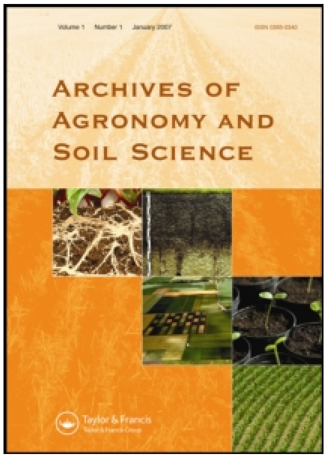

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Bed and flat planted dryland winter wheat as influenced by row configuration

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Abstract
Two experiments were conducted in 2003 – 2005 at Hennessey and Lake Carl Blackwell, Oklahoma, to determine the effect of row configuration in bed and flat planting systems in dryland winter wheat. In the bed and flat systems, 8 and 12 treatments were evaluated that included a factorial combination of 2-varieties ("Jagalene" and "2174"), 2-N rates (0 and 100 kg ha^{-1}) and row configurations. The row configurations were 2- and 3-row on a 75 cm bed. With 2- and 3-row per bed, 30 and 15 cm row spacing were used, respectively. In addition the traditional configuration of a solid stand with 15 cm row spacing was evaluated in the flat system. In four of six site years, bed wheat (either 2- or 3-row per bed) resulted in yields equal to flat planted wheat (15 cm row spacing). No differences in wheat grain yield were found when planting either 2- or 3-row per bed, or on the flat. However, both 2- and 3-row per bed resulted in increased yields when compared to 2- and 3-row configurations without beds. This suggests that bed planting with correct row configuration can help maintain high level of yield through its direct and indirect effect on crop growth characteristics.

Keywords: *Winter wheat, row configuration, nitrogen concentration, bed planting system, flat planting system*

Introduction

Bed planting systems have been used in cultivation for centuries. The origin of raised bed cultivation has traditionally been associated with water management issues either by providing opportunities to reduce the impact of excess water in rainfed conditions or to more efficiently deliver irrigation water in high production irrigated systems (Sayre 2003). Sayre goes on to state that the opportunities for raised bed systems are endless. In dryland agriculture, bed planting systems are used with small dykes to trap water after a rain so the fields are able to retain more water and store moisture for future crops versus letting it run-off.

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Iragavarapu and Randall (1997) stated that spring wheat (*Triticum aestivum* L.) performance was affected by the position of the row in a ridge-till system. On poorly drained soils that tend to be cooler in the spring, wheat rows planted on the ridge tops and shoulders had greater grain and straw yield and total nitrogen (N) uptake than those rows planted in the furrows. They explained that this variation is due to better drainage and warmer soil conditions on the ridge tops and shoulders than in the furrows.

Limon-Ortega and Sayre (2003) noted that an important field-access advantage of bed-planting is the flexibility it allows to apply fertilizer when and where it can be most efficiently used. Fertilizer can be applied by direct placement in bands between the wheat beds or rows when the wheat plant can make the most efficient use without trampling the crop. The bulk of fertilizer application can be delayed in a bed-planted system until the crop requirements are greater.

Hobbs et al. (1998) explained that bed-planted systems have several important advantages. These advantages included: improved water distribution and efficiency; provided an alternative for weed control with the ability to cultivate the furrows; reduced lodging because the wheat plants are not exposed to soft soil conditions and more light can penetrate the canopy, resulting in stronger plants; and allowed for dramatic reductions in seeding rates.

The system of bed-planting wheat for irrigated conditions that has been widely adopted by farmers in north-west Mexico offers an innovative option for diversifying wheat production practices. The great benefit of bed-planting for wheat production is the enhanced field access, which facilitates controlling weeds and other pests, handling nutrients, reducing tillage, and managing crop residues (Sayre & Moreno Ramos 1997).

Fahong et al. (2004) found that nitrogen use efficiency (NUE) could be improved by 10% or more in furrow irrigated bed-planting systems because of improved N placement possibilities. Also, the microclimate within the field was changed to the orientation of the wheat plants in rows on the beds, which reduced crop lodging and decreased the incidence of some wheat diseases. This was explained by the reduction in canopy humidity that is conducive to reduced disease pressure and enhanced healthy wheat growth. These advantages of increased NUE and decreased disease pressure improved grain quality and increased grain yield by more than 10%.

Some previous research work has been reported from rainfed experiments with wheat drilled on raised beds ranging from 1.2–2 m spacing (Morrison & Gerik 1983; Gerik & Morrison 1985). These reports consistently showed that wheat rows next to the furrow produced more heads per square metre and grains per spike than wheat rows in the centre of the bed, in the furrow, or to wheat rows flat-planted. Consequently, the grain yield average of wheat rows planted on beds has been lower than grain yield from wheat planted on the flat. However, grain yield measured individually from rows next to the furrow has been greater than yield from rows on the flat. On the other hand, work by Sayre and Moreno Ramos (1997) has shown that decreasing bed width to 75–80 cm can be used in rainfed conditions with two to three rows drilled 15–20 cm apart on top of those beds.

Mascagni and Sabbe (1990) attributed higher yields on wide beds (193 cm) to greater soil aeration and temperature as well as higher soil temperatures on top of the bed. This experiment investigated crowned beds, flat beds, and a flat planting system. There were no significant differences between planting system types, but there was a definite trend for the crowned beds to have higher yields, NUE, and N uptake. They also stated that one possible benefit of the wide-bed planting system beyond the obvious drainage aspect was that the furrow provides controlled traffic lanes. This may be an advantage in certain production systems and in soils that tend to have compaction problems.

Mascagni et al. (1991) noted that for grain sorghum (*Sorghum bicolor* L.) there was an increase in grain yield, dry weight, and N uptake on crowned beds as compared to the flat planting system. They concluded that the rows in the center of the crowned beds were where the major differences occurred. This suggested that growing conditions were more ideal on top of the crowned beds versus on the edges. Further research also showed that N uptake was higher on the crowned beds than the flat planting system.

Bed planting can be very effective for drainage where water tables result in excess surface moisture, especially after rain or even with irrigation. Under low rainfall conditions where moisture is limiting, initial results demonstrated that moisture can be effectively conserved with proper residue retention and management on permanent beds. Sweeney and Sisson (1988) reported that on poorly drained soils, wheat yields increased when grown on 75 cm raised beds. These researchers also found that soil temperature tended to be higher on the raised beds early in the growing season. Mascagni et al. (1995) observed that wheat produced on raised, wide beds may increase production efficiency and overall profitability. The raised, wide bed system may also integrate well with other crops in a rotation. While finding no grain yield advantage for raised bed wheat production, it was noted that in a situation where the field slope does not provide adequate surface drainage, bedding may be a viable management option. Also, since the use of raised beds did not significantly reduce yields, this practice may integrate into an overall production system including crop rotations and permanent beds.

In 1998, Sayre stated that the crucial first step in initiating research on bed-planting wheat is to test a wide spectrum of varieties with differing heights, tillering abilities, phenologies, and canopy architectures. Close cooperation between wheat breeders and agronomists to jointly identify and understand the proper plant type needed for optimum performance on beds is highly recommended.

In Canada, researchers found that among wheat yield components investigated, heads per unit area decreased as row spacing increased. Similar trends were noted for the number of plants per unit area described above. Plants with wider row spacing produced more kernels per head than plants with narrow row spacing, compensating for the lower number of heads per unit area. For example, plants with 30 cm row spacing produced 34% more kernels than plants in the 10 cm spacing. Row spacing did not have an impact on kernel weight. It was also observed that wide row spacing increased plant height. Higher N concentration available to the plants in the widely spaced rows than those in narrow rows might explain the increase in plant height and more kernels per head. The results of their studies show that a decrease in yield did not occur up to a row spacing of 30 cm (Lafond & Gan 1999).

Cutforth and Selles (1992) noted that paired rows of spring wheat had no agronomic advantage over equidistance row seeding. These pair rows were spaced 10 cm apart and 40 cm between pairs. However, earlier work by Papendick et al. (1985) explained that paired rows in winter wheat appeared to yield as well as, or slightly greater than flat seeded winter wheat. Porter and Khalilian (1995) noted that in a relay cropping system with skipped row wheat, there was no significant yield loss from the flat system wheat. To our knowledge, there was no information documented on the benefit of row configuration in dryland winter wheat in different planting systems with differing cultivar and N fertilizer levels. The objectives of the experiment were: (i) to determine if wheat planted with skipped rows will yield higher on raised beds than the wheat with the same skipped rows planted on the flat; and (ii) to determine if 3-row (15 cm spacing) seeded on a bed will yield more than 2-row (30 cm spacing) on the beds versus the same configurations in a flat planting system in two distinct planning systems.

Materials and methods

Two dryland field experiments were conducted in the fall of 2002 in bed and flat planting systems at two locations in Oklahoma. The first location was Hennessey with a soil classification Shellabarger sandy loam (fine-loamy, mixed, thermic Udic Argiustioll). The second location was Lake Carl Blackwell with a soil classification Pulaski fine sandy loam (coarse-loamy, mixed Thermic Typic Ustifluvent).

The bed and flat planting systems were treated as separate environments. These environments were kept separate because in a bed system the beds must be continuous across the extent of the experiment to allow for drainage of excess water. This bed system would be more representative of how a producer field would be constructed. Due to the importance of continuous beds, the mixing of flat planted plots in the same area was not implemented.

In the bed system, eight treatments comprised a complete factorial combination of varieties, N rates, and row configurations each at two levels. In the flat planting system, the variety and N levels remained the same but the row configurations included one additional level. The two varieties were "Jagalene" and "2174"; two commonly planted varieties in Oklahoma. Nitrogen rates were 0 and 100 kg ha^{-1}. In the bed system the row configurations were winter wheat planted on beds with 2- and 3-rows of winter wheat on 75 cm beds, furrow to furrow. The 2- and 3-row per bed configurations were spaced 30 and 15 cm apart, respectively. The additional configuration in flat planted wheat was solid seeding with 15 cm row spacing. The experimental design was a Randomized Complete Block with three replications. Plot sizes were 3.0×6.1 m.

The seeding rate in both systems was 88 kg ha^{-1}. This resulted in placing more seeds per meter of row on the beds due to the fewer number of rows planted. Beds were formed in early August with a 4-row lister set up on 75 cm centers and reshaped just prior to planting in October. Nitrogen was applied as ammonium nitrate (NH_3NO_3) and incorporated with the reshaping operation prior to planting. Winter wheat was planted with a 3 m AGCO drill set up on 15 cm spacing. All non-experimental plot management activities were accomplished as per Oklahoma State University Extension Service recommendation for the respective sites.

Plots were harvested using a self-propelled Massey Ferguson 8XP combine. The harvested area was 1.5×6.1 m for the bed plots and skipped row plots planted on the flat. An area of 2×6.1 m was harvested for the flat planted plots. A Harvest Master yield-monitoring computer installed on the combine was used to record yield and grain moisture data. Grain yield from each plot was determined and a sub-sample was collected for total N analyses. Grain samples were dried in a forced air oven at 66°C, ground to pass a 140 mesh sieve (100 μm), and analysed for total N content (Schepers et al. 1989) using a Carlo-Erba NA 1500 automated dry combustion analyser. Statistical evaluation and analysis of variance (ANOVA) were performed using SAS (SAS Inst. 2001).

Results

At each location, analysis was performed by year due to contrasting environmental conditions encountered over the length of this study. Thus, interactions by year were not investigated.

Grain yield

For the ANOVA performed by site and year, two-way interactions including system by variety, system by row, system by N rate, variety by row and variety by N rate, were significant in at least one site year. There were no significant three or four way interactions (ANOVA not shown). Although there were significant interactions for each site year, there were definite main effects trends (Table I). The effect of system showed that across the three years of this study, the bed system had a grain yield advantage over the flat system of 170 and 237 kg ha^{-1}

Table I. Main effects of planting system, variety, N rate, and row configuration on wheat grain yield at Hennessey and Lake Carl Blackwell, OK, USA, from 2003 – 2005.

System	Hennessey				Lake Carl Blackwell			
	2003	2004	2005	Avg.	2003	2004	2005	Avg.
	Grain yield, kg ha^{-1}							
Bed	3486 ab	2881 b	2883 a	3083	3488 ab	3832 a	2959 a	3426
Flat (rows)	3104 b	2855 b	2779 a	2913	3193 b	3462 b	2912 a	3189
Flat (solid)	3826 a	3435 a	2935 a	3399	3595 a	3827 a	3091 a	3504
Variety								
2174	3267 a	2681 b	2846 a	2931	3017 b	3578 a	2792 b	3129
Jagalene	3323 a	3055 a	2817 a	3065	3664 a	3716 a	3079 a	3486
N rate								
0 N	3205 a	2903 a	2987 a	3032	2697 b	3051 b	2512 b	2753
100 N	3384 a	2833 a	2676 a	2964	3984 a	4243 a	3360 a	3862
Row								
2-row	3256 b	2702 b	2834 a	2931	3211 a	3681 a	2950 a	3281
3-row	3334 b	3034 ab	2828 a	3065	3470 a	3613 a	2921 a	3334
Solid	3826 a	3435 a	2935 a	3399	3595 a	3827 a	3091 a	3504

Planting system: Bed and flat (rows/solid). Variety: "2174" and "Jagalene". N rate: 0 or 100 kg N ha^{-1}. Row configuration: 2-row (two rows, 30 cm spacing with 45 cm skip), and 3-row (three rows, 15 cm spacing with 45 cm skip) placed on beds and flat systems; Solid = Solid stand at 15 cm spacing placed in flat systems only; Within a column, means followed by the same letter are not different at $p < 0.05$ for each treatment effect.

at Hennessey and LCB, respectively. However, this trend was only observed when comparing the 2- and 3-row planting treatments on the bed and the flat. The flat planting system (solid stand) was superior to the bed and flat row planting in 5 of 6 site years. This trend for greater yield was evidenced by an increase of 316 and 78 kg ha^{-1} in the bed system and 486 and 315 kg ha^{-1} in the flat system at Hennessey and LCB averaged over the length of this study. "Jagalene" was the superior variety in the experiment with yields exceeding "2174" by 125 and 357 kg ha^{-1} at Hennessey and LCB, respectively. There was no response to applied N at Hennessey, and a response of over 1000 kg ha^{-1} of increased grain yield to added N fertilizer at LCB. The flat planting system produced higher yields than the 2- and 3-row configurations in all site years (Table I).

In 2003 at LCB, there was a significant system by variety interaction. "Jagalene" produced similar yields to "2174" in the bed system while yielding over 1000 kg ha^{-1} more grain on the flat. At Hennessey in 2003, grain yield of "2174" in the bed system was significantly higher than grain yield of "2174" in the flat system. "Jagalene" recorded higher grain yields than "2174" in both systems at Hennessey and LCB in 2004. No differences were noted between systems or varieties at Hennessey in 2005. However, grain yield of "Jagalene" was significantly higher than "2174" in the bed and flat systems at LCB in 2005 (Table II). Averaged across years at Hennessey and LCB, "Jagalene" produced higher grain yield in the bed and flat system than "2174".

Simple effects of planting system by row spacing on wheat grain yield are reported in Table V. This interaction was significant at LCB in 2003. The interaction occurred due to no differences between 2- and 3-row configurations in the bed system versus a significant increase in grain yield of 500 kg ha^{-1} of 3-row compared to the 2-row treatment in the flat system. At Hennessey in 2003, the 3-row configuration on the bed yielded similar to the solid stand, however, both of these treatments yielded significantly greater than 2-row on the bed and flat and 3-row on the flat. The solid stand was significantly higher than all other treatments at Hennessey in 2004. Also, the 3-row planting on beds was significantly better than the 2-row bed or either planting on the flat. Similarly at LCB in 2004, the solid stand was the highest yielding, yet both row configurations were significantly higher in the bed system than on the flat. No differences were noted among system or planting structure including the solid stand at both locations in 2005. Across years and locations, there was a distinct advantage of the solid stand over the 2- and 3-row planting structure in both the bed and flat systems. This trend was clearly established since the solid stand produced superior grain yield to the 2- and 3-row planting structures in bed and flat systems at six site years. Finally, 2- and 3-row planting structures were higher yielding in the bed system when compared to the flat (Table III).

There was a significant interaction of system and N rate at Hennessey in 2003. The incidence and severity of lodging increased with added N fertilizer in the bed system, however, reduced lodging was observed in the flat system. The increase in lodging resulted in a reduction in wheat grain yield for the bed system and allowed for grain yield of the flat system to exceed that of the bed system. Another significant interaction of system and N rate occurred at LCB in 2004. This can be explained by an increase in grain yield produced

Table II. Simple effects of planting system and variety on wheat grain yield at Hennessey and Lake Carl Blackwell, OK, from 2003–2005.

		Hennessey				Lake Carl Blackwell			
System	Variety	2003	2004	2005	Avg.	2003	2004	2005	Avg.
		Grain yield, kg ha^{-1}							
Bed	2174	3504 a A	2724 a A	2952 a A	3060	3366 a A	3797 a A	2792 b A	3318
Bed	Jagalene	3468 a A	3038 a A	2814 a A	3107	3610 a A	3867 a A	3126 a A	3534
Flat	2174	3029 a B	2637 b A	2739 a A	2802	2669 b B	3356 a B	2792 a A	2939
Flat	Jagalene	3179 a A	3072 a A	2820 a A	3024	3717 a A	3566 a A	3032 b A	3438

Planting system: Bed and flat (rows/solid); Variety: "2174" and "Jagalene"; Variety means within a planting system followed by the same lower case letter are not different from each other at $p < 0.05$; Planting system means within a variety followed by the same upper case letter are not different from each other at $p < 0.05$.

Table III. Simple effects of planting system and row spacing on wheat grain yield at Hennessey and Lake Carl Blackwell, OK, from 2003–2005.

		Hennessey				Lake Carl Blackwell			
System	Row	2003	2004	2005	Avg.	2003	2004	2005	Avg.
		Grain yield, kg ha^{-1}							
Bed	2-row	3331 a A	2662 b A	2876 a A	2956	3483 a A	3808 a A	3004 a A	3432
Bed	3-row	3618 a A	3101 a A	2822 a A	3180	3492 a A	3784 a A	2915 a A	3397
Flat	2-row	3158 b A	2744 b A	2771 b B	2891	2939 b B	3483 ab A	2897 a A	3106
Flat	3-row	3050 b B	2939 b A	2821 a A	2937	3439 a A	3441 b A	2927 a A	3269
Flat	Solid	3827 a	3435 a	2935 a	3399	3595 a	3827 a	3090 a	3504

Planting system: Bed and flat (rows/solid); Row configurations: 2-row = 2 rows, 30 cm spacing with 45 cm skip placed on beds and flat systems; 3-row = 3 rows, 15 cm spacing; with 45 cm skip placed on beds and flat system; Solid = Solid stand at 15 cm spacing placed in flat systems only; Row configuration means within a planting system followed by the same lower case letter are not different from each other at $p < 0.05$; Planting system means within a row configuration followed by the same upper case letter are not different from each other at $p < 0.05$.

in the bed system 0 kg N ha^{-1} treatments, significantly yielding more grain than the 0 kg N ha^{-1} treatments in the flat system. It is hypothesized that there was possibly increased moisture conservation in the bed system compared to the flat. In 2004 and 2005 at Hennessey, there was no response to added N fertilizer. However, the LCB site proved to be very responsive with 919 and 1298 kg ha^{-1} increase in grain yield in the bed and flat systems, respectively (Table IV).

In 2003 and 2004, significant variety by row interactions were observed. The 2003 crop year resulted in no differences between 2- and 3-row configurations with the variety "2174", however there was an increase in grain yield of nearly 500 kg ha^{-1} from 2- to 3-row configurations in the variety "Jagalene" (Table V). In 2004, 2-row planting was significantly higher than 3-row planting in "2174", whereas in "Jagalene", 3-row exhibited greater grain yield than 2-row planting. At LCB in 2005, no differences were recorded between 2- and 3-row configurations in either variety. Varieties and row configurations gave similar yields at Hennessey in 2003 and 2005. Alternatively, in 2004, grain yield of 2-row "2174" was significantly lower than 3-row "2174" and both plantings of "Jagalene". Across years and locations, the variety "Jagalene" proved to be higher yielding in both 2- and 3-row configurations (Table V).

Table IV. Simple effects of planting system and N rate on wheat grain yield at Hennessey and Lake Carl Blackwell, OK, 2003–2005.

		Hennessey				Lake Carl Blackwell			
System	N rate	2003	2004	2005	Avg.	2003	2004	2005	Avg.
		Grain yield, kg ha^{-1}							
Bed	0 N	3675 a A	2958 a A	3056 a A	3230	2908 b A	3404 b A	2588 b A	2967
Bed	100 N	3297 a A	2805 a A	2711 b A	2938	4068 a A	4260 a A	3330 a A	3886
Flat	0 N	2736 b B	2849 a A	2918 a A	2834	2487 b B	2698 b B	2435 b A	2540
Flat	100 N	3472 a A	2861 a A	2641 b A	2991	3899 a A	4227 a A	3389 a A	3838

Planting system: Bed and flat (rows); N rate: plots received 0 or 100 kg N ha^{-1}; N rate means within a planting system followed by the same lower case letter are not different from each other at $p < 0.05$; Planting system means within a N rate followed by the same upper case letter are not different from each other at $p < 0.05$.

Table V. Simple effects of variety and row spacing on wheat grain yield at Hennessey and Lake Carl Blackwell, OK, 2003–2005.

		Hennessey				Lake Carl Blackwell			
Variety	Row	2003	2004	2005	Avg.	2003	2004	2005	Avg.
		Grain yield, kg ha^{-1}							
2174	2-row	3264 a A	2429 b B	2759 a A	2817	3008 a B	3768 a A	2807 a B	3194
2174	3-row	3269 a A	2933 a A	2932 a A	3045	3027 a B	3387 b B	2777 a B	3064
Jagalene	2-row	3248 a A	2976 a A	2910 a A	3045	3415 b A	3594 a A	3094 a A	3368
Jagalene	3-row	3398 a A	3134 a A	2724 a A	3085	3912 a A	3839 a A	3064 a A	3605

Variety: two common varieties (2174 and Jagalene); Row configurations: 2-row (two rows, 30 cm spacing with 45 cm skip), and 3-row (three rows, 15 cm spacing with 45 cm skip) placed on beds and flat systems; Solid = Solid stand at 15 cm spacing placed in flat systems only; Row configuration means within a variety followed by the same lower case letter are not different from each other at $p < 0.05$; Variety means within a row configuration followed by the same upper case letter are not different from each other at $p < 0.05$.

Significant variety by N rate interactions was observed in 2003 and 2005 at Hennessey. In 2003, there was no response to added N fertilizer with "Jagalene", conversely a grain yield increase of 499 kg ha^{-1} in response to added N fertilization occurred for "2174". On the other hand in 2005, no differences in grain yield were noted in "2174" with added N and "Jagalene" showed a significant depression in grain yield with added N fertilizer. At LCB, both varieties showed a significant response to added N throughout the length of the study (Table VI).

Grain N concentration

For the analysis of variance performed for grain N concentration, variety by row configuration and system by N rate were the only two-way interactions that were significant in more than one site year. Two interaction exceptions were noted in addition to the two-way interactions noted above, but both were only slightly significant and inconsistent across years and locations. Variety and N rate were highly significant in all six site years. Planting system recorded significant differences in 2 out of 6 site years (ANOVA not shown).

The variety "2174" recorded significantly higher grain N concentrations that "Jagalene" across years and locations. Averaged over the duration of the study, the grain N concentration of "2174" was 2.1 and 1.6 g kg^{-1} greater that "Jagalene" at Hennessey and LCB respectively. There was also a highly significant ($p < 0.001$) increase in grain N in response to the addition of N fertilizer. The grain N concentration of the fertilized treatments over the 3 years of the study increased by 5.1 and 4.2 g kg^{-1} N in the grain over that of treatments not receiving fertilizer N, at Hennessey and LCB, respectively. The effect of planting system was inconsistent across locations. At Hennessey, there was a trend for higher concentration of N in the grain in the flat system compared to the bed (>1 g kg^{-1} averaged over 3 years). Conversely, the bed system at LCB produced higher amounts of N in the grain for the length of the study. There was no effect of row configuration on grain N concentration at either location for the duration of the study (Table VII).

At Hennessey in 2004 and 2005 and at LCB in 2004, a significant variety by row interaction was reported in Table VIII. This interaction can be explained in all three instances by the 2-row configurations having higher grain N concentration in the beds system, whereas in the flat system 3-row configurations posted higher grain N.

Across the three years of the study, a significant system by N rate interaction was observed at Hennessey. This interaction was also observed at LCB in 2003. In all cases a synergistic

Table VI. Simple effects of variety and N rate on wheat grain yield at Hennessey and Lake Carl Blackwell, OK, 2003–2005.

		Hennessey				Lake Carl Blackwell			
Variety	N rate	2003	2004	2005	Avg.	2003	2004	2005	Avg.
		Grain yield, kg ha^{-1}							
2174	0 N	3017 b B	2624 a B	2815 a B	2819	2304 b B	2916 b A	2339 b B	2520
2174	100 N	3516 a A	2738 a A	2877 a A	3044	3730 a B	4239 a A	3245 a A	3738
Jagalene	0 N	3394 a A	3183 a A	3159 a A	3245	3090 b A	3186 b A	2684 b A	2987
Jagalene	100 N	3252 a B	2928 a A	2475 b B	2885	4237 a A	4247 a A	3474 a A	3986

Variety: two common varieties (2174 and Jagalene); N rate: plots received 0 or 100 kg N ha^{-1}; N rate means within a variety followed by the same lower case letter are not different from each other at $p < 0.05$; Variety means within a N rate followed by the same upper case letter are not different from each other at $p < 0.05$.

interaction took place where there was a larger increase in grain N in response to added N fertilizer in the bed system than in the flat system (Table IX).

Discussion

Grain yield

The bed system gave similar yields to that of the solid stand at LCB. Similar results were reported in the past in several crops (Mascagni & Sabbe 1990; Tewolde et al. 1993;

Table VII. Main effects of planting system, variety, N rate, and row spacing on wheat grain N concentration at Hennessey and Lake Carl Blackwell, OK, 2003 – 2005.

	Hennessey				Lake Carl Blackwell			
System	2003	2004	2005	Avg.	2003	2004	2005	Avg.
	Grain N, g kg^{-1}							
Bed	24.9 a	24.5 a	24.0 a	24.5	21.3 a	22.3 a	20.3 a	21.3
Flat (rows)	25.9 a	26.0 a	25.5 b	25.8	19.1 ab	21.8 a	19.7 a	20.0
Flat (solid)	25.6 a	25.7 a	25.0 ab	25.4	18.8 b	20.7 a	18.1 a	18.9
Variety								
2174	26.0 a	26.7 a	25.8 a	26.2	21.1 a	22.9 a	20.7 a	21.6
Jagalene	24.8 b	23.9 b	23.7 b	24.1	19.3 b	21.2 b	19.4 b	20.0
N rate								
0 N	23.4 b	22.7 b	21.7 b	22.6	17.8 b	20.0 b	18.2 b	18.7
100 N	27.4 a	27.9 a	27.7 a	27.7	22.7 a	24.1 a	21.9 a	22.9
Row								
2-row	25.5 a	25.5 a	24.8 a	25.4	20.4 a	22.2 a	20.0 a	20.9
3-row	25.4 a	25.1 a	24.7 a	25.1	20.0 a	21.9 a	20.0 a	20.6
Solid	25.6 a	25.7 a	25.0 a	25.4	18.8 a	20.7 a	18.1 a	18.9

Planting system: Bed and flat (rows/solid). Variety: two common varieties (2174 and Jagalene); N rate: plots received 0 or 100 kg N ha^{-1}. Row configurations: 2-row (two rows, 30 cm spacing with 45 cm skip), and 3-row (three rows, 15 cm spacing with 45 cm skip) placed on beds and flat systems; Solid = Solid stand at 15 cm spacing placed in flat systems; Within a column, means followed by the same letter are not different at $p < 0.05$ for each treatment effect.

Table VIII. Simple effects of variety and row spacing on wheat grain N concentration at Hennessey and Lake Carl Blackwell, OK, 2003 – 2005.

		Hennessey				Lake Carl Blackwell			
Variety	Row	2003	2004	2005	Avg.	2003	2004	2005	Avg.
		Grain N, g kg^{-1}							
2174	2 row	26.4 a A	27.5 a A	26.7 a A	26.9	21.6 a A	23.8 a A	21.0 a A	22.1
2174	3 row	25.7 a A	25.8 b A	25.2 a A	25.6	20.6 a A	22.3 b A	20.3 a A	21.1
Jagalene	2 row	24.5 a B	23.4 a B	23.3 a B	23.7	19.2 a B	20.6 a B	19.1 a B	19.6
Jagalene	3 row	24.9 a A	24.4 a A	24.1 a A	24.5	19.4 a A	21.7 a A	19.7 a A	20.3

Variety: two common varieties (2174 and Jagalene); Row configurations: 2-row (two rows, 30 cm spacing with 45 cm skip), and 3- row (three rows, 15 cm spacing with 45 cm skip) placed on beds and flat systems; Row configuration means within a variety followed by the same lower case letter are not different from each other at $p < 0.05$; Variety means within a row configuration followed by the same upper case letter are not different from each other at $p < 0.05$.

Table IX. Simple effects of planting system and N rate on wheat grain yield at Hennessey and Lake Carl Blackwell, OK, 2003–2005.

		Hennessey				Lake Carl Blackwell			
System	N rate	2003	2004	2005	Avg.	2003	2004	2005	Avg.
		Grain N, g kg^{-1}							
Bed	0 N	22.5 b B	21.2 b B	20.4 b B	21.4	18.3 b A	20.2 b A	18.2 b A	18.9
Bed	100 N	27.4 a A	27.9 a A	27.6 a A	27.5	24.4 a A	24.4 a A	22.4 a A	23.7
Flat	0 N	24.7 b A	23.7 b A	22.2 b A	23.5	17.3 b A	19.5 b A	17.8 b A	18.2
Flat	100 N	26.8 a A	28.1 a A	28.3 a A	27.7	20.6 a B	23.3 a B	20.6 a B	21.5

Planting system: Bed and flat (rows) = 2 row (30 cm spacing) and 3 row (15 cm spacing) configurations with 45 cm skips between configurations; Flat (solid) = Solid stand with row spacing of 15 cm; N rate: plots received 0 or 100 kg N ha^{-1}; N rate means within a planting system followed by the same lower case letter are not different from each other at $p < 0.05$; Planting system means within an N rate followed by the same upper case letter are not different from each other at $p < 0.05$.

Hobbs et al. 2000). The extended periods of water-logging conditions offered a more favorable growing environment for the bed planting system. At Hennessey, excess water in the field was not a problem. Therefore, the solid stand consistently outperformed the bed system. The varieties selected for this study were also quite different. "Jagalene" is a newly released variety with a higher yield potential than "2174". This higher yield potential is realized due to improved genetics. Both varieties are commonly grown across the region. In the lower yielding Hennessey location, "2174" and "Jagalene" performed equally. Alternatively, at LCB, "Jagalene" proved to be a superior variety with 357 kg ha^{-1} additional grain yield over "2174" over the 3 years of this study (Table I). It is important to note that there was an increased incidence of lodging of "Jagalene" at Hennessey with the addition of N fertilizer. This is reflected by a reduction of wheat grain yield shown in Table VI. "Jagalene" did not show this susceptibility to lodging at Lake Carl Blackwell.

The flat solid stand of winter wheat achieved greater grain yield than the bed and flat row configurations. Unlike this, Porter and Khalilian (1995) found no significant difference in yield between conventional and skip row configuration. Although there was a distinct trend for increased grain yield in the solid stand configuration, the yield difference was significant in only two site years compared to the bed system. However, the yield advantage of the solid stand was considerably greater compared to grain yield of the 2- and 3-row configurations in the flat system. The solid stand wheat yields were significantly higher than the grain yield of the flat system in four out of six site years.

At Hennessey there was a tendency for higher grain yield with the 3-row configuration compared to the 2-row configuration in both planting systems. However, this trend for increased grain yield with a 3-row configuration was only significant in 2003 in the bed system. Conversely, at LCB, 2- and 3-row configurations performed equally when compared to each other in the same system. In a study conducted to determine the effect of seed row configuration on wheat grain yield, Cutforth and Selles (1992) found that there was no significant yield difference between equidistant and paired row seeding. Similarly, a row spacing study by Lafond and Gan (1999) showed that 20 and 30 cm row spacing did yield as equal as or more than 10 cm spacing. A trend for increased grain yield shows an advantage for the bed system over the flat system when the crop production system requires that wheat is planted with skipped rows. It should be noted that both 2- and 3-row configurations consistently produced higher yields in the bed system compared to the flat system.

With no significant reduction in grain yield using a 2-row configuration, it could be easily implemented into a relay cropping system (Porter & Khalilian 1995). Relay cropping is a system that implements row configurations where skipped rows are used to provide more timely and efficient planting and harvesting of crops in the system. This study would support the use of bed planting with 2- or 3-row configurations in these relay cropping systems with their advantage in grain yield versus that of the flat system. Additionally, these row configurations offer other management opportunities to the cropping system. Skipped row wheat will allow for accessible controlled traffic lanes that can be used during the entire crop season. The adoption of a 2-row configuration means a reduction in seed rate without sacrificing yield. For the bed system to be useful, the current conventional tillage practice must be changed to reduced tillage to make use of bed a planting system for conserving moisture – the essence of bed planting system in dryland production.

Grain N concentration

The Hennessey location assimilated higher amounts of N in the grain than LCB. The difference in grain N concentrations can be attributed to the differences in grain yield that were observed. Lake Carl Blackwell was consistently a higher yielding environment, thus more N was utilized for grain yield resulting in a lower concentration of N in the grain. Alternatively, varieties and response to N fertilizer reacted similarly across locations. The variety "2174" had higher N concentrations in the grain compared to "Jagalene", and the fertilized treatments produced higher N concentrations than unfertilized treatments.

The results of the study indicate that the bed system provided an environment that more efficiently utilized N fertilizer. This is supported by Table IX, which illustrates a greater difference between grain N concentration in the fertilized and check plots across years and locations. At the N responsive site (LCB), the increase in grain yield and greater differences in N concentration reveals that the bed system more efficiently utilized the added N fertilizer than the flat system. Mascagni et al. (1991) found that N content of sorghum grain was improved with a crowned (raised) seedbed compared with a conventional flat seedbed. At Hennessey where no grain yield response to N was recorded, N concentration was not influenced by planting system. However, the difference in N concentration between fertilized and check plots was still greater in the bed system, likely due to improved moisture conservation.

Conclusion

In summary, results reported here confirmed our previous report (Freeman et al. 2006) of similar grain yields in the bed system and the flat solid stand in four out of six site years. A larger increase in grain N concentration was found between the fertilized and check plots in the bed system compared to the flat system. Finally, this study showed a trend for increased grain yield in the bed system over the flat when cropping systems call for skipped row configurations that accommodate controlled traffic lanes or relay cropping.

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