

TALL FESCUE SEED PRODUCTION ALLEY CROPPED IN A HARDWOOD TREE
PLANTATION

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TALL FESCUE SEED PRODUCTION ALLEY CROPPED IN A HARDWOOD TREE
PLANTATION

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ABSTRACT

Alley cropping is an agroforestry practice that utilizes the space between rows of trees to produce an alternate crop. Tall fescue (*Lolium arundinaceum* (Shreb.) S.J. Darbyshire) demonstrates shade tolerance and may be well suited for the production of certified seed in alley-cropping systems in Missouri. The objective was to evaluate tall fescue seed production in alley cropping. Three management practices associated with grass seed production were also evaluated; row spacing, N fertilization, and post-harvest residue management.

In 2002, foundation seed of ‘Houndog 5’ tall fescue was seeded in 40- and 60-cm row spacings in an existing hardwood tree plantation and in open areas adjacent to the plantation. Three N fertilization treatments (0, 84 and 168 kg N ha⁻¹) were split-applied (50/50) in early March and April. Post-harvest residue removal treatments, cutting or not cutting regrowth after harvest, were applied each year. Data were taken 2004 and 2005 for seed yield and seed yield components (culms m⁻¹ of row, 100 seed weight, and seeds culm⁻¹).

In 2004 seed yields in the alley-cropped plots were similar to the open plots; in 2005, all plots had reduced yield and the alley-cropped plots yielded significantly less than the open plots. We attribute the decrease of the second year harvest to poor soil moisture and increased competition from trees. Both years the center rows of the alley cropped plots yielded significantly greater than other rows within the alleys. Seed yields were greater for 40-cm wide rows than for 60-cm wide rows. Nitrogen fertilization improved yield; however plots receiving 168 kg N ha⁻¹ yielded no greater than plots

receiving 84 kg N ha⁻¹. Post-harvest residue removal had no significant affect on yield. Seed yield was closely related to the number of reproductive culms m⁻¹ of row; however, there were no differences among treatments for seed weight and seeds culm⁻¹.

This research shows that tall fescue seed yield in an alley-cropping system can be equal to yields from pasture until competition for resources from the trees has a negative influence on the crop. A producer who is interested in establishing an orchard should find that certified turf-type tall fescue is a viable crop for an alley-cropping system.

INTRODUCTION

Missouri is the second largest producer of common Kentucky 31 tall fescue (*Lolium arundinaceum* (Schreb.) S. J. Darbyshire) seed in the United States with over 29 million kg produced in 2002 (Anonymous 2005a). In Missouri, tall fescue seed is harvested as a secondary crop to hay or grazing operations, which maximizes overall crop yield but does not achieve maximum seed yield (Kroth et al. 1976). To achieve maximum seed yield, a different strategy is used from pasture production. Pasture production focuses on maximizing herbage so a dense planting is more desirable. To maximize seed production wide plant spacing is required to allow light penetration into the crown which stimulates the production of reproductive tillers (Deregibus et al. 1985). This can be achieved by growing the grass in rows.

Growing certified turf-type grass seed may be desired because it is more valuable than common tall fescue seed. Sixty percent of the world supply of certified turf-seed is produced in the Pacific North West (Steiner et al. 2006). In Oregon, the number one state for turf seed production, 76,000 hectares are devoted to tall fescue seed production and yielded over 109 million kilograms of seed in 2002 (Anonymous 2005a). Although less land is put into grass seed production in Oregon than in Missouri, seed yield is greater in Oregon. They enhance seed yield by manipulating the growing systems specifically for seed production. Land availability is becoming limited in Oregon yet there is still excess demand for turf seed. Tall fescue grows well in Missouri and producers may profit by managing for certified seed production.

Agroforestry is the integration of tree crops and agricultural crops and/or livestock. Alley-cropping is an agroforestry management practice where trees are grown

in widely spaced rows and the area between the trees are used for annual crops while trees mature to produce fruit, nuts, or timber products (Delate et al. 2005). The purpose of growing crops in the alleys is to provide annual income during the early stages of tree growth when no revenue sources can be derived from the trees. Growing certified tall fescue seed in an alley-cropping system may be a good crop for tree growers who want to produce some income from their land while the trees become established.

The objective of this study was to evaluate production of turf-type tall fescue seed as a specialty crop when grown in an alley-cropping system. We compared seed yield of tall fescue grown in open field plots to the seed yield of tall fescue grown in the alleys of a mixed hardwood tree plantation. We also wanted to see if the common grass seed management strategies of row spacing, nitrogen fertilization, and post-harvest residue removal would affect tall fescue seed yield differently within the alley environment compared to the open areas.

LITERATURE REVIEW

Agroforestry

Agroforestry is an intensive land management strategy integrating tree crops with agronomic crops and/or livestock in order to optimize the biotic interaction for production and conservation benefits (Nair 1985). People are being encouraged to reintroduce trees into pasture and other crop land as a sustainable farming option (Delate et al. 2005). There are five agroforestry practices utilized in the temperate USA; silvopasture, windbreaks, riparian buffers, forest farming, and alley-cropping. Silvopasture is the intentional combination of trees, forage, and livestock into an integrated practice. In this practice, trees can benefit animals by providing protection from summer heat and winter cold (Novak et al. 2002). Windbreaks reduce the force of natural wind paths to protect crops, animals, housing, and roads. Riparian buffers reduce runoff and erosion into creeks, streams, and rivers by stabilizing banks and filtering runoff. Forest farming utilizes existing forest to provide a proper environment for understory crops, typically mushrooms and shade tolerant medicinal herbs. Alley-cropping is the integration of more traditional row crops grown within rows of trees. Benefits of alley-cropping are increased income diversity, biodiversity, and aesthetic appeal. Nitrate leaching can be reduced by the deep roots of trees in an alley cropping system minimizing groundwater contamination (Allen et al. 2004).

Alley Cropping

Alley cropping is perhaps the least accepted agroforestry practice. Competition for light (Friday and Fownes 2002) and moisture (Gillespie et al. 2000, Lin et al. 1998, Miller and Pallardy 2001) are the primary competitive factors limiting crop production

within the plantation. By severing the roots of trees at the dripline, Jose et al. (2000) were able to show that competition of trees for water is the most important limiting factor in the growth of maize in an alley cropping system and light and nutrients had little impact. Grass is a perennial and tillers are stimulated to turn reproductive in the fall (Canode and Law 1978), so the interactions and competitive factors are not the same for grass seed production as in corn crops. Shade from the trees in the fall may influence the number of tillers that are stimulated to reproductive states.

As trees mature and shade envelops the area within the alleys there is greater competition for resources (Rozados-Lorenzo et al. 2007). It has been suggested that the competition for light, moisture, and nutrients are too great for economic returns to alley cropping (Vandermeer 1998). Alley-cropping systems should be managed to reduce direct competition between tree and intercrop to optimize returns from the land use area. In this system fruits or nuts become important financial inputs.

Turf-Type Tall Fescue

Tall fescue is a cool season grass that displays drought resistance, shade tolerance, and remains green throughout a large portion of the year (Anonymous 2007b). Houndog 5 turf-type fescue has narrow dark green blades and prostrate growth (Anonymous 2002). Approximately 80% of Houndog 5 plants are infected with the endophytic fungus *Neotyphodium coenophialum*. The endophyte provides greater resistance to crown feeding insects and nematodes (Clay 1988) and improves stress tolerance (Funk et al. 1993). Houndog 5 demonstrates excellent overall characteristics for a wide variety of turf applications with a high mean turf-grass quality rating from the national turf-grass evaluation program (Anonymous 2005b).

Turf-type fescue is a popular grass for lawns and parks. Grass grown for seed requires special management to provide proper light and nitrogen during all stages of plant development (Fairley and Lefkovitch 2000). Light penetration and nutrient levels affect all aspects of seed production (Canode and Law 1978). Growers manage these variables by manipulating row spacing, nitrogen fertilization, and post-harvest management.

Row Spacing

Grass seed production is maximized when grown as a row crop. Growing tall fescue in rows opens up space for light penetration to the crown, stimulating tiller conversion to a reproductive state (Fairey and Lefkovitch 1999a). An individual grass plant, grown without any competition, will produce the maximum number of tillers and seed per plant. Under these conditions, the yield per plant is maximized but yield per unit area is low. On the other hand, grass plants grown in a high density turf will produce few tillers per plant and seed production per plant declines, limiting the yield per unit area. Much like row crops, grass grown for seed will produce the greatest amount of seed per unit area when a balance of plant density and row space are achieved.

Row spacing is a transient measure, as plants grow they send more tillers into any available area, making rows denser and closer together. When deciding on what row spacing to use, growers must determine the length of time they will grow the crop before replanting. Wider row spacing may allow more years of production from the original planting before yield begins to decline. Most research has focused on 20- to 80-cm row spacings (Chastain et al. 2001, Young et al. 1998a, Fairey and Lefkovitch 1998).

Chastain et al. (2001) found no significant difference in tall fescue seed yield between 30-cm and 61-cm row spacings over a three year period when seeded at approximately 200 seeds m⁻¹. Yield components from their study showed that there were differences in the number of fertile tillers m⁻² which dropped as row space increased; however, spikelets per spike and florets per spikelet increased so overall yields were similar. In Oregon's Willamette Valley, Young et al. (1998a) found production of turf-type fescue seed was greater at 33-cm row spacing than at 66-cm row spacing when the residue was burned. However when residue was not burned, wider row spacing produced more seed per unit area. Fairey and Lefkovitch (1998) found 30-cm spacing to be optimal in one trial, but the following year a range of 20- to 60-cm row spacing were not significantly different for a three year rotation (Fairey and Lefkovitch 1999b). Plants need space to produce the optimum amount of seed. Row spacing is desirable to achieve the space needed by plants and wider rows can be planted more densely. If the plants are too close even at wide row spacing, yield reductions can be greater than when narrower row spacings are used with low density within the row (Fairey and Lefkovitch 1999a).

Nitrogen

Nitrogen is a critical element for plant growth and cell division. Nitrogen is an integral element in the formation of DNA, amino acids, and proteins. Nitrogen is often a limiting nutrient in the growth and development of plants, and the most important element in tall fescue seed production (Young et al. 1999a). Nitrogen is not a nutrient that can be added without limit because excessive nitrogen can cause lodging (Young et al. 1998a). Tall fescue is more susceptible to lodging at fertilizer rates greater than 120

kg N ha⁻¹ and this is an important consideration as lodged plants can make harvest difficult and cause significant reductions in seed yield (Young et al. 1999a).

There have been many experiments to determine the ideal amount of nitrogen to apply for a given species, however there are many factors that interact in the determination of an amount to recommend. Young et al. (2001) reports 90-135 kg N ha⁻¹ is the optimal range for tall fescue and a current recommendation from an Oregon producer was 86 kg N ha⁻¹ (Personal communication). The local climate is a critical consideration because average temperatures and rainfall vary from region to region. Thus, yearly differences in climate within a location can have a tremendous effect on seed yield despite N rate (Fairey and Lefkovitch 2000). Although regional differences affect recommendations for optimal nitrogen fertilization (Kroth et al. 1976, Watson and Watson 1982, Fairey and Lefkovitch 1998, Young et al. 1999a, Fairley and Lefkovitch 2000, and Loepky and Coulman 2002) all agree that adding some amount of nitrogen is beneficial.

Environmental factors, especially moisture affect a plant's ability to utilize available nitrogen. Under dry conditions, seed production is sacrificed to vegetative growth in response to nitrogen fertilization; however, under adequate moisture conditions, seed yields are increased with additional nitrogen (Loepky et al. 2002).

There are many recommendations for timing of applications of nitrogen fertilizer, such as fall application plus spring application, fall application for seed production, spring application for forage production, or split applications in spring for seed production (Young et al. 1999a, Loepky et al. 2002). Factors which affect reproductive development give considerable flexibility in nitrogen fertilization timing, so as long as

nitrogen is applied before vigorous growth begins in the spring (Young et al. 1999a). Once vigorous growth commences, additional nitrogen will be allocated to herbage production at the expense of reproductive development (Loeppky and Coulman 2002). Although excessive nitrogen can cause lodging, when combined with paclobutrazol, a growth retardant to reduce plant height, rates up to 180 kg N ha⁻¹ can increase seed yield (Young et al. 1999b).

There are also considerable variety differences in response to N. When comparing seed yield of four varieties of turf-type fescue in Oregon, Young et al. (1998b) found that one variety yielded greatest at 100 kg N ha⁻¹ rather than 145 kg N ha⁻¹ or 190 kg N ha⁻¹. However, another variety in the same experiment yielded most at 145 kg N ha⁻¹. Thus, when considering N rate, it is important to view variety as a factor.

Nitrogen rate and timing also affects seed yield components. Young et al. (1999a&b) showed that N rates between 90 and 210 kg N ha⁻¹ affected seed yield components differently; however seed yields were not different. In this study it was also shown that delaying the nitrogen application to the time of spikelet initiation, which is the end of March for the region, reduced seed production. All seed yield components were reduced when nitrogen was applied at time of spikelet initiation as compared to application at double ridge stage, which is late February to early March.

Post-Harvest Management

Reproductive tillers form in the fall and are affected by light penetration into the crown (Young et al. 1998b). Post-harvest management is the removal of herbage that might otherwise intercept light before reaching the crown, thereby increasing the total number of fertile tillers per unit area. Cutting at harvest is essential for the following

year's seed harvest (Kroth et al. 1976). There is a negative correlation of fall tiller height to fertile tillers the following year (Meints et al. 2001). The traditional method of post-harvest management was burning the field after harvest which had the added benefit of reducing weeds and disease vectors (Canode 1978). Air quality regulations have restrained the burning of fields in some areas, so other alternatives are being sought. In an alley-cropping application, trees are at risk of damage from fire.

Alternative post-harvest management strategies strive to duplicate the results of burning. When straw residue is cut and completely removed from the field, tall fescue seed yields are comparable to those where the residue is burned; however, herbicide treatments are needed to maintain stand purity (Young et al. 1999a, Mueller et al. 1995a). Careful procedures must be followed in straw removal because seed yields of tall fescue are sensitive to mechanical and chemical damage in the post-harvest time period (Mueller et al. 1995b). Some studies show complete removal of the straw demonstrates negligible difference from chopping the straw and leaving it on the field, so long as the chopped straw does not cover the grass stubble (Steiner et al. 2006). Leaving the clippings in the field also helped reduce soil erosion, conserve soil moisture, and reduce weed competition.

Chewings fescue can be maintained for a maximum seed yield with mechanical removal of post-harvest residue with no significant difference from field burning; however, creeping red fescue requires the burning of plant residue to achieve maximum seed yield and seed quality (Young et al. 1998c). Straw removal in tall fescue increased the total number of fertile tillers per unit area and extended production years of seed plots (Young et al. 1998b). When growing turf-type fescue, the seed weight was not as

important as the number of fertile tillers to overall yield, and this may be facilitated by residue removal.

Harvest

Harvest timing of tall fescue seed is critical to obtain maximum yield. Berdahl and Frank (1998) found that if seed harvest is delayed until maximum seed mass is attained, yield losses are often higher. Young et al. (1998b) suggest that the greatest yields are derived when the maximum number of seeds are harvested rather than waiting for seed to reach maximum seed weight. Seed loss to shatter can be a major economic loss if the timing of harvest is not appropriate (Berdahl and Frank 1998). If harvest is too early, seeds may not be mature and will have poor germination. If the harvest is late, seed will be lost to shatter.

The objective of this study was to evaluate production of turf-type tall fescue seed as a specialty crop when grown in an alley-cropping system. We compared seed yield of tall fescue grown in open field plots to the seed yield of tall fescue grown in the alleys of a mixed hardwood tree plantation. We also wanted to see if the common grass seed management strategies of row spacing, nitrogen fertilization, and post-harvest management would affect tall fescue seed yield differently within the alley environment compared to the open areas.

MATERIALS AND METHODS

This experiment was conducted at the University of Missouri Horticulture and Agroforestry Research Center (HARC) in Howard county, Missouri (39° 1' 2" N; 92° 46' 1.4" W). The site is southwest facing on a 3-5% slope and underlain by a Menfro silt loam, (fine-silty, mixed, superactive, mesic typic hapludalf).

This research utilized an agroforestry application combining trees and an agronomic crop. An alley-cropping system was created in an existing hardwood-tree plantation that was planted in 1996. The trees were planted 2.4 m apart within rows spaced 6 m apart. Tree rows were planted north-south and consist of chestnut (*Castanea spp.*), oak (*Quercus spp.*), and black walnut (*Juglans nigra*, L.). Four alternate rows of trees were removed at the west end of the plantation to create alleys 12-m wide. To evaluate the affect of the alley environment, control plots, where there were no trees, were located on the north and west side of the plantation. All plots measured 6 m x 12 m.

Foundation seed of Houndog 5 turf-type fescue was planted with rows starting 0.76 m from the base of the trees, at a rate of 9 kg ha⁻¹ to a depth of 0.6 cm in September 2002 with a Truax Flex II® seed drill. For the two row spacing's evaluated (40- and 60-cm), the 12-flute drill was operated with either every other flute open (40-cm rows) or every third flute open (60-cm rows).

For the nitrogen treatments, ammonium nitrate (34-0-0) was split-applied; 50% in early March and 50% in early April of each year. Three application rates used were (0, 84, and 168 kg N ha⁻¹). Post-harvest treatment of mowing the regrowth herbage and raking the plots clear was performed in the second week of September in the year preceding each harvest. Pendimethalin, (Prowl 3.3 EC) a pre-emergent, was applied at a

rate of 2.8 L ha⁻¹ in late March and in June (following harvest) each year. Broadleaf weeds were sprayed as needed with 2, 4-D applied at a rate of 1.75 L ha⁻¹. Plots were grown for one year prior to seed harvest to establish plots.

To assess maturation differences between treatments, developmental stage was determined on each culm within 1 m section of a row from each treatment in each replication. Culms were assigned a numerical value for their growth stage as described by Moore et al. (1991). There are five growth stages in the model with subsections of each stage. The stages are (0.0-0.9) for germination, (1.0-1.9) for vegetative, (2.0-2.9) for elongation, (3.0-3.9) for reproductive, and (4.0-4.9) for seed ripening. Mean stage count (MSC) for each plot was calculated with the following formula:

$$MSC = \sum_{i=0}^{4.9} (S_i \times N_i) / C$$

Where:

S_i = growth stage, 0 to 4.9

N_i = number of tillers in stage S_i

C = total number of tillers

The MSC ratings were done when anthesis became visible, the third week in May each year, to determine that plants in the alley-cropped plots were at the same maturity as plants in the open plots. Harvest timing was determined by a seed shatter test where seeds dislodge from culm with a gentle tap into the hand. When an estimated 10% of the seed shattered, harvests were initiated. There appeared to be no differences in the seed shatter test between locations so the open plots were harvested concurrent with the alley cropped plots.

Seed were harvested June 17, 2004 and June 22, 2005 by cutting culms from ten, 1 m of row samples in each plot. At each harvest, seed yield and seed yield components (seed yield meter⁻¹, culms meter⁻¹, 100 seed weight, and seeds culm⁻¹) were determined. In the alley-cropped plots, two, 1 m of row samples were harvested from five positions across the alley-cropped plots: the center of the plot, each tree drip-line, and each midpoint between the center and each drip-line. Seed yield and seed yield components were determined from the samples at each position. For total plot yield, the ten samples were combined. In the open plots, seed yield components were determined on one of the ten 1 m of row samples and then all ten samples were combined for seed yield determinations. All samples were dried in a solar drying room.

Culms were hand counted for each sample and then the seeds were hand threshed. The seeds were then cleaned using a Redmond model 3876 seed winnower. Cleaned seed were weighed for total weight. Weights per 100 seeds were obtained by manually counting 100 seeds and weighing. These data were then used to calculate the number of seeds per culm, seed yield per hectare and culms per hectare with the following formulas:

$$\text{Seed Yield (kg ha}^{-1}\text{)} = \{ \text{Seed yield (g m}^{-1}\text{ of row)} / [\text{Row Spacing (m)} / 10,000 \text{ (m}^2\text{ ha}^{-1}\text{)}] \} / 1000 \text{ (g kg}^{-1}\text{)}$$

$$\# \text{Culms (m}^{-2}\text{)} = \# \text{Culms (m}^{-1}\text{ of row)} \times [1 \text{ (m}^2\text{)} / \text{Row Spacing (m)}]$$

$$\text{Seeds per Culm} = \{ \text{Seed yield (g m}^{-1}\text{ of row)} / [100 \text{ Seed Weight (g)} / 100] \} / \# \text{Culms (m}^{-1}\text{ of row)}$$

The experiment was arranged as a randomized complete block design in a split-split plot arrangement. Each treatment was replicated four times. Years were main plots, tree or open areas were subplots, and twelve managements (three rates of N x two row spacings x two post-harvest managements) were sub-sub plots. Experimental data from each year (2004, 2005) and each placement (open areas, alley) were analyzed separately to determine homogeneity of variance across location and year. Homogeneity of variance was confirmed so data were pooled and analyzed with analysis of variance using PROC MIXED (SAS Institute 2001) with year and all interactions with year specified as random effects. Transect positions were treated as nested sub-samples and analyzed with PROC MIXED with replication and all treatment interactions with replication specified as random effects. Orthogonal contrasts were used to compare management treatments. All analyses were conducted with a Type I error of $\alpha = 0.05$ ($p \leq 0.05$).

RESULTS AND DISCUSSION

Mean Stage Count

In an alfalfa-shade study, maturity of shade grown-plants was delayed relative to open-grown plants (Niedermann 2005). There were no significant differences in maturity between open-grown and alley-cropped tall fescue through a mean stage count (Table 1). In 2004 and 2005 mean stage counts were 3.4 for all plots, both in the alleys and in the open.

Alley cropped vs. Open cropped

Seed yields differed between the two study years. There were no interactions affecting seed yield other than placement (open vs. alley) with year of harvest so data were pooled over row spacing, nitrogen rate, and post-harvest management (Table 2). In 2004, seed yields were similar in the open plots and the alley plots when combined over all row spacing, nitrogen, and post-harvest management treatments. Seed yield means were 716 kg ha⁻¹ for open plots and 769 kg ha⁻¹ for alley-cropped plots.

Seed yields were similar on a plot basis; however, the alley cropping farm will lose some land to trees. At the time of planting in 2002, rows of tall fescue seed were planted 0.76 m from the base of the trees. The area lost to trees was approximately 12.7%, thus the realized yield on a hectare of alley-cropped land would be 671 kg ha⁻¹.

In 2005, all plots yielded less than in 2004; however, seed yield was reduced more in the alley-cropped plots than the open plots (Table 3). Alley-cropped plots yielded a mean of 279 kg ha⁻¹, only 36% of the previous year, while the open plots yielded 465 kg ha⁻¹ or 65% of the previous year. In 2004 total rainfall from March through May was above normal (Figure 1). Precipitation was 151%, 51%, and 119% of the 30 year average

in March, April, and May, respectively (Figure 1). Above average moisture in 2004 may have contributed to the seed yield by reducing the competition between the trees and tall fescue. In 2005, precipitation was only 28%, 70%, and 37% of the 30 year average in March, April, and May, respectively (Figure 1). These months of below average moisture, during the development of the culms and seed, appear to be the cause of reduced seed yields. Also, trees had another year's growth and this likely contributed to increased competition through greater root mass and shading. The root mass competes for moisture and nutrients and the shading can reduce the number of tillers that are stimulated to reproductive states.

Row Spacing

Row spacing significantly affected seed yield. Row spacing did not interact with year, open or alley plots, nitrogen, and post-harvest treatments (Table 2), so data were pooled over years and treatments. Seed yield of the 40-cm row spacing was 633 kg ha⁻¹ and the 60-cm row spacing yielded 481 kg ha⁻¹ (Table 4). Plots were planted at a constant seeding rate of 9 kg seed ha⁻¹ so, seeds were planted closer together in the 60-cm row spacings than those in the 40-cm rows. The 60-cm row spacings had seed yields 27.6 g m⁻¹ of row and the 40-cm rows yielded 23.7 g m⁻¹ of row (Table 4). The 60-cm row spacings yielded 16% more seed m⁻¹ of row than the 40-cm row spacings yield. However, there were 33% fewer rows when planted at the 60-cm spacing compared to the 40-cm spacing, thus the 40-cm rows yielded more on a per hectare basis.

Nitrogen Rate

Nitrogen significantly affected seed yield. Nitrogen did not interact with year, open or alley plots, row spacing, or post-harvest treatments (Table 2), so data was pooled

over years and treatments. Means were 478, 623, and 569 kg ha⁻¹ for the 0, 84, and 168 kg N ha⁻¹ respectively (Table 5). It was beneficial to add nitrogen; however, adding more than 84 kg N ha⁻¹ resulted in no increases in yield. In 2004 there was a strong storm less than a week before harvest and plots in the open with the highest application of nitrogen suffered the greatest amount of lodging. The alley-cropped plots had much less lodging even at the high nitrogen rate. There was not a noticeable loss of yield because the culms were lifted for harvest, but a typical mechanical harvest may have had reduced yields due to lodging.

Post-Harvest Management

Post-harvest management of cutting and raking the herbage that re-grows in summer did not significantly affect seed yield in this study (Table 2). In the past, the preferred post-harvest management practice for grass seed production was field burning. In an alley-cropping environment, burning could damage the tree component so, mowing and raking would be the recommended method for residue removal. Many seed producers employ the management strategy of mowing and raking and most research shows that this practice increases yields; however, in this study we did not see a response when this practice was employed.

Alley Transects

When comparing seed yield across the alleys, trends were similar for both years. Position within the alley significantly affected seed yield; however, there were no interactions with row spacing, nitrogen rate, or post harvest treatment so data were pooled over these treatments (Table 2). In 2004, seed yield from the center rows of the alleys was 937 kg ha⁻¹ which was significantly greater than seed yield in the open plots

which yielded 789 kg ha⁻¹ (Figure 2). Rows midway between the drip-line and alley centers declined in seed yield to 83% when compared to center rows. East-center and west-center rows yielded 791 kg ha⁻¹ and 770 kg ha⁻¹ respectively. The east and west drip line rows yielded 507 and 584 kg ha⁻¹ respectively. These yields are 54% and 62% of the center rows yield respectively.

In 2005, precipitation was below average and, although trends were similar, alley cropped yields were reduced more than open-grown yields. Open grown plots yielded 508 kg ha⁻¹ in 2005, which was 64% of the open plot yield in 2004. Center rows in the alleys yielded 474 kg ha⁻¹, which was only 51% of the previous year for this position. The decline in yields was more definitive as sampled rows grew nearer to the tree drip-line. The east-center rows yielded 359 kg ha⁻¹, which was 76% of the center row yield and 45% of the previous year for this position. West-center rows yielded 353 kg ha⁻¹, which was 74% of the center row yield and 46% of the previous year for this position. East and west drip-line rows yielded 122 and 144 kg ha⁻¹, respectively. The east drip-line was 26% and the west drip-line 30% of the center row yields. These yields were 24% and 25% of the year 2004 for these positions, respectively. Seed yields are reduced in dry years but there is a greater reduction when tree competition is present. One can interpret these data as showing that increased competition from the trees in the dry year produced a greater reduction in yield as the plants approached the trees.

Seed Yield Components

Seed yield components, 100 seed weight, number of culms m⁻¹ of row, and number of seeds culm⁻¹, were delineated to help identify attributes that are affecting yield. There were no interactions with row spacing, nitrogen rate, or post harvest

treatment (Table 2) so results were pooled over treatments. We found no significant difference in 100 seed weight or the number of seeds culm⁻¹. In this study, seed yield is positively associated to the number of culms (Figures 2, and 3). Position within the alley significantly affected the number of culms and seed yield. In 2004, there were 508 culms m⁻² in the center rows of the alleys and 514 culms m⁻² in the open plots (Figure 3). Culm numbers in the rows midway between the drip-line and alley centers declined compared to the center rows. East-center rows and west-center rows had 481 and 471 culms m⁻², which was 95 and 92% of the center rows, respectively. East and west drip lines had 374 and 377 culms m⁻² respectively. These culm counts are both 73% of the center rows figures.

In 2005 precipitation was below average and culms m⁻² was reduced from 2004. The alley-cropped plots were reduced much more than the open plots. The open plots declined to 342 culms m⁻², which was 66% of the previous year. Alley-center rows had a mean of 344 culms m⁻², which was 68% of the previous year. Rows midway between the drip-line and the center declined even more to 84% of the center and 61% of the previous year. The drip line samples had 51% of the center row and 47% of the pervious year for these positions. The greater reduction in culm numbers near tree rows indicates that reductions in seed yields resulted from fewer culms produced in 2005. Thus, tree competition that reduced yield in the dry year (2005) acted by reducing the number of culms and not seed weight or seeds culm⁻¹.

SUMMARY and CONCLUSION

In 2004, when moisture was adequate, alley-cropped seed yields when combined over row spacing, nitrogen treatment, and post-harvest treatment, were similar to open plot yields. In 2005, when moisture was below average, yields were significantly reduced. Both years the 40-cm row spacings produced greater yield than 60-cm row spacings. Nitrogen fertilization is beneficial, but there was no added benefit beyond 84 kg N ha⁻¹, in this study. Post-harvest management of mowing the herbage is widely practiced and could be considered, although in this study, we saw no increase in yield when herbage was removed. Yield was positively associated with the number of culms. Treatments did not affect seed weight or the number of seeds culm⁻¹.

In 2004, the yield on a hectare of alley-cropped land in this study was 769 kg ha⁻¹ and in 2005, yield was 279 kg ha⁻¹. However, these data do not accurately represent overall land use for alley cropping in this study. At the time of planting in 2002, rows of tall fescue seed were planted 0.76 m from the base of the trees. The unplanted area occupied by trees represents approximately 12.7% of the overall land use. Thus, in 2004, yield would be 671 kg ha⁻¹. Wholesale price of turf-type tall fescue is currently for \$3.85 kg⁻¹ (Personal communication, Oregon Wholesale Seed Co., 25 Sept. 2007). Despite losing 12.7% of the land area to trees, gross revenue in the alley-cropped plots would still be \$2,583.00 ha⁻¹. In 2005, using the same land loss factor, realized yield would be 244 kg ha⁻¹, and gross revenues would be a respectable \$939.00 ha⁻¹.

This research shows that tall fescue seed yield in an alley-cropping system can be equal to yields from pasture until competition for resources from the trees has a negative

influence on the crop. A producer who is interested in establishing an orchard should find that certified turf-type tall fescue is a viable crop for an alley-cropping system.

Table 1. MSC for 2004 and 2005 combined across all other treatments.

Placement	2004	2005
	-----MSC-----	
Open	3.4 a †	3.4 a
Alley	3.4 a	3.4a

† Values with the same letter are not statistically different ($P > 0.05$).

Table 2. Analysis of variance for proc mixed with year and all interactions with year specified as random effects.

Source	df	Seed yield	Culms	Seed/Culm	100 Seed weight
Year (Y)	1	**	**	NS	NS
Rep	3	**	**	NS	NS
Placement (P) Open vs Alley	1	**	**	NS	NS
Row spacing (RS)	1	**	**	NS	NS
Nitrogen rate (NR)	2	**	**	NS	NS
Post harvest (PH)	1	NS†	NS	NS	NS
Y x P	1	**	NS	NS	NS
Y x RS	1	NS	NS	NS	NS
Y x NR	2	NS	NS	NS	NS
Y x PH	1	NS	NS	NS	NS
P x RS	1	NS	NS	NS	NS
P x NR	2	NS	NS	NS	NS
P x PH	1	NS	NS	NS	NS
RS x NR	2	NS	NS	NS	NS
RS x PH	1	NS	NS	NS	NS
NR x PH	2	NS	NS	NS	NS

* Significant at the 0.05 probability level.

** Significant at the 0.01 probability level.

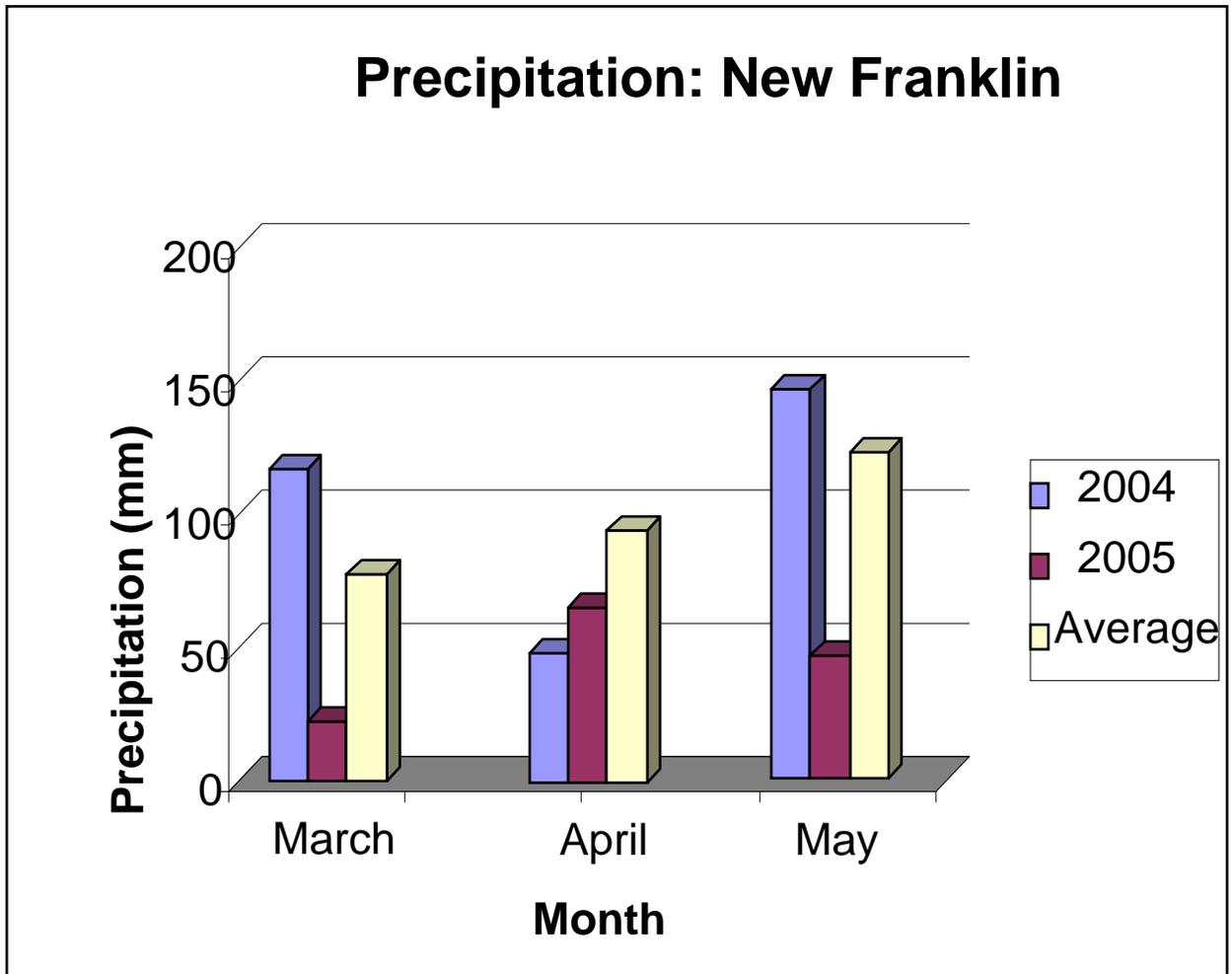
† NS, not significant at $P \leq 0.05$.

Table 3. Seed yield for 2004 and 2005, Open plots vs. Alley plots combined across treatments.

Placement	2004	2005
	-----kg ha ⁻¹ -----	
Open	716 a †	465 b
Alley	769 a	279 c
Alley less 12.7%	671	244

† Values with the same letter are not statistically different ($P > 0.05$).

Figure 1. Precipitation data for New Franklin, MO 2004, 2005 with average precipitation.



Average is the 30 year average precipitation.

Table 4. Seed yield for row spacing combined across years and treatments kg ha^{-1} and g m^{-1}

Row Spacing	Seed Yield	
	kg ha^{-1}	g m^{-1}
40 cm	633 a †	23.7 c
60 cm	481 b	27.6 d

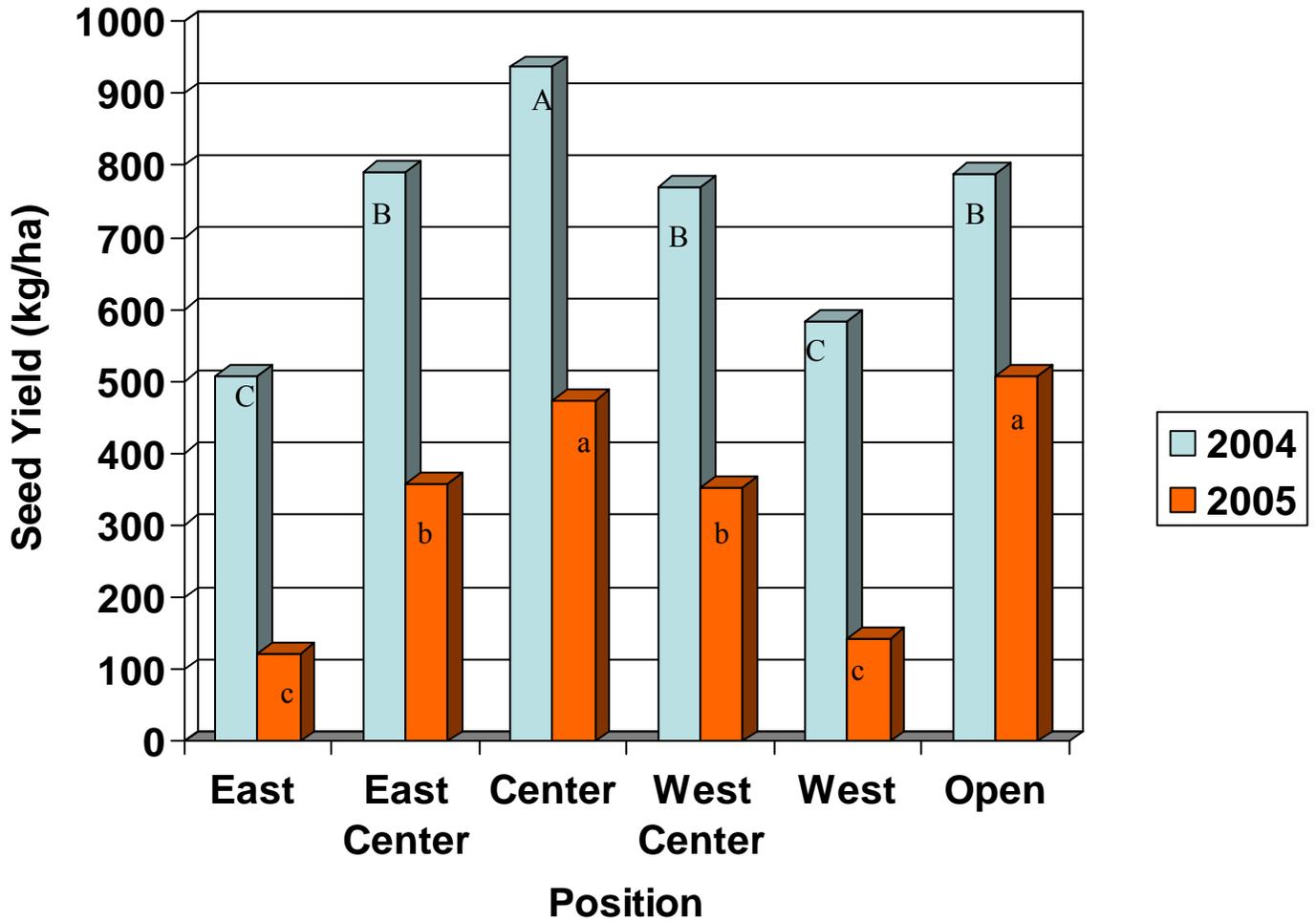
† Values with the same letter are not statistically different ($P > 0.05$).

Table 5. Seed yield for Fertilizer rate combined across years and treatments.

Fertilizer Rate	Seed Yield
	--kg ha ⁻¹ --
0 kg N ha ⁻¹	478 a †
84 kg N ha ⁻¹	623 b
168 kg N ha ⁻¹	569 b

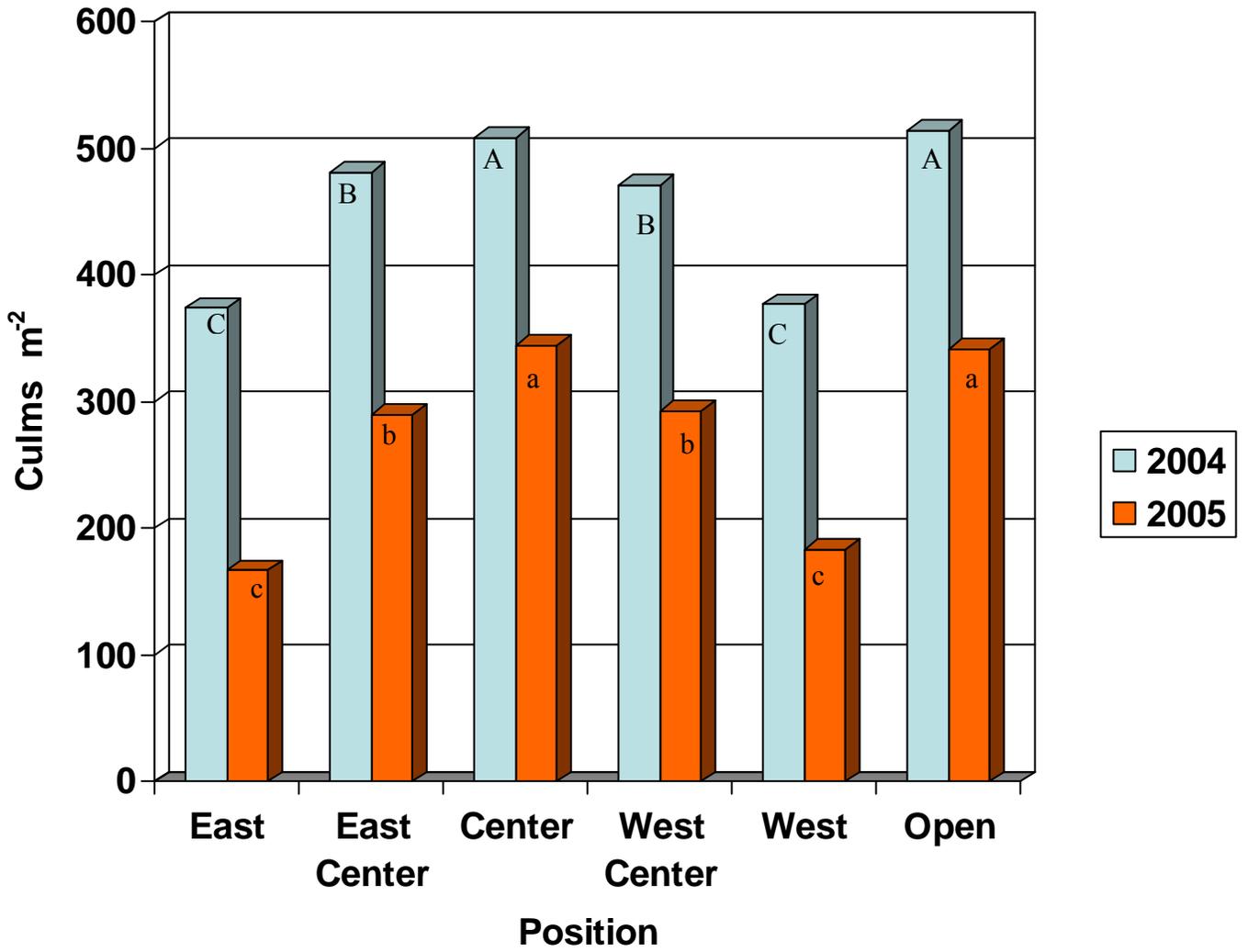
† Values with the same letter are not statistically different ($P > 0.05$).

Figure 2. Seed yield: Transects across alleys also including open plots separated by year, combined across all other treatments.



Values with the same letter are not statistically different ($P > 0.05$).

Figure 3. Culm counts: Transects across alleys also including open plots separated by year, combined across all other treatments.



Values with the same letter are not statistically different ($P > 0.05$).

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