Thinopyrum intermedium (Host) Barkw. & Dewey – a review, and evaluation of intermediate and pubescent wheatgrass for dryland agriculture in New Zealand

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Abstract

Intermediate and pubescent wheatgrasses (*Thinopyrum intermedium*) are potentially useful as dryland forage grasses in New Zealand. The recent literature on their international and local use in pasture and cropping situations is reviewed. Under semi-arid conditions at Bendigo Station over a 13-year period, cv. Luna wheatgrass has spread several metres from the original drill lines and it provides very high ground cover. In terms of dryland soil resource conservation this contrasts with adjacent cocksfoot and, to a lesser extent, lucerne plots which have wide-spaced plants interspersed with litter and much bare ground. In a mixed drilling containing wheatgrass, hairy dorycnium, birdsfoot trefoil and sheep's burnet, the first two species now dominate. At Takapau, central Hawke's Bay, annual yields from intermediate and pubescent wheatgrasses produced over 80% of the yield of 10 New Zealand cultivars in spring, summer and autumn, and 65% in the winter. Of the wheatgrasses, cv. Topar intermediate wheatgrass and a pubescent wheatgrass (unnamed line) were the lowest yielding, whereas cv. Oahe and cv. Mandan produced the highest yields. Cv. Greenleaf pubescent wheatgrass had higher foliar nitrogen content than all other species, but *in vitro* organic matter digestibility was less than 700 g OM/kg DM. Although the wheatgrasses had satisfactory herbage yield and nutritional value, better alternative species are available for pastoral farming in central Hawke's Bay. On Belfield in the Hakataramea Valley, cv. Rush has been the most vigorous wheatgrass for establishment and it seems to handle cold winds and frost well. Hay made from a wheatgrass/ lucerne mix is considered better than that from the individual species as this can increase production by 40–50%, depending on soil and climatic conditions. Usually only one cut per year is taken from the mixed pasture. Crop maintenance includes the application of 200 kg/ha of sulphur super extra every 3–4 years and the pH is maintained at about 5.9–6.4 by liming. A significant advantage is that no stock health, pest or plant disease problems have been noted as yet with any of the wheatgrass varieties available in New Zealand.

Keywords: dryland agriculture, New Zealand, *Thinopyrum*, wheatgrass

Introduction

Many wheatgrass species, including western, slender and crested wheatgrasses, have been evaluated in New Zealand for revegetating depleted, erosive, dry and semi-arid country, and for forage production. Investigations with wheatgrasses and other dryland species, sited mainly in the South Island, have been conducted periodically since the mid 1900s. This research originally concentrated on the soil conservation attributes of the plants but latterly has also investigated on-farm applications. Recent North Island trials have concentrated on forage production.

Intermediate and pubescent wheatgrasses are considered to have potential as useful dryland forage grasses in New Zealand, both on hill country and on lower altitude agricultural land. Internationally they are useful in cereal breeding programmes and as grain crops.

This paper 1) reviews historical use of wheatgrasses in New Zealand and recent overseas literature, 2) provides management information from research and practical farming viewpoints for wheatgrasses in South Island dryland farming situations, and 3) presents selected yield and nutritional data from a spaced-plant evaluation of wheatgrasses in the lower North Island.

Literature review

Most wheatgrasses (Family Poaceae, Tribe Triticeae), many of which are perennial relatives to wheat, are adapted to steppe or desert with subhumid to arid climates. About 30 species are native to North America and 100 to Eurasia, with a few species occurring in South America, New Zealand, Australia and Africa (Asay & Knowles 1985; Jarvie & Barkworth 1993).

The most promising species for New Zealand (NZ) are intermediate wheatgrass (*Thinopyrum intermedium* (Host) Barkw. & Dewey, syn. *Agropyron intermedium* (Host) Beauvois, *Elymus hispidus* (Opiz) Melderis, *Elytrigia intermedia* (Host) Nevski), and its close relation pubescent wheatgrass (*T. intermedium* ssp. *barbulatum* (Schur) Barkw. & Dewey, syn. *A. trichophorum* (Link) Richter, *Elymus hispidus* ssp. *barbulatus* (Schur) Melderis, *Elytrigia trichophora* (Link) Nevski). Both have been evaluated in the South Island since about 1940, including the Pisa Flat trials, Central Otago (Calder 1944), and in trials in the Mackenzie Basin during the 1950s (Douglas 1974), but commercial interest did not develop until the mid 1980s (Wills 1984; Wills *et al.* 1987).

Description

Intermediate and pubescent wheatgrasses are long-lived (50+ years) perennial, cool-season grasses with short rhizomes and a deep-feeding root system. Leaves are 4–8 mm wide, green to blue-green and sometimes drooping, and plants grow to a height of 1–1.5 m. The seed spikes may be 100 to 200 mm long. As the common name implies, the spikes, spikelets, glumes, lemmas and leaves of pubescent wheatgrass are densely covered with hairs whereas intermediate wheatgrass vegetative structures are mostly smooth, but may have ciliate hairs on the leaf margins. Intermediate and pubescent wheatgrasses readily cross and commercial seed often contains both types (Wheeler 1950; Asay & Knowles 1985; USDA-PMC 1997). Interspecific hybrids with other Triticeae species have also been reported (Napier & Walton 1981).

Pubescent wheatgrass is better adapted to droughty, infertile loamy to sandy and shallow soils while intermediate wheatgrass can provide abundant high quality forage on fertile sites with well drained loamy- to clayey-textured soils, and at higher elevation. Both will tolerate slightly acidic to mildly saline conditions, are cold tolerant (pubescent wheatgrass is considered more winter hardy), can withstand moderate periodic flooding in the spring, and are very tolerant of fire (USDA-PMC 1997). They grow poorly on wet, waterlogged or moderately saline to alkaline soils, or under prolonged inundation (Hafenrichter *et al.* 1968; Hull 1974).

Several cultivars of intermediate wheatgrass, developed in the US, are available: Amur, Chief, Clarke, Greenar, Oahe, Ree (discontinued), Reliant, Rush, Slate and Tegmar. Pubescent wheatgrass cultivars include Greenleaf, Luna, Mandan, Manska and Topar (Asay 1992). The origins and attributes of these cultivars are summarised in Table 1.

Schulze-Schaeffer & Ditterline (1991) registered several vegetatively propagated parental lines of intermediate wheatgrass (MT6-MT15), all with forage yields equal to or higher than Oahe. The strong resistance of intermediate wheatgrass to barley yellow dwarf luteovirus and several rusts has recently been exploited to improve wheat genetics via backcrossing to fertile amphiploids (Larkin *et al.* 1995).

Establishment

Based on US experience, wheatgrasses should be drilled at a depth of 10 mm on medium to fine-textured soils and no more than 25 mm deep on coarse-textured soils. Single species seeding rate recommended for intermediate and pubescent wheatgrasses is 11–14 kg/ha Pure Live Seed (PLS). A firm weed-free seedbed enhances stand establishment. They are compatible with other pasture species, particularly lucerne, and stand longevity and productivity can be enhanced by seeding with a legume.

Best dryland results are obtained from seeding in early spring on heavy to medium textured soils and in late autumn on medium to light textured soils. Irrigated areas should be seeded in spring through summer (Lawrence 1983; Wheeler 1950; USDA-PMC 1997). For mined lands, roadsides and other critical areas, the seeding rate should be increased to 18–20 kg/ha PLS.

Management

Intermediate wheatgrass is very productive early in the life of a stand (Asay & Knowles 1985) and although the newer cultivars are better, they are sometimes criticised in the USA for their lack of longevity when mismanaged or subjected to environmental stress.

In the Hakataramea Valley (South Island, NZ) Woodman & Fraser (1991) observed that intermediate wheatgrass, along with cocksfoot, tall oatgrass and smooth brome, had potential as a productive and sustainable pasture grass with a wide seasonal growth pattern. Hunter *et al.* (1994) noted that production of Luna in Marlborough/mid-Canterbury improved with time, especially on stony loam soils, that it grew well into summer but less so in autumn, and was highly palatable.

Wheatgrass produces good hay yields both individually and combined with lucerne where its stiff stems help keep the legume from lodging. Several cultivars have been selected for hay production (Table 1). Regrowth after cutting is slow, so a single cut for hay each season is best. Intermediate and pubescent wheatgrasses respond well to irrigation with similar production to cocksfoot; however, the latter will normally out-produce them for hay production in multiple cutting situations.

Table 1 Intermediate and pubescent wheatgrasses – cultivar attributes*

Cultivar	Type	Origin	Released	Attributes	Intended Use
Amur	Intermediate	Manchuria, China	1952	Leafy, vigorous-growing, strong seedling vigour, good seed production but slow sod-former	Disturbed land revegetation, rangeland reseeding at higher elevations
Chief	Intermediate	USSR x Canada	1961	High seed yield & forage quality	Grass component in lucerne hay crops & for heavily grazed pastures
Clarke	Intermediate	USSR x Canada	1980	Drought tolerance, winter hardiness, high seed yield	Dryland or irrigated hay & pasture
Greenar	Intermediate	USSR x USA	1945	Vigorous, moderate sod-forming, broad leaf, early spring growth, productive & disease resistant	Hay & pasture
Oahe	Intermediate	USSR x USA	1961	Drought tolerance, vigorous, winter hardy, rhizomatous & produces high yields of large seed	Hay, pasture & conservation
Reliant	Intermediate	USA selection	1991	Medium height, leaf-spot resistance, late maturing, high sustained forage & seed yields & quality	Hay & pasture in annual precipitation >350mm
Rush	Intermediate	Germany	1994	Superior seedling vigour & establishment, good spring growth, rhizomatous & high forage & seed production.	Erosion control & revegetation, forage, hay and pasture
Slate	Intermediate	USA selection	1969	Strongly rhizomatous, erect form	Grass component in lucerne hay & pasture mixes
Tegmar	Intermediate	Turkey	1968	Long-lived, late maturing, dwarf growth form, seedling vigour & rapid sod-formation, drought-tolerance.	Erosion control & revegetation, dam stabilisation, grassed waterways
Greenleaf	Pubescent	Unknown x Canada	1966	High forage yields & seedling vigour, winter hardy, sod-forming, moderate drought & salinity tolerance	Winter hardy cultivar for pasture & hay production, short-term pasture under heavy grazing
Luna	Pubescent	USSR x Turkey	1963	Excellent seedling vigour, fast establishment and good forage production, broad site adaptibility	Irrigated pasture, range reseeding and revegetation of disturbed areas
Mandan	Pubescent	USSR x USA	No official release	Good seedling vigour & forage production, rhizomatous	Grass component in lucerne hay & pasture mixes, short-term pasture under heavy grazing
Manska	Pubescent	USSR x USA	1992	Good vigour and leaf-spot resistance, high forage & seed production, high nutritional quality	Hay & pasture in annual precipitation >350mm. Replacement for Mandan
Topar	Pubescent	Turkey x USA	1953	Vigorous growth, late-maturing, sod-forming and drought-resistant, better adapted to low fertility, elevation & salinity	Disturbed land revegetation, rangeland reseeding at higher elevations, dams & grassed waterways

* Based on agronomic experience in USA and Canada

When planted with a legume, hay should be harvested at the optimum stage for the legume. This will allow the grass to be harvested before flowering and result in high quality hay. Pure stands of wheatgrass should be harvested when plants start to flower. Nitrogen (N) can be applied as needed to maintain vigorous growth. Irrigated pastures and those in higher rainfall zones (450 mm +) respond well to annual applications of 50 kg N/ha during the establishment year and 75–100 kg N/ha each autumn (USDA-SCS 1972; USDA-PMC 1997). Productivity (non-irrigated) of cv. Chief in Alberta, Canada (AAFRD 1997) is 4.5–11.0 t DM/ha (hay yield).

Plants are drought-tolerant, but they grow best in areas receiving at least 300 mm precipitation during the growing season. Wheatgrass provides excellent spring, early summer and autumn pasture, but must be carefully managed to ensure maintenance of the stand and high production (Lawrence 1983; USDA-PMC 1997).

In the US, wheatgrasses are preferred by cattle, sheep, horses, antelope and deer in spring, early summer and autumn, and are a desirable feed in summer and winter (Austin *et al.* 1994). Before grazing is permitted on established stands, 250–300 mm of new growth should be attained in spring. Under heavy, continuous grazing it will not maintain a healthy productive stand, but wheatgrass is not as susceptible to spring and autumn freezing as smooth brome or cocksfoot.

Karn & Berdahl (1985) noted consistent differences between intermediate wheatgrass clones in their *in vitro* organic matter digestibility (52–64% at one sampling date), suggesting nutritional quality could be readily improved by breeding programmes. A comparison of four intermediate wheatgrass populations under grazing (Moore *et al.* 1995) demonstrated their potential for livestock forage and was instrumental in the release of cv. Manska. Un-grazed strips of wheatgrass provide good nesting cover for game birds and migratory waterfowl.

Intermediate and pubescent wheatgrasses are well adapted to stabilising disturbed soils and several cultivars have been specifically selected for this purpose (Table 1). They can be used in areas where irrigation water is limited and to stabilise banks, dykes and roadsides. With its heavy root production, wheatgrass can also be used to improve soils. In the top 200 mm of soil, almost 8 t DM/ha of root material has been measured in 5-year-old stands (Monsen & Plummer 1978).

Environmental concerns

Although long-lived, vegetative spread of intermediate and pubescent wheatgrasses is slow and little spread occurs via seed distribution. In the US they are not considered "weedy" or invasive species, but will spread into adjoining vegetative communities under ideal climatic and environmental conditions. They co-exist with native taxa and provide additional biodiversity in those situations. On favourable sites, wheatgrass can maintain dominance and exist as a monoculture. There is no scientific documentation indicating that intermediate and pubescent wheatgrasses cross with native species (USDA-PMC 1997).

Seed production

Seed production of intermediate and pubescent wheatgrass is straightforward. Providing seed fields are kept in rows and adequate fertility levels are maintained, seed can be produced for 7–10 years or more. Inter-row spacings of 1000 mm dryland and 600–1000 mm irrigated are recommended. As wheatgrass is rhizomatous, cultivation is required to maintain separate rows.

In the US, average production of 250–350 kg/ha is expected under dryland conditions and 450–550 kg/ha under irrigated conditions. Seed yields drop significantly after about 4 years of production. Harvesting is best completed by windrowing then heading the cured rows. Seedheads shatter when mature and if direct heading is planned the stand should be harvested with 15–20% seed moisture content. This will require drying to 12% moisture content before storing in bins and to 15% if storing in sacks. Seed is generally harvested in mid autumn (USDA-PMC 1997).

Perennial grain cropping

Intermediate wheatgrass has good potential for development as a perennial grain crop, commonly known as "Wild Triga" (Wagoner & Schauer 1990). Any of the cultivars can be used for grain, but Oahe and Luna are preferred owing to their good seed yield and quality, and the ease with which they shed their hulls. Advantages of Wild Triga are that it can be planted on hilly land not suitable for continuous annual crop production, or in contour strips alternating with annual crops and rotated with annuals on a 5- to 7-year basis.

Yields are less than those of annual grains but production costs are lower, thus net profits are still feasible. Production is also maintainable over 4–6 years. Yields are typically 500–600 kg/ha in the first year of production, but decline in subsequent years. Seed weight averages 5.3 g/1000 seeds (Schulz-Schaeffer & Haller 1987). It should be direct harvested when the heads are completely dry, although some grain may shatter before this condition is attained. Harvester settings must be adjusted to accommodate the smaller grain of Wild Triga and dehulling may be necessary.

Appropriate management techniques can help reduce the yield decline. Intermediate wheatgrass stands can be rejuvenated in autumn by adding nitrogen, either through fertiliser or manure from grazing animals, thus providing a secondary harvest product, the forage. Wild Triga can also be chiselled or grubbed to rejuvenate sod-bound stands, which has a positive effect on yields without jeopardising the stand or subjecting the land to erosion.

Wild Triga grain can be ground into flour to make baked products, or cooked whole like rice for human consumption. The grain has a sweet, mild, nutty flavour, and has higher levels of protein (20.8%), fat (3.2%) and ash (2.6%) than wheat (Becker *et al.* 1986). The protein is nutritionally limiting in lysine, as for wheat, but it has higher levels of all other essential amino acids, especially methionine and cysteine. At wheat flour replacement levels of 100%, 66% and 33%, whole flour from intermediate wheatgrass grain performs well in baked products. Wheat flour-perennial grain flour blends were preferred (sweet/nutty) over pure wheat flour controls. The performance of cv. Luna was very similar to that of a high quality wheat dough but cv. Oahe did not compare as favourably. Thus there may be sufficient variability among the intermediate wheatgrasses to select and develop lines for different culinary purposes (Wagoner & Schauer 1990).

No functional gluten has been found in samples tested by the USDA. Tolerance of Wild Triga grain by individuals with wheat or gluten allergies is unknown. Although anti-nutritive substance levels (tannins and trypsin inhibitors) are low, intermediate wheatgrass is closely related to wheat so may cause similar problems.

Materials and methods

South Island

Direct drilling trials commenced at Bendigo Station, Central Otago, in spring 1984 and 1985, involving dryland species including wheatgrass, cocksfoot, birdsfoot trefoil, hairy dorycnium, sheep's burnet and lucerne (Table 2). Single species plots (2 × 30 m size) were drilled with a Hunter slot seeder drill with 2 replicates in a completely random design. Seeding rates were 15 kg/ha for lucerne and trefoil, 20 kg/ha for all other species. A mixed sowing (wheatgrass, dorycnium, trefoil and burnet at 50% above rates) was also established. Fertiliser was applied at establishment only – legumes with 250 kg/ha sulphur super 200 and grasses with 200 kg/ha ammophos. Plots were sampled for herbage mass twice annually (Dec/Mar) until 1995. After sampling they were mown or stocked with Merino sheep to leave a residual height of about 50 mm.

In autumn 1997, the persistence and growth characteristics of wheatgrass were compared to the other dryland species. Attributes assessed were ground cover (%), plant spread (m), and accumulated herbage mass (kg dry matter (DM)/ha). Ground cover was determined from 4 randomly sited 10 m transects per plot which were point analysed at 0.25 m intervals. Two recordings were made at each point; a primary vegetation hit (to detect the most dominant plant species) and a secondary hit to detect any sub-dominant species if present (in the case of a centre hit on, e.g., a large cocksfoot plant, this might be the same species, or it could be bare ground).

Trial results at other properties in Central Otago, and on practical farming experience with wheatgrass at Belfield, in the Hakataramea Valley, are also outlined.

North Island

Forty lines of wheatgrass, comprising a range of species, were evaluated on a flat, cultivated site at Takapau, central Hawke's Bay on a drought-prone, fertile stony silt loam. Species included intermediate, pubescent, tall and crested wheatgrasses, and many of the lines were named cultivars. New Zealand-bred cultivars of 9 other grass species were included for comparison including those of cocksfoot, phalaris and tall fescue. The experiment comprised 3 randomised complete blocks. Each plot (experimental unit) was a single row of 6 plants at 300 mm spacing and plots were 1 m apart. Seedlings were transplanted in October 1991 and the trial was fenced to exclude rabbits. Weeds were controlled by hand-weeding and appropriate herbicides.

All lines were assessed from December 1991 to October 1995 for numerous morphological attributes, but only yields are presented in this paper. Herbage mass was scored non-destructively on a scale of 1 (low) to 5, and expressed as g DM/plant by harvesting 10–15 plants in each score class, determining their dry weights, and regressing dry weight against score. There were 4–6 harvests per year and the trial was mob-stocked with sheep after each harvest. In November 1995, foliage of selected lines was assayed for several nutritional attributes using Near Infra-red Reflectance procedures. Selected results for the intermediate and pubescent wheatgrasses, and the New Zealand-bred cultivars, are presented.

Results and discussion

South Island

With a mean annual rainfall of about 425 mm at Bendigo Station, wheatgrass was slow to establish but eventually formed excellent groundcover under windy, dryland conditions. The herbage yield of pure wheatgrass (cv. Luna) during sampling over the past decade has been about 3.5 t DM/ha/year. In the pasture mixture including dorycnium, burnet and trefoil, the herbage yield has been up to 11 t DM/ha/year in good seasons.

Compared to other dryland plants at Bendigo, wheatgrass has spread slowly but effectively via its rhizomatous root system. It has spread several metres from the original drill lines, in many cases overgrowing adjacent plots (Table 2). Spread by seed is limited by the size and weight of the seed.

The ground cover (%) provided by wheatgrass was very high compared with that of cocksfoot or lucerne, the amount of bare ground around cocksfoot in particular being quite high. Litter levels for wheatgrass were low in the primary hits, being a little higher in the secondary hits. In terms of dryland soil resource conservation this contrasted with cocksfoot which had wide-spaced plants interspersed with litter and bare ground. Plant moisture content of wheatgrass was relatively low. The mixed drilling, which originally contained wheatgrass, hairy dorycnium, birdsfoot trefoil and sheep's burnet, has grown well with the former two species now dominating.

North Island

Annual yields of intermediate and pubescent wheatgrasses averaged 85% of the ten New Zealand cultivars

Table 2 Growth parameters and ground cover of dryland plant species established 1984/85 at Bendigo Station, Central Otago using a Hunter slot seeding drill – 1998 results.

Bendigo Hunter Drilling Trial **DM Yield & Groundcover, 1998**

				Primary Hits				Secondary Hits			
				Drilled Spp	Bare Ground	Litter	Other Spp	Drilled Spp	Bare Ground	Litter	Other Spp
	Vegetation Moisture Content (%)	DM Weight (Kg/ha)	Vegetative Spread from plot (m)	Ground Cover (%)	Ground Cover (%)	Ground Cover (%)	Ground Cover (%)	Ground Cover (%)	Ground Cover (%)	Ground Cover (%)	Ground Cover (%)
Drilled Species											
Wheatgrass - Mandan	31	2455	4.5	91	0	1	8	64	0	23	13
Grasslands Wana	43	2111	0.0	68	15	15	3	26	18	53	4
Dorycnium - 1059†	56	3220	0.2	45	0	2	53	41	0	5	54
Red Fescue - Scaldis	34	2504	0.1	87	0	4	9	54	0	40	6
Lucerne - WL318	56	1331	0.1	49	0	17	34	26	0	21	53
Mix - Wheatgrass]	32	2696]	4.7	72]	0	1	4	54]	0	9	12
Mix - Dorycnium]	56	868]	N/A	23]	As for wheatgrass >			25]	As for wheatgrass >		
Sheep's Burnet - 2303†	39	1513	0.0	36	1	14	49	29	1	39	30
LSD 0.05	3	794	0.7	8	-	4	7	13	-	10	8

† - Accession identification number] - Dorycnium foliage was separated from wheatgrass for weighing analysis, read groundcover & DM totals as combined

(210 vs 250 g/plant), and cultivars of all species produced nearly 40% of their annual yield in spring (Table 3). The wheatgrasses produced over 80% of the yield of the New Zealand cultivars in spring, summer and autumn, but 65% in the winter. Cocksfoot cv. Grasslands Kara and phalaris cv. Grasslands Maru were the only cultivars to yield more than 300 g/plant annually. Within the wheatgrasses, cv. Topar intermediate wheatgrass and pubescent wheatgrass (unnamed line) were the lowest ($P<0.05$) yielding, whereas cv. Oahe and cv. Mandan produced the highest yields.

Cv. Greenleaf pubescent wheatgrass had the highest foliar nitrogen content which was higher ($P<0.05$) than for all other species (Table 3). Soluble carbohydrate and lipid contents varied considerably among the New Zealand bred cultivars, but were relatively constant for the three wheatgrasses assayed. *In vitro* organic matter digestibility of the wheatgrasses was less than 700 g OM/kg DM and lower ($P<0.05$) than for prairie grass cv. Grasslands Matua, Yorkshire fog cv. Massey Basyn and perennial ryegrass cv. Grasslands Nui. Across all species, digestibility estimates were poorly related to fibre content. The results indicate that the wheatgrasses have satisfactory herbage yield and nutritional value, but that there are better alternative species for pastoral farming in central Hawke's Bay. They are considered to have more potential for lower fertility sites than the one used here, such as those found in the South Island tussock grasslands.

Farmer Experience – Belfield, Hakataramea Valley (Kurow)

The average rainfall at Belfield is approximately 450 mm with a 30% variation depending on season. Hot summers and cold winters are normal. With an altitude of 200–400 m a.s.l. snow is not a problem, although frosts may be severe. Soils are quite fertile with a pH of 5.5 to 6.6 with added lime, and they range from stony riverbed types to good cropping types. Before the use of wheatgrass, Belfield had large areas of land decimated by grass grub, leaving only weeds and some subterranean clover.

At a field day in 1985 on Bill Simpson's property at Duntroon, Luna pubescent wheatgrass was observed growing excellently in a high-fertility cropping programme despite the prevailing drought conditions. This, together with additional advice, resulted in the introduction of cv. Luna and cv. Mandan wheatgrasses to Belfield, starting a move into new dryland species, several of which have since been tried with varying results.

Introduction of intermediate wheatgrass was the next step in the development of Belfield, this having all the benefits of pubescent wheatgrass plus greater production

Table 3 Seasonal and annual plant yield (g/plant) averaged over 4 years and forage quality[1] in November 1995, of intermediate and pubescent wheatgrasses and New Zealand bred pasture cultivars in central Hawke's Bay.

Species	Plant yield (g/plant)					N	CHO	Lipid	OMD	ADF	NDF
	Annual	Seasonal									
		Spring	Summer	Autumn	Winter						
Thinopyrum intermedium cv. Amur	209	76	63	53	17						
Thinopyrum intermedium cv. Chief	239	96	69	53	21						
Thinopyrum intermedium cv. Clarke	207	81	64	46	16						
Thinopyrum intermedium selection[2]	245	103	69	51	22	27	136	33	683	248	440
Thinopyrum intermedium cv. Greenar	217	81	64	50	22						
Thinopyrum intermedium cv. Oahe	245	96	73	52	24						
Thinopyrum intermedium cv. Slate	231	89	65	57	20						
Thinopyrum intermedium cv. Tegmar	196	69	60	45	22						
Thinopyrum intermedium cv. Topar	155	56	47	34	18						
Thinopyrum trichophorum	158	60	50	34	14						
Thinopyrum trichophorum cv. Greenleaf	216	75	67	55	19	36	142	31	685	240	424
Thinopyrum trichophorum cv. Luna	220	84	60	52	24						
Thinopyrum trichophorum cv. Mandan	242	91	70	60	21	25	140	30	670	244	435
Thinopyrum trichophorum cv. Mandan 759	197	67	59	52	19						
Bromus inermis cv. Grasslands Tiki	231	82	72	58	19	26	147	33	735	210	405
Bromus sitchensis cv. Grasslands Hakari	236	93	63	55	25	24	141	32	745	246	443
Bromus stamineus cv. Grasslands Gala	248	92	66	62	28	23	132	34	716	253	457
Bromus willdenowii cv. Grasslands Matua	196	66	51	51	28	24	183	30	830	213	389
Dactylis glomerata cv. Grasslands Kara	332	130	86	69	47	28	110	38	725	267	489
Dactylis glomerata cv. Grasslands Wana	286	106	76	70	34	27	123	34	691	250	504
Festuca arundinacea cv. Grasslands Roa	281	113	66	61	41	18	136	26	709	286	492
Holcus lanatus cv. Massey Basyn	208	77	52	55	24	21	169	34	850	239	436
Lolium perenne cv. Grasslands Nui	176	65	46	41	24	15	160	29	875	239	424
Phalaris aquatica cv. Grasslands Maru	319	126	80	69	44	30	122	32	718	255	454
LSD (5%)	64	17	18	15	5	4	18	3	60	22	36

[1] N = total nitrogen (g N/kg DM), CHO = soluble carbohydrates (g CHO/kg DM), Lipid (g/kg DM), OMD = organic matter digestibility (g OM/kg DM), ADF and NDF = acid and neutral detergent fibre (g/kg DM), respectively; [2] New Zealand selection from cv. Chief and cv. Clarke.

in this environment. It performs well and has a longer growing season than pubescent wheatgrass. However, for very harsh, arid conditions cv. Luna or cv. Mandan are preferred as they have a more vigorous and persistent root system. The two intermediate wheatgrasses tried at Belfield are cv. Oahe and the recently released cv. Rush. Wheatgrasses have now been used as a pasture plant at Belfield for some 14 years because of their drought tolerance, palatability and resistance to grass grub.

For sowing, a fine, firm seed-bed is required and seed depth is kept to 8–12 mm. For pure stands the sowing rate is about 8 kg/ha plus 200 kg/ha drilling super and in mixed stands with lucerne the seed rate is split (4–5 kg each of wheatgrass and lucerne), with the lucerne consisting of 40% cv. Runner creeping lucerne and 60% standard lucerne. Wheatgrass plants spread quickly underground if they have space and stands thicken up as they get older, but they do not compete well with weeds when young.

For sunny aspects the following pasture mix is recommended:

3–4 kg/ha wheatgrass
3–4 kg/ha cv. Runner creeping lucerne OR 2 kg/ha cv. Grasslands Goldie birdsfoot trefoil
and/or 2 kg/ha subterranean clover
and/or 3 kg/ha small leaf or cv. Grasslands Huia white clover
For winter production 0.5 kg cv. Grasslands Kara cocksfoot could be added.

The most vigorous wheatgrass for establishment is cv. Rush which also seems to handle cold winds and frost well. Drilling is usually conducted at a similar time to lucerne; the soil must be warm and moist with a pH in the range 5.7–6.4. In the US similar soils are some 20% higher in pH, which may account for the longevity of wheatgrass there. The parent stand for the cv. Mandan wheatgrass sown on Belfield 6 years ago was apparently planted in North Dakota in 1915. Subsequent management has included some mowing, occasional grazing by cows and burning in autumn to keep it clean. It has never seen a sheep!

Wheatgrass can be grazed lightly with lambs during the first season to maintain the desired grass/legume ratio. Break feeding with hoggets in early winter is successful as wheatgrass does not suffer frost-burn. Growth of intermediate wheatgrass starts early in the spring and it can be grazed by lambing ewes and hoggets at that time to take advantage of its high nutritive value. After lambing, wheatgrass paddocks being kept for hay are closed.

At Belfield a wheatgrass/ lucerne mix is preferred to pure stands as this can increase production by 40–50%, depending on soil and climatic conditions. Similar results have been noted with cv. Luna drilled into old lucerne stands on nearby Riverside (M. Brosnan, pers. comm.). Lucerne boosts the growth of wheatgrass with its nitrogen fixation and the wheatgrass helps protect the lucerne from wind damage. Usually only one cut per year is taken from the mixed pasture. Good hay has also been produced from wheatgrass/clover (white or red, and subterranean) mixes.

With a one-cut policy, the crop is mown just as the lucerne starts to flower, at which time the intermediate wheatgrass is just producing flower-heads. Lucerne/ wheatgrass hay is very sweet smelling and bulky and dries better than pure lucerne. Pubescent wheatgrass is similar in a lucerne mix, but has slightly less leaf.

Crop maintenance includes the application of 200 kg/ha of sulphur super extra every 3–4 years depending on the paddock and whether hay has been produced from it. The pH is maintained at about 5.9–6.4 by liming and liquid fertiliser may be applied with added minerals if the paddock is used for hay. No stock health, pest or plant disease problems have been noted with any of the wheatgrass varieties available in New Zealand, this being a major advantage. Wheatgrass juice is used as a human health tonic overseas.

Growth of wheatgrass slows or ceases during winter but accumulated foliage is little affected by cold and frosting. In a drought the plant slows down but it recovers quickly after rain. Care must be taken when stocking wheatgrass after stress periods as it is very palatable compared with other pasture plants and could easily be over-grazed.

Intermediate wheatgrass has grown well at Belfield and more cv. Rush will be sown this coming season, some for seed, the rest with lucerne for hay.

Conclusions

Intermediate and pubescent wheatgrass are extremely valuable for use in friable, erodible dryland soils owing to their sod-forming nature. They are abundant seeders and have good seedling vigour which permits their sowing with a minimum of seed-bed preparation. Seed availability from imported or locally grown sources is good. Their adaptation to a wide range of soils, moisture conditions and climatic extremes make wheatgrasses extremely useful for plantings intended to protect and secure dryland soil resources.

Under dryland hill conditions, intermediate and pubescent wheatgrass establish slowly but they are moderately productive and eventually form a dense groundcover owing to slow rhizome spread. On fertile soils they can be quite productive and their yield may approach that of the New Zealand-bred cultivars of

other genera. Wheatgrasses are suitable for *in situ* grazing or for hay-making, and may have potential as perennial grain crops. Palatability is good and the foliage overwinters well. Both intermediate and pubescent wheatgrasses are well suited to dryland areas of New Zealand receiving an annual rainfall of 450–900 mm, especially on drought-prone downland and coastal hill sites, and inland valleys.

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