Comparing stacked and alternate-year cropping systems in a semiarid environment

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Diversification of wheat-fallow systems can improve economic and environmental sustainability of semiarid cropping systems, but the influence of rotation type and management level are little known. We conducted a study from 2005 through 2011 comparing two sets of crops in stacked and alternate-year rotations under conventional and ecological management levels. Crop sets were durum-canola-pea and durum-flax-pea. Continuous durum was included as a control. Conventional management included preplant tillage with a field cultivator, broadcast urea, standard seeding rates, and short durum residue height at harvest. Ecological management included zero tillage, banded urea at planting, greater seeding rates, and tall durum residue height at harvest **(Table 1)**.

Table 1. Management practices for durum in conventional and ecological systems.

Parameter	Conventional	Ecological
Urea fertilizer application	Preplant broadcast	Banded in single-pass planting
Tillage	Spring, field cultivar	Zero tillage
Planting rate, seed ha^{-1}	2,223,000	2,964,000
Planting date 2005-2007	Standard	Delayed 2-3 weeks from Standard
Planting date 2008-2011	Standard	Same day as Standard
Stubble height at harvest	Short	As tall as possible

Table 2. Stand density, grain yield, yield components, and crop and weed biomass for durum in two management systems and five rotations for seven years.

Treatment	Stand	Grain	Tillers	Seed	Seed	Height	Crop biomass	Harvest index	Weed biomass
	# m^2	kg ha^{-1}	# m^2	# tiller	mg seed	cm	kg ha^{-1}		kg ha^{-1}
Management									
Conventional	192 b†	1821	287 b	29.6	35.0	61	5001	0.38	278
Ecological	227 a	2009	335 a	28.3	35.3	63	5421	0.37	226
Rotation									
Continuous Durum	188 b	1891	313 ab	30.4 a	34.8	63	5120	0.38	340 a
D-Canola-D-Pea	210 ab	1860	315 ab	28.2 b	34.9	61	5179	0.36	212 b
D-D-Canola-Pea	226 a	1891	303 b	28.2 b	34.8	61	4992	0.38	267 ab
D-Flax-D-Pea	211 a	2015	299 b	28.7 b	35.9	62	5294	0.39	236 ab
D-D-Flax-Pea	213 a	1918	327 a	29.2 ab	35.4	62	5468	0.35	205 b
Year									
2005	193 d	2170 b	352 b	30.2 b	35.2 c	69 b	5529 b	0.41	248 b
2006	251 ab	908 e	257 d	28.2 c	25.0 e	55 d	4399 cd	0.21	235 b
2007	121 e	-	-	-	-	-	-	-	-
2008	230 c	1601 d	305 c	25.2 e	28.1 d	54 d	4102 d	0.39	4 d
2009	258 a	2391 a	308 c	26.7 d	47.2 a	51 e	5335 b	0.45	100 c
2010	236 bc	2498 a	396 a	32.2 a	35.4 c	80 a	7186 a	0.35	454 a
2011	178 d	1921 c	251 d	31.2 ab	40.1 b	63 c	4714 c	0.43	470 a
Significance						*P* > F			
Management (M)	*‡	NS	*	NS	NS	NS	NS	NS	NS
Rotation (R)	***	NS	NS	*	NS	NS	NS	NS	0.054
M x R	*	*	NS	NS	NS	*	NS	NS	NS
Year (Y)	***	***	***	***	***	***	***	***	***
M x Y	*	***	**	*	NS	***	***	*	***
R x Y	**	NS	*	NS	NS	NS	NS	NS	*
M x R x Y	NS	NS	NS	NS	NS	NS	NS	NS	NS

† Means followed by different letters within columns and treatment differ at P=0.05.
‡ *=0.05, **=0.01, ***= 0.001, respectively.

Rotations differed for stand and tiller density, and seed head-1, but differences were not consistently related to rotation type **(Table 2)**. The greater seeding rate for ecologically managed durum resulted in denser crop stand and reproductive tillers, however, it did not result in decreased weed biomass **(Table 2)**. Interactions of rotation with management **(Table 3)** and year **(Table 4)** were significant for durum yield. Durum yield was greater three of six years under ecological management than under conventional management. When differences existed, durum under ecological management was taller and had more reproductive tillers, but fewer seed head-1, than durum under conventional management. Rotation type and management inconsistently influenced weed biomass. Continuous durum had the greatest mean weed biomass at harvest **(Table 2)**. Weed biomass in durum did not differ between conventional and ecological management systems in four of six years **(Table 4)**. Durum was severely damaged following application of bromoxynil-MCPA herbicides during an unusually hot and humid day in 2007 and results for that year are not presented.

When systems are compared across all crop phases, conventional and ecological management provided similar grain yield, crop biomass, harvest index, and weed biomass **(Table 5)**. Continuous durum had the greatest grain yield. Stacked- and alternate year rotations with canola had higher grain yield than the stacked rotation that included flax; the alternate year rotation with flax was intermediate to all other rotations. Weed biomass was lower in rotations that included canola than rotations that included flax, regardless of rotation type **(Table 5)**. Harvest index was not influenced by rotation type. Economic analyses will provide additional information necessary for improved farmer decision making with these production systems.

Conclusions

Stacked- and alternate year rotation types generally were similar for the durum agronomic parameters measured in this study. Diversification of continuous durum production systems decreased weed biomass at harvest regardless of rotation type.

Table 3. Management by rotation interaction for **durum** grain yield averaged over six years.

Rotation	Management: Conventional	Management: Ecological
	yield kg ha^{-1}	
Continuous Durum	1833 a	1948 a
Durum-Canola-**Durum**-Pea	1826 a	1893 a
Durum-**Durum**-Canola-Pea	1701 b	2081 a
Durum-Flax-**Durum**-Pea	1827 a	2203 a
Durum-**Durum**-Flax-Pea	1918 a	1917 a

Table 4. Management system by year interactions for durum.

Year	Management: Conventional	Management: Ecological
	Grain yield, kg ha^{-1}	
2005	2074 a	2266 a
2006	963 a	853 a
2008	1759 a	1443 b
2009	2247 b	2535 a
2010	2269 b	2726 a
2011	1614 b	2227 a
	Tillers, no. m^2	
2005	321 b	382 a
2006	251 a	264 a
2008	303 a	307 a
2009	274 b	342 a
2010	354 b	437 a
2011	222 b	280 a
	Seed, no. head^{-1}	
2005	30.6 a	29.9 a
2006	29.6 a	26.8 b
2008	26.6 a	23.9 b
2009	27.7 a	26.7 a
2010	33.1 a	31.3 b
2011	30.2 a	32.1 a
	Crop biomass, kg ha^{-1}	
2005	5038 b	6021 a
2006	4657 a	4140 a
2008	4287 a	3916 a
2009	5219 a	5452 a
2010	6894 a	7477 a
2011	3910 b	5517 a
	Harvest index	
2005	0.44 a	0.38 b
2006	0.21 a	0.21 a
2008	0.41 a	0.36 a
2009	0.44 a	0.46 a
2010	0.34 a	0.37 a
2011	0.43 a	0.43 a
	Weed biomass, kg ha^{-1}	
2005	276 a	218 a
2006	258 a	213 a
2008	2 a	7 a
2009	41 b	160 a
2010	583 a	324 b
2011	508 a	433 a

Means within parameter and rows followed by the same letter do not differ at P=0.05

Table 5. Grain yield, crop biomass, harvest index, and weed biomass for five rotations in two management systems over 7 years.

Treatment	Grain kg ha^{-1}	Crop biomass kg ha^{-1}	HI	Weed biomass kg ha^{-1}
Management				
Conventional	1647	4885	0.34	285
Ecological	1802	5170	0.35	242
Rotation				
Continuous Durum	1891 a	5120 ab	0.38	340 a
D-Canola-D-Pea	1762 a	5318 a	0.34	183 b
D-D-Canola-Pea	1706 a	5119 a	0.34	194 b
D-Flax-D-Pea	1689 ab	4815 b	0.35	277 a
D-D-Flax-Pea	1577 b	4767 b	0.35	325 a
Year				
2005	1934 b	5333 b	0.39 a	261 ab
2006	970 d	4279 c	0.23 c	245 ab
2007	-	-	-	-
2008	1496 c	4370 c	0.34 b	46 c
2009	1938 b	5176 b	0.37 a	143 b
2010	2227 a	6325 a	0.36 a	536 a
2011	1786 b	4684 c	0.41 a	350 a
P > F				
Management (M)	NS	NS	NS	NS
Rotation (R)	*	**	NS	***
M x R	NS	NS	NS	NS
Year (Y)	***	***	***	***
M x Y	*	**	NS	**
R x Y	NS	NS	NS	NS
M x R x Y	NS	NS	NS	NS