and dry summer for seed production. In the forage and turf groups, Chile has not developed a competitive industry, due to the low and variable international price for forage and turfgrass seeds. These have not allowed the competitive development, in a medium-term perspective, of the required know-how for the industry to compete. To guarantee seeds of the best adapted cultivars to local conditions, a successful pasture seed industry must be developed [52].

In the last 60 years, few Chilean forage cultivars have been developed and reached the market. Only *T. pratense* has been important for both national and export markets [55]. The first two cultivars of the native grass *Bromus valdivianus* (Bromino-INIA and Bronco-INIA) that were developed in the last decade are only just now slowly getting into the market as "new" species [65]. Therefore, most of the forage and turf seed is imported and the amount of imported seed or national production depends on multiple factors (dollar change rate, international seed prices, competitive crop prices such as cereals, and others).

Local research on new imported pasture species is needed. In addition, introduced and local cultivars must be evaluated under abiotic stress conditions to measure their potential impact on yield and, in the case of turfgrass varieties, ornamental features. Forage breeding, from the range that comprises Mediterranean to Nordic areas, should improve plant strategies to face abiotic stresses and optimize growth and phenology to new seasonal changes [25]. Under these conditions, the introduction and evaluation of species or cultivars to extend the production period and increase productivity under rain-fed environments [43] is a first strategy to increase livestock productivity. For those with irrigation, strategies to improve water productivity to optimize forage production are documented [66,67].

4.3. Implications for the Agricultural Policies

The official source of data, which come from the Office of Agricultural Studies and Policies (ODEPA) with information from the National Customs Services, is detailed in terms of genus, but in many cases the data are incomplete in terms of species, cultivars or the intended use of the seed (forage or turfgrass). In some cases, there is no clear description of the species belonging to a specific genus (mean percentage of ND data is 17.9% in *Lolium* spp.). For dual-purpose species, identifying the cultivar name is the way to know the final use [8]. This implies that a more exact classification system should be implemented by the Office of Agricultural Studies and Policies (ODEPA) and the National Custom Services once the seed arrives at the national territory in order to specify data in terms of cultivar, blend name and the intended use of seed. These will allow a continuous quantification of the pasture seed imports at a country level, the estimation of the theoretical surface and tendencies at the species level.

5. Conclusions

The results show that over the last 19 years, pasture seed imports have an increasing trend and positive annual changes, largely dominated by the genera *Lolium* and *Festuca* spp., and *L. perenne* at the species level. However, the level of not determined data and the lack of cultivar information and/or the intended use of seed within each of both genera limits a more precise analysis. The genus *Trifolium* spp. and its main species (*T. repens*, *T. subterraneum* and *T. alexandrinum*) have a decreasing trend over time as a proportion of the total. Only *D. glomerata*, *P. lanceolata* and *C. intybus* showed some increasing trends. Focused on the results, Chilean end-users have been increasing the use of *Lolium* and *Festuca* spp., decreasing the use of *Trifolium* spp. and slowly adopting some new pasture species. The analysis of these tendencies is important to orientate plant breeding programs, research and extension to the farmers; however, more detailed data at the species and cultivar levels are needed to perform a more precise analysis. This would allow the design of agricultural policies to cope with climate change conditions and the prioritization of breeding and research in the agronomy of new species to enhance pasture and turfgrass systems.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/agriculture11060552/s1, Figure S1: Boxplot of monthly precipitation of each month from 2001 to 2019; Figure S2: Boxplot of monthly mean air temperature of each month from 2001 to 2019; Figure S3: Pastures and related turfgrass import CIF prices.

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