RESEARCH PROJECT TITLE: Identifying superior *Brassica* species and cultivars within species that are suitable for direct seeding throughout the Pacific Northwest region.

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FINAL REPORT: Final report of project started in 1999.

PROJECT OBJECTIVES:

- Examine interactions between four *Brassica* crop species (*B. napus, B. rapa, B. juncea* and *Sinapis alba*) to determine which spec es has the greatest adaptability to different regions th ughout the Pacific Northwest.
- Examine genotype by tillage system interactions within canola (*B. napus*), yellow mustard (*S. alba*), and oriental mustard (*B. juncea*) and identify specific cultivars with superior adaptability to direct seeding systems in different rainfall regions of the Pacific Northwest.

KEY WORDS: canola, mustard, genotype by tillage interactions

STATEMENT OF PROBLEMS TO BE ADDRESSED:

Predominance of monoculture cereal production in the Pacific Northw st dryland regions over the past 100 years has resulted in a buildup of soil-borne diseases. Rainfall in the Pacific Northwest can vary from high (> 20 inches annually) to low (<8 inches annually), and the traditional cropping systems have been winter wheat/summer fallow and wheat/barley/legume rotations. Farmers have shown increased interest in annual cropping systems, and the advantages of *Brassica* crops have induced growers to include them in their crop rotations. At present, growers in the Pacific Northwest region have the option of planting four different spring-planted *Brassica* species: canola, rapeseed (from either *B. napus* or *B. rapa*), yellow mustard (*S. alba*) or oriental mustard (*B. juncea*). Of the four species available, *B. napus* is least heat and drought tolerant, followed by *B. rapa* and *B. juncea*, with *S. alba* showing greatest adaptability to driest regions. Genotype by environment interaction is in some way involved in most problems associated with quantitative genetics and all problems in plant breeding. It is difficult to believe that a change from conventional tillage to direct seeding systems will not be associated with some degree of cultivar by seeding system interaction. To identify the most appropriate spring *Brassica* species from different regions throughout the Pacific Northwest and to select the most productive cultivars from within each species will require a more detailed description of cultivar response to direct seeding.

AGRONOMIC ZONE OF INTEREST: Annual cropping; low, intermediate and high rainfall; non-irrigated.

ABSTRACT OF RESEARCH FINDINGS:

Yield potential of canola, oriental mustard and yellow mustard cultivars (and advanced breeding lines) was evaluated under direct seeding and conventional management systems in three years (2000, 2001, and 2002). Genotypes by tillage interactions were significant in all years. All species showed a significant yield reduction when direct seeded, most likely due to later planting and greater weed competition. Greatest reductions in seed yield were found where land had previously been in conventional tillage systems; conversely, yields were most similar when land had been direct seeded for several years. Genotype by tillage interactions were found to be greatest in yellow mustard (*S. alba*) and least in canola (*B. napus*). On average, canola cultivars performed the same under the two tillage management schemes. However, there were large differences between individual canola cultivars, whereby performance under the two schemes was not related. In mustard species, the most adapted lines suited to direct seeding were not the most adapted to conventional tillage. The results suggest that advances will be made in cultivars for direct seed systems if they are selected specifically for such tillage management systems. In conclusion, it is recommended that *Brassica* genotypes need to be evaluated under direct seeding and conventional tillage systems to ensure that the cultivars best suited to different management systems are identified.

RESULTS AND INTERPRETATION:

Two separate, but related trials were conducted: (1) *Four species experiment*, where four cultivars from each of four different *Brassica* species (*B. napus, B. rapa, B. juncea,* and *S. alba*) were grown in an split-plot design at three locations, where main-plots were seeding treatment (direct vs. conventional), and species and cultivars within species were subplots and sub-subplots respectively; (2) *Regional cultivar testing*, where canola (*B. napus*), oriental mustard (*B. juncea*) and yellow mustard (*S. alba*) cultivars and were grown at five locations (Moscow, ID; Genesee, ID; Pendleton, OR; Davenport, WA; Nezperce, ID) each year under direct seed and conventional seed conditions.

Four species experiment

In 2000, averaged over all species, seed yield from direct seeding was significantly reduced (approximately 10%) compared to conventional seeding (Table 1). The species by seeding treatment interaction was significant, whereby *B. napus* and *B. rapa* yield in the two seeding situations were not significantly different; however, the two mustard species (*B. juncea* and *S. alba*) showed significant yield loss when direct seeded. Initially this result was unexpected, as past experience had shown that the mustard species (especially *S. alba*) were well adapted to direct seeding. Averaged over both treatments, highest yield was obtained from *B. juncea* and lowest yield from *S. alba*, while the two canola species (*B. napus* and *B. rapa*) were not significantly different.

In this first year it should be noted that the three sites were chosen to represent one site which had been under a direct seed system for sixteen years (Nezperce), one which has been under a direct seed system for four years (Davenport) and the other (Genesee) which had been conventionally

seeded until this experiment. A highly significant interaction was observed between sites and seeding treatment (Table 2). At Nezperce (long-term direct seeding), all four species produced significantly higher seed yield from direct seeding compared to conventional tillage. Conversely, at the other two sites the conventional seeding was more productive. Direct seed resulted in an average 19% and 32% yield loss in direct seeded plots at Davenport and Genesee, respectively. Therefore, as might be expected, the benefit for direct seed *Brassica* crops increases with the number of years into a direct seed system. Greater work will be necessary to allow farmers to overcome any potential yield loss that occurs in the transition period in getting the full benefits of direct seeding systems.

Despite the overall yield reduction under direct seeding, the relative performance of the four species, and cultivars within species, was constant. However, even with very few cultivars within species, there were changes in relative rank. The *B. rapa* cultivars ranked identically under both seeding treatments. In *B. napus* the highest yielding line ('Hyola.401') under direct seeding was the highest yielding under conventional seeding. However, the second highest yielding canola cultivar ('Sunrise') was ranked last under direct seeding. Similarly, there were changes in relative performance in both mustard species.

Seed yield from the 2001 direct seeded plots were significantly lower than yield from conventionally tilled plots (Table 3). In this year, greatest yield reduction was found in the *B. napus* (canola) cultivars (33%) and least difference noted in the *S. alba* (yellow mustard) cultivars (19%). The difference between direct seeded and conventional tillage varied markedly at the different sites. Yield from both tillage treatment were very similar at the Moscow location while the direct seed yield was half that from conventional tillage at Nezperce (Table 4). The relative performance of the cultivars and species under different tillage systems was similar. The oriental mustard (*B. juncea*) cultivars proved to be most adapted to either tillage system and were always highest yielding.

Regional cultivar testing

The greatest limitation in cultivar development is genotype by environment interaction. If cultivar relative performance can be predicted in one environment and that performance is highly related to another, then greatest progress will be made. For example, if performance under conventional tillage is highly related to direct seeding, then plant breeders need only test breeding lines in one of the systems and the "better" lines can be identified for both. The performance of cultivars under the different treatments can be examined using correlation; higher correlation coefficients between yields from different environments will indicate low genotype by environment interaction, while low correlation coefficients indicate high interactions and would question selection under one environment to identify cultivars suitable for the other.

A trend similar to the above was noted for entries in the Pacific Northwest Canola Variety Trial and the Pacific Northwest Mustard Variety Trial under conventional and direct seed situations (Table 5). Correlation coefficients were obtained across all 10 environments in this study (5 locations, each with direct seeded and conventionally seeded plots). Correlation coefficients were averaged for each species according to the following: (1) between direct seeding and conventional

seeding at the same site; (2) between conventional seeding at different sites; (3) between direct seeding at different sites; and (4) between direct seeding at one site and conventional seeding at another. The average correlation coefficients are shown in Table 6 for each of the three species examined. In general, correlation coefficients for yield between different environments were high for canola, intermediate to high for oriental mustard, and low for yellow mustard. Correlation coefficients for yield between seeding treatments at the same sites were significant for canola and oriental mustard (accounting for 20% and 25% of the total variation in yield in canola and oriental mustard, respectively). Greater genotype by environment interactions were detected in oriental mustard between conventional seeding at different sites than direct seeding at different sites.

A similar pattern in treatment effects was noted in the 2001 Regional Trial results, where the *B. napus* (canola) cultivars appeared most responsive to direct seeding (Table 7). Averaged over all cultivars, direct seed yield was more than 23% reduced compared to conventional tillage. As with the four species experiment, the yellow mustard cultivars were only slightly lower yielding under direct seeding compared to conventional tillage (11% reduction). The oriental mustard cultivars were intermediate in response with a 19% yield reduction in direct seeded plots.

The relationship between performances under the two tillage systems again examined in 2001 by correlation (Table 8). Overall, the performance of the canola cultivars was relatively similar irrespective of location and tillage management, where performance under conventional tillage provided a good indication as to performance in a no tillage system. The correlation between average yield in both systems was very high ($r = 0.91$). Indeed four of the top yielding canola cultivars under conventional tillage were amongst the top five lines when direct seeded. The good relative relationship between canola yields under the two systems can be seen graphically in Figure 1. The correlation between conventional and direct seeding for oriental mustard (*B. juncea*) was lower than for the canola, but in most cases was highly significant. Similarly, performance under conventional seeding was a reasonable indicator to performance under direct seeding (Figure 2), where average yield in both systems was correlated at $r= 0.83$. In contrast, performance of yellow mustard cultivars under conventional tillage provided little indication as to the yield potential when direct seeded. Although only eleven lines were evaluated the five highest yielding lines under conventional tillage included only two of the top five yielding lines when direct seeded. Although the advanced breeding line 'UI.3277', was highest in yield in both tillage systems (Figure 3) there were large relative differences in yield potential of yellow mustard lines in the different management systems ($r = 0.39$).

Despite non-significant interactions between tillage treatment and cultivar in 2002, heritability estimates were only moderate for oriental mustard and very low for canola. This would suggest that performance under conventional tillage was not strongly related to yield performance under direct seeding situations (Table 9). Examining first the canola cultivars and their relative performance (Figure 4), the highest yielding cultivar under conventional tillage was 'Hylite 289' which averaged 1876 lb/acre. Hylite, however, was only ranked 15th in overall yield (1526 lb/acre) under direct seeding. Similarly, 'Clearwater' (a new Raptor® resistant spring canola release from the University of Idaho) was ranked as second highest yield under conventional tillage (1799 lb/acre), but produced significantly lower yield (1450 lb/acre) and ranked as 20th under direct seeding. Converse

examples were found when the "better" cultivars under direct seeding were examined. The highest yielding cultivar when direct seeded was the breeding line 'UISH00.3.13', which produced an average of 1849 lb/acre direct seeded but only 1633 lb/acre (ranking 9th) when conventionally seeded. 'KAB 36' ranked second under direct seeding (1840 lb/acre) but 12th (1596 lb/acre) when conventionally seeded. The results shown here for canola differed from the previous year where the "best" lines under direct seeding were indeed also the "better" ones when conventionally seeded. This might again be explained by the more severe drought condition of 2002 compared to 2001.

Highest heritability between tillage treatment yields was found in oriental mustard cultivars. Indeed inspection of yield in oriental mustard under the different tillage treatments (Figure 5) does suggest a good relationship. However, it should be pointed out the 'Pacific Gold' was significantly highest yielding under both direct seed and conventional seed than any other cultivars in trial. This does indicate that an oriental cultivar can be selected that has high yield potential in both systems. Also, the lowest yielding cultivar, 'Common Brown' has previously been shown to be highly unadapted to the Pacific Northwest region. These two cultivars therefore have perhaps bias the heritability estimate, and as is shown from Figure 5, the other cultivars did not express the same repeatability under the different treatments.

Yellow mustard heritabilities for yield under different tillage management were also moderately low. Often there were large differences between yield potential under the two treatments (Figure 6). An advanced University of Idaho breeding line, 'UI3277,' was highest yielding entry in both direct and conventional seeding. 'IdaGold' also showed adaptability to both tillage management schemes. However, line '92XH.83.8' ranked second with average yield of 1572 lb/acre when conventionally seeded but ranked as the lowest yielding (1201 lb/acre) when direct seeded.

There is some indication that the "better" canola lines under direct seeding can be identified by evaluation of genotypes under conventional tillage systems. However, one should note that the primary character of interest when determining canola line adaptability is early flowering (to avoid heat damage). Early flowering under direct seeding would be equally important (or more so) since planting time in a direct seed system can often be delayed compared to conventional seeding. Oriental mustard is less sensitive to heat damage and yellow mustard is relatively tolerant to heat so the later seeding under direct seeding is not so influenced by cultivar flowering time. It is therefore concluded that cultivars need to be evaluated in and selected for adaptation to different tillage systems in order to ensure that cultivars have the greatest adaptability to differing management practices. Overall, the results from all three years conclude that it will be necessary to test canola, oriental and yellow mustard breeding lines for adaptability to direct seeding situations early in the selection scheme to ensure that the "better" adapted lines suitable for direct seeding systems are not lost from the program due to somewhat inferior adaptation to conventionally tilled systems.

PUBLICATIONS AND PRESENTATIONS:

Abstracts and Proceedings

Erickson, D.A., J. Brown, J.B. Davis, L. Seip, and T. Gosselin, 2002. Developing yellow mustard cultivars for the Pacific Northwest. *In:* Proceedings of the Western Society of Crop Science Meeting, Hawaii, June 3, 2002.

Brown. J., 2002. Developing *Brassica* crops and management systems for direct seeding. 2002 Direct Seed Conference, Spokane, Washington, January 18, 2002.

Davis, T., J. Brown, D. Erickson, and J.B. Davis, 2001. Selection efficiency in early breeding stages of a canola cultivar development program. *In:* **P**roceedings of Western Society of Crop Science Meeting, Tuscon, Arizona, June 11-13, 2001.

Davis, T., J. Brown, D. Erickson, and J.B. Davis, 2001. Selection Efficiency in early breeding stages of a canola cultivar development program. *In:* Proceedings of Pacific Northwest Regional Canola Meeting, Spokane, Washington, January 17, 2001.

Davis, J.B., J. Brown, D. Erickson, and L. Seip, 2001. Compare performance of direct-seeded and seeding after conventional tillage of three *Brassica* crops species in the PNW. In proceedings of Pacific Northwest Regional Canola Meeting, Spokane, Washington, January 17, 2001.

Brown, J., J.B. Davis, A.P. Brown, D. Erickson & L. Seip, 1999. Comparison performance of cultivars from three *Brassica* species when direct-seeded and conventionally seeded. *In:* Proceedings Pacific Northwest Canola Meeting, Great Falls, MT, November 1999.

Reports

Brown, J., and D. Wysocki, 2003. Identifying superior *Brassica* species and cultivars within species that are suitable for direct seeding throughout the Pacific Northwest region. *In:* Department of Plant, Soil and Entomological Sciences 2003 Field day. Research and Extension Report. Pp. 24-28.

Brown, J., J.B. Davis, D.A. Erickson, L. Seip, and T. Gosselin, 2001. Identifying superior *Brassica* species and cultivars within species that are suitable for direct seeding throughout the Pacific Northwest region. Pp 9.

Brown, J., and D. Wysocki, 2000. Identifying superior *Brassica* species and cultivars within species that are suitable for direct seeding throughout the Pacific Northwest region. Prepared for STEEP, November 2000.

Presentations

Brown, J. Developments in *Brassica* breeding. Presented to State and Federal legislators, Moscow, Idaho, August 16, 2000.

Brown, J. Canola and Mustard Breeding at the University of Idaho. Presented to Washington State Crop Improvement, Moscow, Idaho, November 14, 2001.

Brown, J. Alternative cropping systems including rapeseed, canola and mustard. Presented to Columbia County Growers Meeting, La Crosse, Washington, January 25, 2001.

Brown, J. Developments in canola, rapeseed, and mustard breeding. Presented to Moscow Idaho Seed Growers, Moscow, Idaho, February 9, 2001.

Developments in canola, rapeseed, and mustard breeding. Presented to Moscow Idaho Seed Growers, Kendrick, Idaho, February 16, 2001.

Including *Brassica* crops in your rotation. Presented to Bonner County Growers, Bonners Ferry, Idaho, February 27, 2001.

Developments in canola, rapeseed, and mustard breeding. Presented to Colfax Grain Growers, Colfax, Washington,

Including *Brassica* crops in rotation with small grain cereals. Northwest Direct Seed Intensive Cropping Conference, Pendleton, OR, January, 2000.

Comparison of performance of cultivars from three *Brassica* species when direct-seeded and conventionally seeded. Pacific Northwest Canola Meeting, Great Falls, MT, November 1999.

Table 1. Average seed yield of four *Brassica* species grown under direct seed and conventional seed situations in 2000.

Treatment	Species				
	B. napus	*B. rapa*	*B. juncea*	*S. alba*	Mean
	lb/acre				
Direct	1926	1852	1978	1635	1848
Conventional	1950	1905	2376	1942	2043
Mean	1938	1876	2177	1789	

Table 2. Average seed yield of four *Brassica* species at three sites grown under direct seed and conventional seed situations in 2000.

Site	Treatment	Species				
		B. napus	*B. rapa*	*B. juncea*	*S. alba*	Mean
		lb/acre				
Nezperce	Direct	2171[1]	2269[2]	2316[3]	2181[4]	2234
	Conventional	1767	1821	1763	1571	1730
Davenport	Direct	2074	2036	2188	1731	2007
	Conventional	2590	2423	2734	2242	2497
Genesee	Direct	1269[3]	1116	1436	1386	1302
	Conventional	2157	2169	1780	1502	1902
Mean		1938	1876	2177	1789	

[1] $LSD_{5\%}$ within treatments and sites for *B. napus* = 432.2; ; [2] $LSD_{5\%}$ within treatments and sites for *B. rapa* = 199.5; [3] $LSD_{5\%}$ within treatments and sites for *B. juncea* = 325.2; [4] $LSD_{5\%}$ within treatments and sites for *S. alba* = 164.2.

Table 3. Average seed yield of four *Brassica* species grown under direct seed and conventional seed situations in 2001.

Treatment	Species				
	B. napus	*B. rapa*	*B. juncea*	*S. alba*	Mean
	lb/acre				
Direct	1375	1394	1761	1426	1489
Conventional	2064	1909	2461	1760	2049
Mean	1720	1652	2111	1593	

Table 4. Average seed yield of four *Brassica* species at three sites grown under direct seed and conventional seed situations in 2001.

Site	Treatment	Species				Mean
		B. napus	*B. rapa*	*B. juncea*	*S. alba*	
		lb/acre				
Moscow	Direct	1763[1]	1814[2]	2626[3]	2013[4]	2054
	Conventional	2169	2148	2559	1834	2177
Genesee	Direct	2368	2111	3094	2322	2474
	Conventional	1365	1349	1844	1509	1517
Davenport	Direct	1211	968	1374	1042	1149
	Conventional	1081	1168	1517	1200	1242
Nezperce	Direct	2638	2209	2674	1684	2301
	Conventional	1162	1445	1201	1139	1237
Mean		1720	1652	2111	1593	

[1] $LSD_{5\%}$ within treatments and sites for *B. napus* = 256.9; [2] $LSD_{5\%}$ within treatments and sites for *B. rapa* = 219.1; [3] $LSD_{5\%}$ within treatments and sites for *B. juncea* = 154.0; [4] $LSD_{5\%}$ within treatments and sites for *S. alba* = 259.4.

Table 5. Average seed yield of three *Brassica* species at five sites grown under direct seed and conventional seed situations in 2000.

Species	Treatment	Site					Mean
		Moscow	Genesee	Pendleton	Davenport	Nezperce	
		lb/acre					
B. napus	Direct	1696[1]	1231	978	2187	2719	1762
	Conv.	1980	2719	817	2957	1807	2056
B. juncea	Direct	2182[2]	1428	530	1939	2266	1669
	Conv.	2259	2324	530	2644	1708	1893
S. alba	Direct	2023[3]	1417	505	1936	2013	1579
	Conv.	1975	1739	559	2241	1693	1368

[1] $LSD_{5\%}$ within treatments and sites for *B. napus* = 345.2; [2] $LSD_{5\%}$ within treatments and sites for *B. juncea* = 444.2; [3] $LSD_{5\%}$ within treatments and sites for *S. alba* = 322.6.

Table 6. Average correlation coefficient for seed yield between the following: (1) direct seeing and conventional seeding at the same site; (2) direct seeding at different sites; (3) conventional seeding at different sites; and (4) direct seeding and conventional seeding at different sites, of three *Brassica* species in 2000.

Relationship	Canola *B. napus*	Oriental mustard *B. juncea*	Yellow mustard *S. alba*
Direct v conventional, same site	0.450	0.499	0.158
Direct seeding at different sites	0.329	0.544	0.164
Conventional seeding at different sites	0.466	0.130	0.098
Direct *v* conventional, different sites	0.385	0.211	0.093

Table 7. Average seed yield of three *Brassica* species at five sites grown under direct seed and conventional seed situations in 2001.

Species	Treatment	Site				
		Moscow	Genesee	Davenport	Nezperce	Mean
		lb/acre				
B. napus	Direct	2180[1]	2308	1272	1539	1825
	Conv.	2436	2989	1373	2674	2369
B. juncea	Direct	2615[2]	1693	880	1387	1644
	Conv.	2145	2934	1513	1565	2039
S. alba	Direct	2005[3]	1538	839	924	1326
	Conv.	1491	2304	1175	967	1484

[1] $LSD_{5\%}$ within treatments and sites for *B. napus* = 363.2; [2] $LSD_{5\%}$ within treatments and sites for *B. juncea* = 367.2; [3] $LSD_{5\%}$ within treatments and sites for *S. alba* = 401.9.

Table 8. Average correlation coefficient for seed yield between the following: (1) direct seeding and conventional seeding at the same site; (2) direct seeding at different sites; (3) conventional seeding at different sites; and (4) direct seeding and conventional seeding at different sites, of three *Brassica* species in 2001.

Relationship	Canola *B. napus*	Oriental mustard *B. juncea*	Yellow mustard *S. alba*
Direct vs. conventional, same site	0.739	0.438	0.064
Direct seeding at different sites	0.645	0.226	0.261
Conventional seeding at different sites	0.625	0.457	0.103
Direct vs. conventional, different sites	0.639	0.343	0.094

Table 9. Average seed yield of three *Brassica* species at five sites grown under direct seed and conventional seed situations in 2002.

Species	Treatment	Site				
		Moscow	Genesee	Davenport	Nezperce	Mean
		lb/acre				
B. napus	Conv.	1373[1]	2645	580	1725	1581
	Direct	1280	2465	723	1865	1583 ns
B. juncea	Conv.	1842[2]	2088	521	1563	1504
	Direct	1490	954	593	1575	1158***
S. alba	Conv.	1750[3]	1857	920	1347	1468
	Direct	1272	1635	1046	1232	296***
Mean		1501	1941	731	1551	

[1] $LSD_{5\%}$ within treatments and sites for *B. napus* = 714.2; [2] $LSD_{5\%}$ within treatments and sites for *B. juncea* = 106.7; [3] $LSD_{5\%}$ within treatments and sites for *S. alba* = 200.7. *** = Conventional tillage significantly higher yield than direct seeding ($P<0.001$); ns = Conventional tillage yield not significantly different from direct seeding.

Figure 1. Yield of 28 spring canola cultivars grown under conventional tillage and direct seed into cereal straw in 2001.

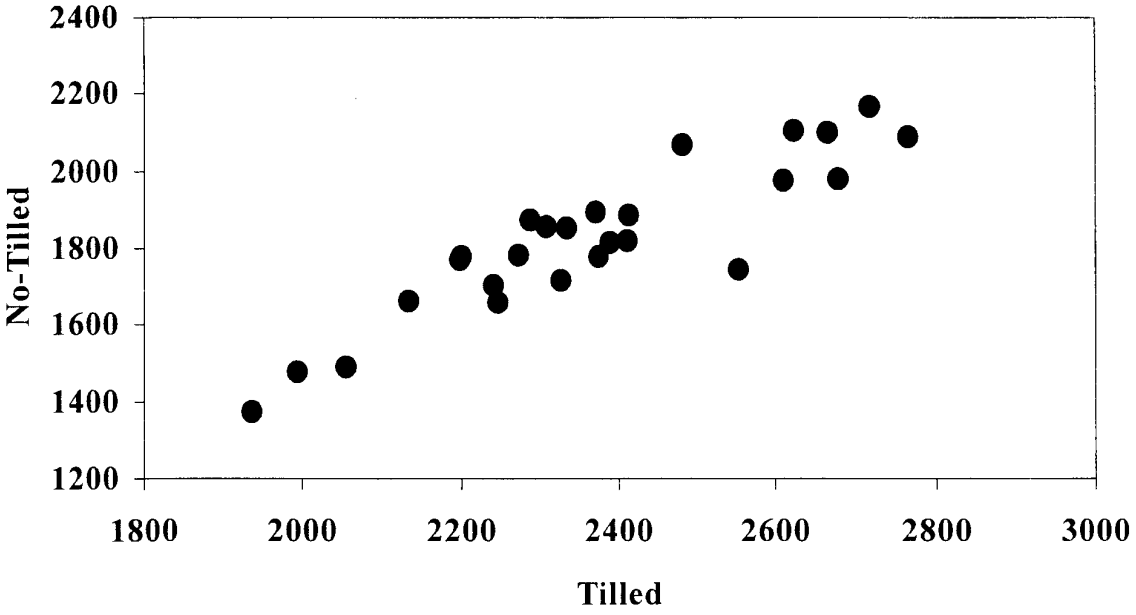

Figure 2. Yield of 9 oriental mustard cultivars grown under conventional tillage and direct seed into cereal straw in 2001.

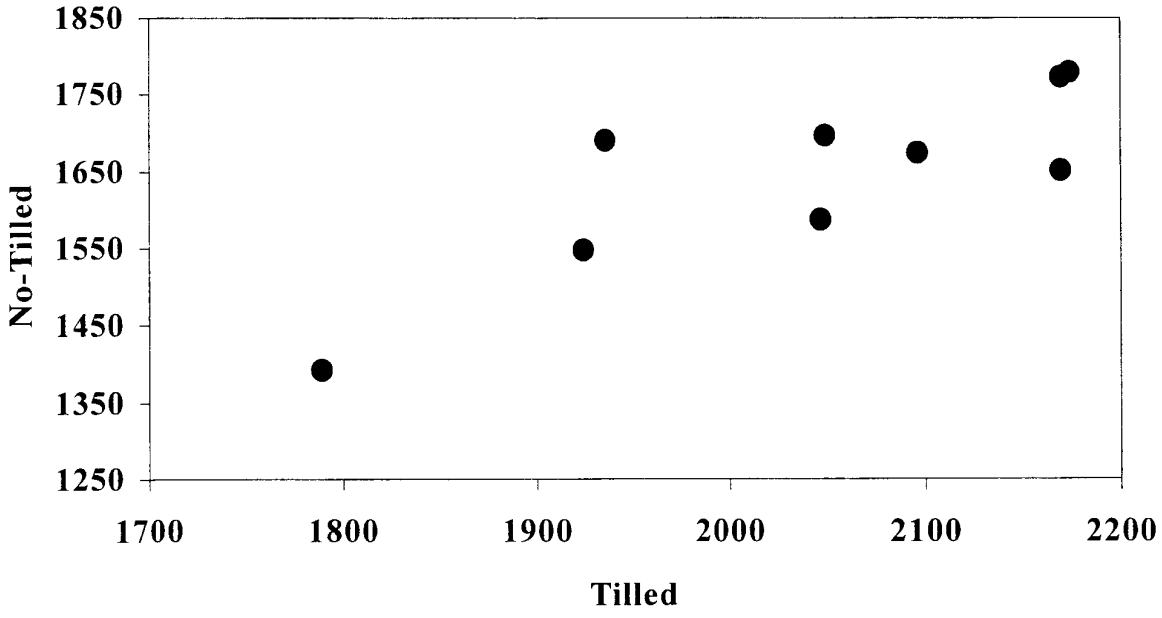

Figure 3. Yield of 11 yellow mustard cultivars grown under conventional tillage and direct seed into cereal straw in 2001.

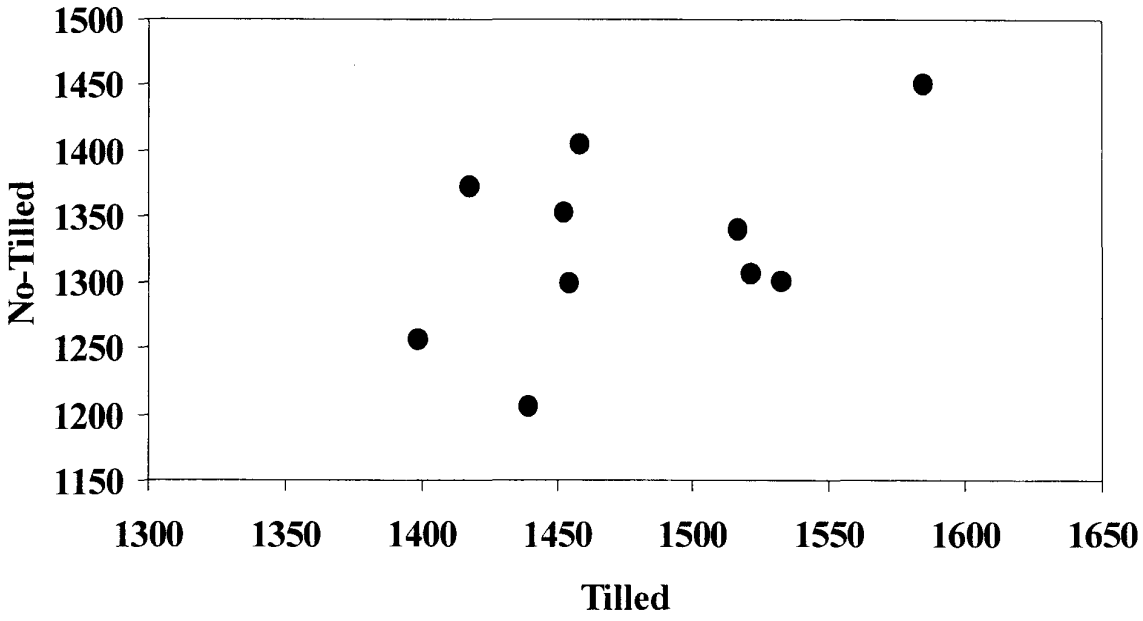

Figure 4. Seed yield (lb/acre) of 22 canola (*B. napus*) cultivars grown under direct seed and conventional seed situations in 2002.

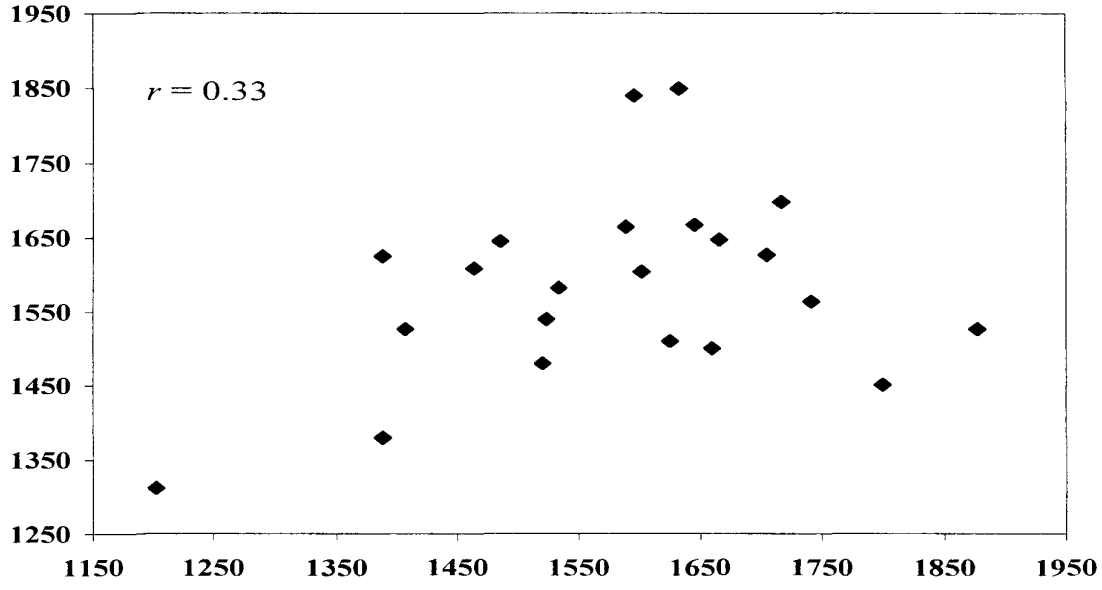

Figure 5. Seed yield (lb/acre) of 9 oriental mustard (*B. juncea*) cultivars grown under direct seed and conventional seed situations in 2002.

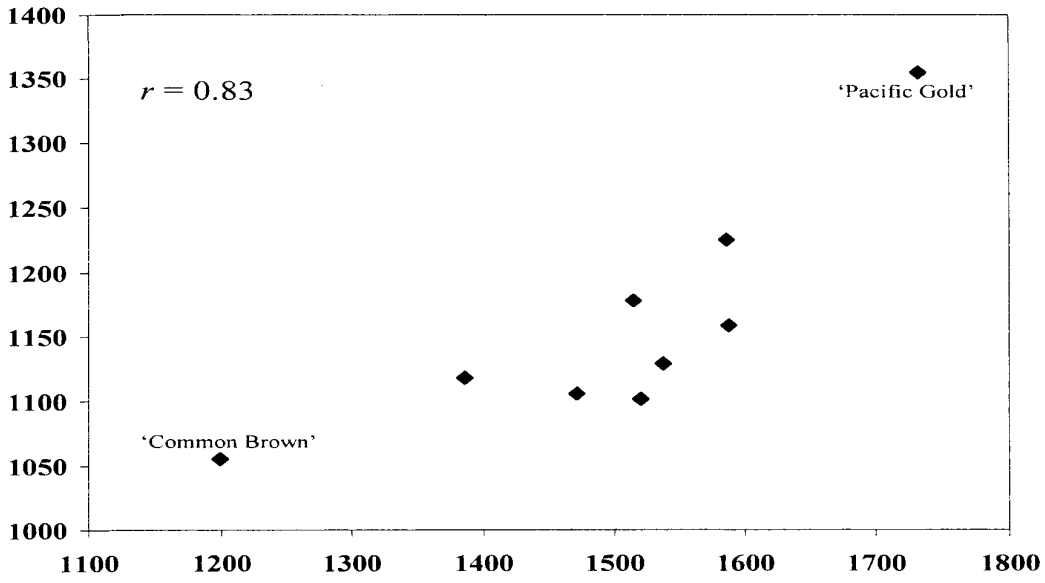

Figure 6 Seed yield (lb/acre) of 15 yellow mustard (*S. alba*) cultivars grown under direct seed and conventional seed situations in 2002.