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Effect of Seeding Rate on Alfalfa Stand Longevity

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ABSTRACT

Alfalfa (*Medicago sativa* L.) seeding rates greatly affect the number of surviving plants after one year. The objective of this research was to determine what affect seeding rate has on alfalfa stand density two or more years after seeding. Different alfalfa cultivars were spring seeded at rates ranging from 3 to 27 kg ha^{-1} pure live seed (PLS) into tilled seedbeds in Missouri and Pennsylvania to provide eight location-years of data. After the seeding year, herbage was removed four or five times each year. Stand densities were determined 1 to 3 and 5 to 8 months after planting (MAP) and annually in the spring thereafter for up to seven years after planting. Increasing seeding rates resulted in near linear increases in plant densities from 100 to 800 plants m^{-2} within three MAP. Higher plant densities experienced 8x higher plants deaths the first year after planting compared to lower plant densities. At all eight location-years of this research, the period 24 to 36 MAP had the least amount of plant deaths regardless of seeding rate. Higher plant densities associated with seeding rates greater than 17 kg ha^{-1} did not persist beyond six MAP. Seeding rates of 10 and 17 kg ha^{-1} had similar plant densities by 24 MAP in 75% of the location-years although further reductions in seeding rate reduced plant density for up to four years after planting. Seeding rates greater or slightly less than those recommended have little to no affect on the life expectancy of an alfalfa stand.

Abbreviations: MAP, months after planting; PLS, pure live seeds.

The effect of seeding rate on alfalfa yield has been examined with mixed results. Cramer and Jackobs (1963) found that seeding rates had little effect on seeding year DM yield provided that plant density was above an unreported minimum threshold. Others reported that seeding rates above 4.5 kg ha^{-1} in NY (McDonald, 1955), 6.7 kg ha^{-1} in OH (Van Keuren, 1973), 9.0 kg ha^{-1} in SD (Hansen and Krueger, 1973), 10.1 kg ha^{-1} in MO (Nelson et al., 1996), PA (Hall, 1993) and NE (Moline and Robison, 1971), 13.4 kg ha^{-1} in SD (Kephart et al. 1992), and 17.9 kg ha^{-1} in MI (Tesar, 1976) did not increase DM yield in the seeding year.

Once alfalfa is established, plant density is positively associated with total DM yield ha^{-1} but negatively associated with DM yield $plant^{-1}$ (Volenec et al., 1987; Bolger and Meyer, 1983; Rumbaugh, 1963). Cowett and Sprague (1962) and Volenec et al. (1987) reported that in established alfalfa stands plant density had limited affect on yield until the plant density fell below ≈43 plants m^{-2}. Below this threshold, decreases in plant density caused a concomitant decrease in yield. Kephart et al. (1992), under dryland conditions in SD, found higher DM yields with higher seeding rates into the third year after seeding. However, Nelson et al. (1996) and Hall (1993) found little relationship between seeding rate and DM yield after the seeding year.

Increased seeding rates resulted in nearly linear increases in plant densities one MAP (Hall, 1993; Kephart et al. 1992; Nelson et al., 1996, 1998, 2001). Thereafter, plants in higher density populations experienced higher mortality rates than lower density populations. In spite of greater mortality, differences in plant densities between low and high seeding rates still existed six MAP (Hall, 1993; Nelson et al., 2001) and 48 MAP (Kephart et al. 1992).

Since alfalfa seeding rates affect plant densities for at least 6 MAP, could seeding rates shorten or extend the duration an alfalfa stands remains above the ≈43 plants m^{-2} threshold? The objective of this research was to determine what affect seeding rate has on alfalfa stand density as the stand ages.

MATERIALS & METHODS

Missouri Study

Alfalfa was seeded into a tilled Huntington silt loam (fine-silty, mixed mesic Fluvenic Hapludoll) soil in early April of 1994 at rates of 3, 7, 10, and 17 kg PLS ha^{-1} at the Southwest Missouri Research Center near Mt. Vernon, MO. In late March 1995 and 1997, and in early April 1998, alfalfa was seeded at the same location and seeding rates except that a 25 kg ha^{-1} rate was added. Alfalfa cultivars seeded included 'Alfagraze', a dual purpose hay and grazing-type cultivar; '5373', a multiple pest resistant hay-type cultivar; and 'Cody', an older but commonly used cultivar. Alfalfa cultivars were main plots and seeding rates were subplots in a split block arrangement of a completely randomized block design. Prior to planting, soils were limed and fertilized according to soil test recommendations and 4.5 kg AI ha^{-1} EPTC (S-ethyl dipropyl carbamothioate) was incorporated into the seedbed for weed control. Seeds were hand broadcast on each 1.5 x 6.1 m subplot and compacted with a corrugated roller. Each treatment was replicated four times. For the remainder of this paper, the Missouri studies are identified as MO94, MO95, MO97 and MO98, the number indicating the establishment year

Forage was removed four times during the seeding year (three times before 15 September and a late-fall cut) and five times in subsequent years (four times before 15 September and a late-fall cut) when the alfalfa was at late-bud. Plant density was determined by counting stems at 1 or 3 MAP, crowns at 6 to 8 MAP, and crowns annually in the spring of each year on four, randomly selected 0.09 m^{-2} areas within each subplot. Crowns were counted in situ without digging up the plants. For the MO94 study, stem density was also determined for the duration of the study beginning 13 MAP. Data were collected for 6, 7, 3, and 2 yrs for the MO94, MO95, MO97, and MO98 study, respectively. Weed and insect pests were controlled when necessary using pesticides and the area was top-dressed annually in September with 67, 224 and 3 kg ha^{-1} P_2O_5, K_2O and B, respectively.

Pennsylvania Study

'Alfagraze' and '5456' alfalfa were seeded at 7, 10, 13, 17, 20, 24, and 27 kg PLS ha^{-1} into tilled seedbeds in mid April 1998 at four Pennsylvania locations; 1) Centre (Murrill silt loam; fine-loamy, mixed, mesic Typic Hapludults), 2) Dauphin (Calvin-Leck Kill shaly silt loam complex; consisting of approximately 70% loamy-skeletal, mixed, mesic Typic Dystrochrepts and 30% fine-loamy, mixed, mesic Typic Hapludults), 3) Lancaster (Hagerstown silt loam; fine-loamy, mixed, mesic Typic Hapludalfs), and 4) Lebanon (Duffield silt loam; fine-loamy, mixed, mesic Ultic Hapludalfs) counties. At each location, soils were limed and fertilized as needed according to soil test recommendations. Cultivars and seeding-rate treatments were replicated four times and arranged in an experimental design the same as that used in MO. A plot seeder was used to place seed in rows that were 15 cm apart in 0.9 x 4.6 m subplots.

Seedings at Dauphin and Lebanon sites were each located in a uniform area within a commercial production field that was seeded to alfalfa immediately after the plot area was seeded. Soil fertility (maintained in the optimum to high range), pest control (as needed), and harvest management were identical between the plot and field area and were completed by the cooperator farmers based on their management practices. The Centre and Lancaster sites were on Experiment Station Research Centers where insect and weed pests were controlled with pesticides when needed and the area was top-dressed in April each year with 84 and 280 kg ha^{-1} of P_2O_5 and K_2O, respectively.

At all location-years, forage was removed twice during the seeding year and four or five times annually thereafter when the alfalfa was at late-bud. Plant density was determined counting crowns 1 and 6 MAP, and annually thereafter in late April on three randomly selected 0.09 m^{-2} areas within each subplot. Data were collected for 4 yrs at the Dauphin and Lebanon county sites and for 5 yrs at the Centre and Lancaster county sites.

Statistical analyses for all locations were completed using the PROC GLM procedure of SAS (SAS Institute, 1997). Data were examined to determine if the assumptions of analysis of variance held, then analysis of variance (ANOVA) procedures were used to test the effect of cultivar and seeding rate on stand density and stem density (MO94 only). Homogeneity of variance was tested using Hartley's *F*-max test and accordingly data from Centre and Lancaster counties (CE & LA, PA) and Dauphin and Lebanon counties (DA & LE, PA) in PA were combined. Tukey's multiple comparison procedure was used for mean separations. Differences reported in this paper are all at the $P < 0.05$ level of significance.

RESULTS AND DISCUSSION

There was no cultivar X seeding rate interactions at any of the location-years so cultivar data were pooled for analyses. Data presented are the means of all cultivars within a location-year.

Seedling Numbers

Averaged across all seeding rates, percent of PLS that produced an alfalfa seedling 1 to 3 MAP varied between location-years (Fig.1). Less than 38% of the PLS planted at MO94, MO95, and MO98; 47-53% of the PLS at MO97 and CE & LA, PA; and 79% of the PLS at DA & LE, PA produced a seedling 1 to 3 MAP. Differences between location-years could be the result of different seeding method used in MO (hand broadcast and then rolled) than PA (plot seeder). Annual applications of manure to the DA & LE, PA sites ("on-farm sites") before seeding the alfalfa may have played a role in higher seedling numbers at those locations. None of the other location-years had manure applied before seeding. As alfalfa seeding rates increase, seedbed and environmental conditions seem to play an increasing role in maximizing seedling numbers.

In each location-year, the number of seedlings was directly proportional to seeding rate, but y-intercepts at all locations were positive, ranging from 50-84 plants m^{-2} in PA and from 52-66 in MO (Fig. 1). This suggests that lower seeding rates have higher emergence rates or that thinning may have begun before the initial plant count (1 to 3 MAP) and/or was more severe at higher seeding rates. For example, at each location-year in MO the lowest seeding rate resulted in the highest percent of PLS that produced a seedling (52%) and the highest seeding rate had the lowest (22%).

Plant density in PA was generally determined sooner after planting than in MO. Subsequent research (unpublished) suggests that emergence is complete in MO within 21d after planting, which agrees with the 19 d reported by Triplett and Tesar (1960). Consequently, some thinning of seedlings could be occurring simultaneously with emergence in our research, especially at the higher seeding rates.

Plant Mortality Rates

Averaged over all locations-years, higher seeding rates (higher plant densities) had greater plant mortality rates (70%) than lower seeding rates (40%) the first year after planting (Fig. 2). This relationship and the mortality rates were similar for all location-years regardless of the initial plant density. Following the seeding year, plant mortality rates were similar or only slightly greater for higher seeding rates compared with lower seeding rates (Fig. 2). The greatest mortality rates occurred within 24 MAP regardless of the seeding rate. In all location-years, the lowest mortality rate occurred between 24 and 36 MAP for all seeding rates (Fig. 2). This relatively low mortality rate during this period may be attributed to declining intra-species competition and subsequent elevated mortality rates associated with external stresses (pests, management, environment) as the alfalfa stand ages.

At all location-years, higher plant densities experienced greater plant deaths than lower plant densities during almost every time period (Table 1). This trend was most pronounced during the first year after planting when plant death in the highest seeding rate was eight times that of the lowest seeding rate (Fig 2). However, the trend continued, to a lesser extent, throughout the duration of all studies. Greater numbers of plant deaths at the higher than the lower plant densities accounts for the narrowing of plant densities between seeding rates with time, even though the mortality rates were similar among plant densities later than one year after planting (Fig. 2, 3 & 4).

Plant Density

Plant densities began higher and remained higher for the duration of the studies in PA (Fig. 3) than in MO (Fig. 4). Plant densities generally remained ranked according to seeding rate, and the high and low rates were significantly different through 49 MAP for the MO94 and MO95 studies. Differences were still significant at the last sampling (25 MAP) for the MO98 study, 37 MAP for the MO97 study, and 60 MAP for the CE & LA, PA studies (Fig. 3 & 4). However, the densities were not different at 36 MAP for the DA & LE studies (Fig. 3). These general results, from more humid environments, are consistent with the dryland environment findings of Kephart et al. (1992) in that seeding rate can affect plant density up to 48 MAP.

Plant density in each of the MO location-years was less than 40 plant m^{-2} at 26 MAP. A density of ≈43 plants m^{-2} has been found to a threshold below which yield begins to decline precipitously (Cowett and Sprague, 1962; Volenec et al., 1987). Lower initial plant densities in the MO compared to the PA studies, regardless of the seeding rate, suggests that seeding techniques and soil conditions to maximize seedling establishment are more important than seeding rate if an alfalfa stand is to maintain optimum productivity for more than a few years.

Two factors likely contributed to the higher seeding rates being able to maintain higher plant densities. First, beginning with more plants increases the probability of survival although plant-to-plant competition will be higher. Having fewer shoots per root may be advantageous over having more shoots per root which was the situation in the low-density stand. The second factor could be a genetic shift within the heterogeneous population that favored survival of plants for the long term if the characteristics favoring survival were those associated with the ability to tolerate competition at early growth stages. For example, averaged over all the experiments in MO, the 3 and 17 kg ha^{-1} seeding rates had plant densities of 75 and 205 plants m^{-2}, respectively, 1 to 3 MAP. Three years after planting the plant densities were 22 and 32 plants m^{-2} for the same seeding rates, indicating much stronger selection pressure for plant survival at the higher density.

Potential forage yield at low plant densities depends on the plant’s ability to form more stems $plant^{-1}$, a process that depends on climatic conditions such as available moisture and light penetration to the crown. Under non-irrigated dryland condition, reduced seeding rates reduced yield through three production years (Kephart et al., 1992). However, under more humid conditions in the mid-west plant density had limited effect on forage yield (Nelson et al., 1996; Hall, 1993; Moline and Robison, 1971).

Stem Density

Stem densities for the MO94 study (data not presented) were not different among seeding rates at any sampling time. There were 623 stems m^{-2} 13 MAP and only 350 stems m^{-2} by 25 MAP. Stem density remained nearly constant at that level through 49 MAP. During the same time period, plant density declined from an average of 100 down to 25 plants m^{-2}. This means that there was a 4x increase in stems $plant^{-1}$ from 25 to 49 MAP during the same time period. Thereafter, stem density continued to decline to 290 and 260 stems m^{-2} at 63 and 73 MAP, respectively, while plant density fell below 15 plants m^{-2} during the same time period. Crowns develop stems in response to light (Cowett and Sprague, 1962), and apparently could not continue to maintain high stem density with the thin stand and older plants.

CONCLUSIONS

Initial seedling densities were a near linear function of seeding rate and those rankings remained consistent as the stands thinned during 48 MAP. Plant density thinned much more rapidly at high densities than at low densities during the first 12 MAP. Thereafter, the stands thinned at a rate that was less associated with plant density. Significant differences in plant density due to seeding rate existed until about 48 MAP. Stems plant^{-1} increased at low plant densities so stem densities remained similar for all plant densities.

Seeding alfalfa at higher rates than 17 kg ha^{-1} initially resulted in higher plant densities but these differences did not persist beyond six MAP. Consequently, it is doubtful that elevated seeding rates above those recommended will increase the viable life of an alfalfa stand. However, seeding at rates below 17 kg ha^{-1} resulted in lower plant densities for up to four years after planting. At 24 to 26 MAP, the 10 kg ha^{-1} seeding rate had lower plant density than the 17 kg ha^{-1} rate in just two of the eight location-years, while the 7 kg ha^{-1} seeding rate had lower plant densities in seven of the eight location-years.

Increasing alfalfa seeding rates above recommended levels (≈17 kg ha^{-1}) provided no measurable long-term benefit. An important consideration is the method of seeding and seedbed preparation as plant densities in this study ranged more than four-fold between location-years. Improvements in consistencies in seedbed technology to allow at least 50% of the PLS to form seedlings would allow lower seeding rates to be less problematic or risky for producers.

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Table 1. Relationship of alfalfa plant densities over time. Linear regressions, slopes and correlation coefficients are for location-years at sequential time periods.

	Age of plants (months)						
X axis is plant density at:	1-3	12-13	24-26	36-38	48-49	61	73
Y axis is plant density at:	12-13	24-26	36-38	48-49	60-61	73	85
Location-year			slope (r^2)				
MO94	0.42[†] (0.93)	0.36 (0.99)	0.80 (0.93)	0.41 (0.64)	0.29 (0.76)	0.79 (0.56)	
MO95	0.34 (0.96)	0.52 (0.90)	0.40 (0.92)	0.65 (0.75)	0.43 (0.61)	1.03 (0.37)	0.65 (0.85)
MO97	0.11 (0.92)	0.32 (0.98)	1.03 (0.93)				
MO98	0.13 (0.99)	0.50 (0.82)					
CE & LA, PA	0.15 (0.87)	0.52 (0.92)	0.72 (0.91)	0.69 (0.78)			
DA & LE, PA	0.20 (0.83)	0.38 (0.88)	0.35 (0.86)	0.46 (0.79)	0.32 (0.84)		

[†] Slopes > 1.0, = 1.0, and < 1.0 indicates that greater, equal, fewer numbers of plants, respectively, are dying in the low than high population densities during that time period.

Fig. 1. Density of alfalfa 1 -3 months after planting (MAP) at various rates in eight location-years. Values are the average of three cultivars at the MO location-years and two cultivars at the PA sites.

Fig. 2. Mortality rates during yearly time periods (months after planting, MAP) for alfalfa seeded at various rates. Values are the average of eight location-years and multiple cultivars.

Fig. 3. Effect of alfalfa seeding rate on stand density over time for combined locations in Pennsylvania. Numbers above data points indicates the $LSD_{0.05}$ for that sampling date. The range in Y-axis values among graphs allows optimum differentiation between treatments.

Fig. 4. Effect of alfalfa seeding rate on stand density over time at the Southwest Research Center near Mt. Vernon, MO. Numbers above data points indicates the $LSD_{0.05}$ for that sampling date. The range in Y-axis values among graphs allows optimum differentiation between treatments. The dashed horizontal line on some graphs indicates the density needed to achieve maximum yield (Cowett and Sprague, 1962).

Fig. 1

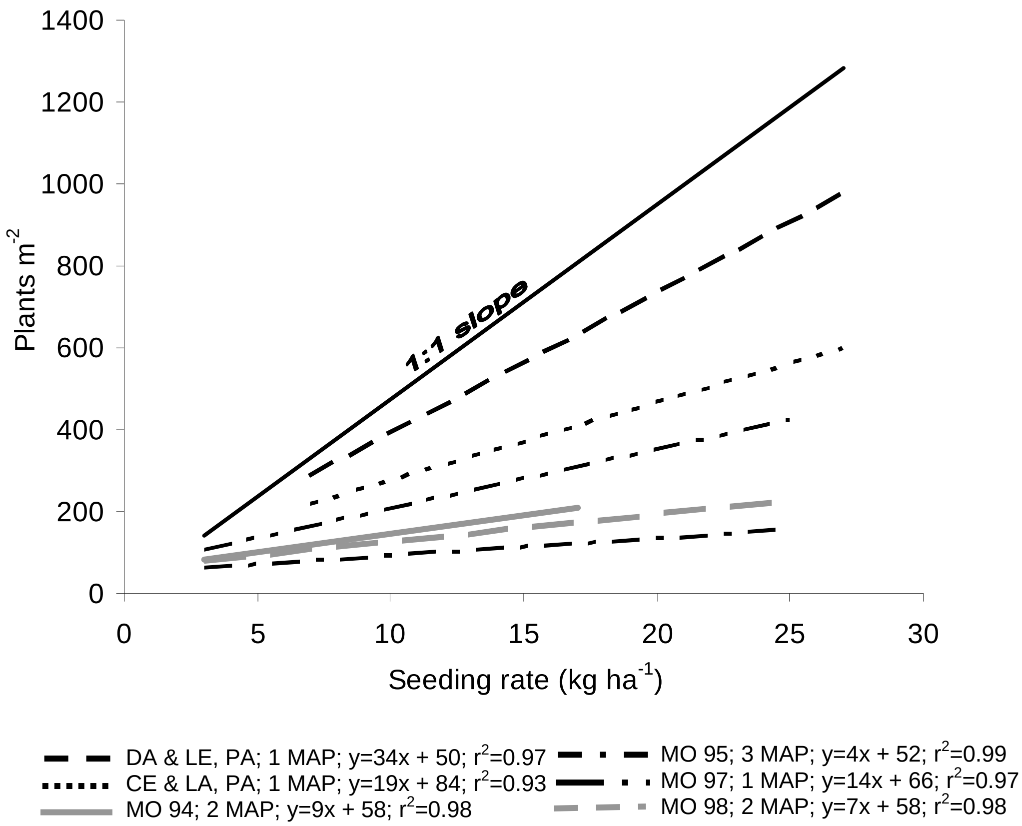

1400
1200
1000
800
600
400
200
0
Plants m-2
1:1 slope
0
5
10
15
20
25
30
Seeding rate (kg ha-1)
DA & LE, PA; 1 MAP; y=34x + 50; r2=0.97
CE & LA, PA; 1 MAP; y=19x + 84; r2=0.93
MO 94; 2 MAP; y=9x + 58; r2=0.98
MO 95; 3 MAP; y=4x + 52; r2=0.99
MO 97; 1 MAP; y=14x + 66; r2=0.97
MO 98; 2 MAP; y=7x + 58; r2=0.98

Fig. 2.

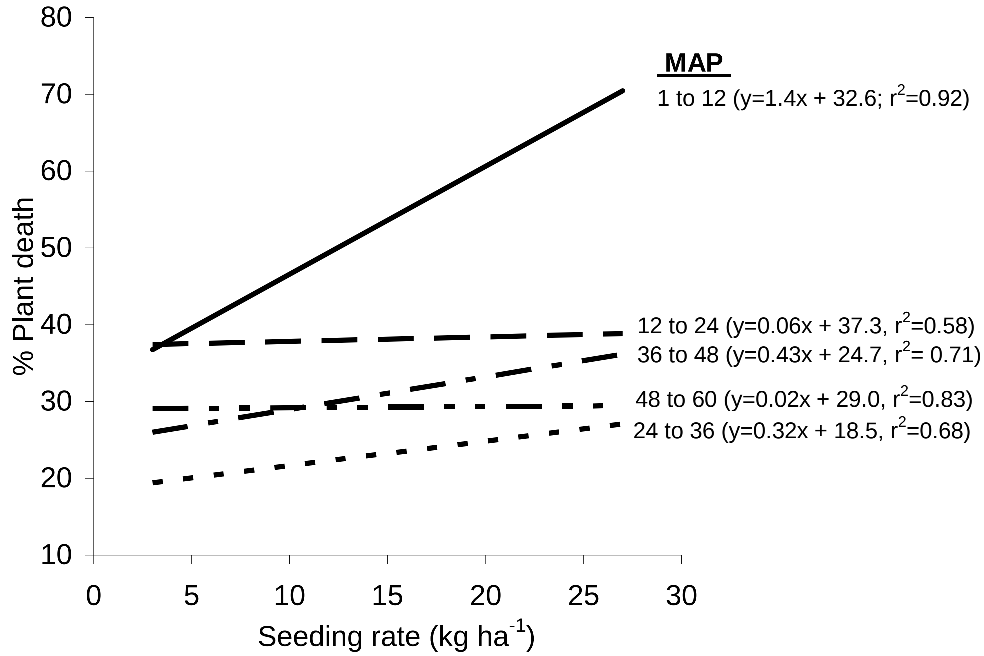

80
70
60
50
40
30
20
10
% Plant death
0
5
10
15
20
25
30
Seeding rate (kg ha^{-1})
MAP
1 to 12 (y=1.4x + 32.6; r^2=0.92)
12 to 24 (y=0.06x + 37.3, r^2=0.58)
36 to 48 (y=0.43x + 24.7, r^2= 0.71)
48 to 60 (y=0.02x + 29.0, r^2=0.83)
24 to 36 (y=0.32x + 18.5, r^2=0.68)

Fig. 3

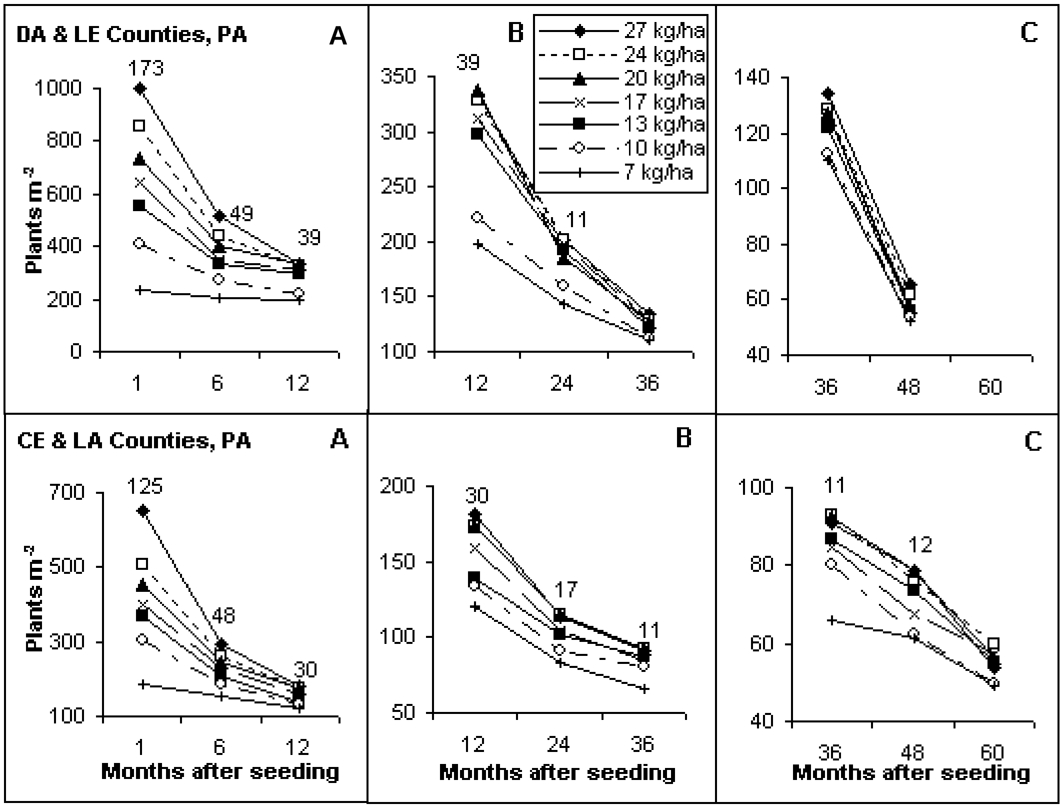
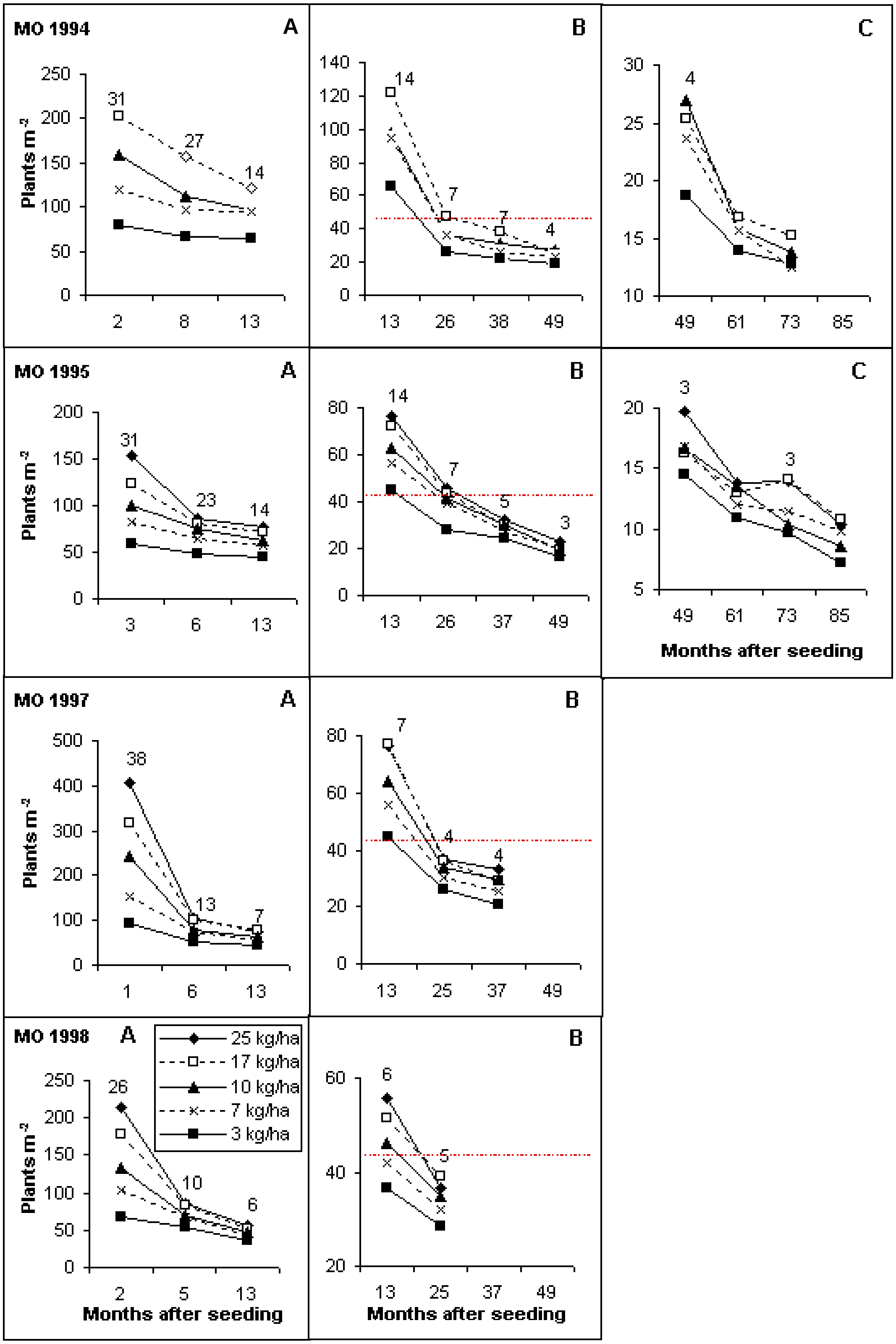

DA & LE Counties, PA
A
B
C
27 kg/ha
24 kg/ha
20 kg/ha
17 kg/ha
13 kg/ha
10 kg/ha
7 kg/ha
Plants m-2
173
49
39
39
11
CE & LA Counties, PA
A
B
C
125
48
30
30
17
11
11
12
Months after seeding
Months after seeding
Months after seeding

Fig. 4



MO 1994
A
B
C
Plants m-2
MO 1995
Months after seeding
MO 1997
MO 1998
25 kg/ha
17 kg/ha
10 kg/ha
7 kg/ha
3 kg/ha
Months after seeding
Months after seeding