WINTER ANNUAL LEGUME COVER CROPS IN A WHEAT-GRAIN SORGHUM ROTATION IN SOUTH CENTRAL KANSAS

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Abstract

Winter annual legumes in humid regions of the country can have a positive effect on subsequent corn (*Zea mays)* and grain sorghum (*Sorghum bicolor)* crops, mainly through N contribution of the legume and, in some cases, soil improvement. However, water use by the cover crop in drier regions has the potential to reduce yields in subsequent crops. This study was initiated in south-central Kansas to look at the agronomic implications of adding a winter annual legume cover crop to a winter wheat (*Triticum aestivum*)-grain sorghum rotation. Experiments using Austrian winter pea (*Pisum arvense*) and hairy vetch (*Vicia villosa*) were established at the KSU South Central and Harvey County Experiment Fields. Results showed that in good rainfall years, establishment of cover crop was adequate, and no significant difference occurs between sorghum yields following cover crops versus following wheat with fertilization. There was a significant nitrogen (N) contribution from hairy vetch and benefits to sorghum. For cover crops to be attractive options for farmers in this part of Kansas it may be necessary to use them for livestock feed and/or for early spring grazing, other cultivars and/or management systems that use less water must be developed, experiments must be conducted to ascertain benefits of cover crops during the second rotation cycle; and the price of N fertilizer must increase to the point that use of alternative sources is economical.

Introduction

Annual legumes have been tested in many regions of the U.S. (Smith et al., 1987) and have been successful in providing or supplementing nitrogen (N) to corn (Power et al., 1991; Utomo et al., 1990; Holderbaum et al., 1990; Decker et al., 1994); and sorghum (Sweeney and Moyer, 1994; Schlegel and Havlin, 1997). In some cases, the N from cover crops is released late in the growing season (Huntington et al., 1985). Though plant uptake of N is initially higher from fertilizers than from cover crop sources, more cover crop N remains in the soil organic and microbial pools and may be released later (Harris et al., 1994). In addition to the N benefit, yield increases have been documented when fertilizer is combined with cover crop use (Utomo et al., 1990; Blevins et al., 1990), possibly because of soil quality enhancement (Sweeney and Moyer, 1995). Additional benefits of cover crops are reduced erosion (Bilbro, 1989); greater uptake of N left over from the preceding crop (McCracken et al., 1994); and providing habitat for soil-improving organisms such as mycorrhizal fungi (Galvez et al., 1995). However, water use by cover crops also can decrease yields in subsequent crops in dry regions or during dry years (Schlegel and Havlin, 1997). Therefore, the objective of this study was to determine the effect of cover crop termination date and N contribution on subsequent grain sorghum yields in a wheat-sorghum rotation in on-station trials.

Methods and Materials

To fulfill the objective of the study trials were implemented at the KSU South Central Experiment Field, Hutchinson, and the KSU Harvey County Experiment Field, Hesston.

Hutchinson Site: Date of Termination Study, 1995/96 1998/99

The site of the trial consisted of an Ost loam soil where wheat had been grown in 1994/95. The research used a randomized block design and was replicated four times. Cover crop treatments consisted of fall-planted winter peas with intended termination dates in April and May and no cover crop (fallow). The winter peas were planted on 14 September, 1995 at a rate of 35 lb/a in 10-inch rows with a double-disk opener grain drill. Actual dates of termination were 16 May, 1996 and 4 June, 1996. Prior to termination of the cover crop, above ground biomass samples were taken from a 10.76-ft^2 area. These samples were used to determine forage yield (winter pea and other) and forage N and phosphorous (P) contents for the winter pea portion. Weeds were controlled with a broadcast application of propachlor and atrazine after planting. Fertilizer treatments consisted of a control (zero N) and three N levels (30, 60, and 90 lb N/a) that were broadcast and applied as ammonium nitrate (34-0-0) prior to planting of grain sorghum on 17 June, 1996. Phosphate was applied at a rate of 40 lbs/a P_2O_5 in the row at planting. Grain sorghum plots were harvested on November 25 (replications 1 and 2) and December 8, 1996 (replications 3 and 4) to determine yield, moisture, test weight, and N and P contents of grain. In preparation for the 1999 grain sorghum crop, winter peas were planted in the same plots as they were in 1995 on September 15, 1998. These plots were terminated on April 21 (DOT199) and May 19 (DOT299) 1999. Grain Sorghum was planted on June 11, 1999. The sorghum plots were harvested for grain yield on October 29, 1999.

Hesston Site: Date of Termination Study, 1995/96

The trial site consisted of a Geary silt loam soil on which unfertilized winter wheat was grown in 1995. Soil sampling was done prior to vetch planting to establish soil nutrient and moisture status. Additional soil sampling was done at vetch termination, grain sorghum planting, and at the end of the season. Reduced tillage practices with a disk and field cultivator were used to control weeds and prepare a seedbed. Hairy vetch plots were roller harrowed and planted at 15 lb/a in 8 in. rows with a grain drill equipped with double-disk openers on 15 September. Rainfall shortly after planting favored fall stand establishment. Volunteer wheat was controlled by a mid-October application of Fusilade and crop oil concentrate. Fall, winter, and early spring months were very dry. Consequently, hairy vetch had too little growth to merit termination in early April, the first target date. Subsequent wet weather delayed initial termination by disking until 20 May. The second set of plots was terminated on 11 June, about 5 weeks later than intended. Vetch forage yield was determined by harvesting a 10.76 ft^2 area in plots on 16 May and 11 June. Nitrogen fertilizer was broadcast as ammonium nitrate, at the same rates as in the Hutchinson site, on specified plots before the last preplant tillage on 14 June. Grain sorghum was planted on 14 June. Weeds were controlled with a preemergence application of Microtech and atrazine. Grain sorghum was combine harvested on 27 October. In 1996/97 the experiment was established on a Geary silt loam soil on which unfertilized winter wheat was grown in 1995 and 1996. Reduced tillage practices with a disk and field cultivator were used to control weeds and prepare a seedbed. Hairy vetch plots were planted at 15 lb/a in 8 in. rows with a grain drill equipped with double-disk openers on 13 September. Rainfall shortly after planting favored fall stand establishment of hairy vetch. Precipitation during the entire vetch growing season was near to or slightly above normal. Volunteer wheat was controlled by a mid-March application of Fusilade and crop oil concentrate. Vetch plots were terminated by disking on 25 April and 14 May. Vetch forage yield was determined by harvesting a 10.76 ft^2 area from each plot immediately before termination. Nitrogen fertilizer treatments were broadcast as ammonium nitrate on 23 June, 1997. All plots received 35 lb/a of P_2O_5, which was banded as 0-46-0 at planting. Grain sorghum was planted after a rain delay at approximately 42,000 seeds/a on 3 July, 1997. Weeds were controlled with a preemergence application of Microtech and atrazine. Grain sorghum was combine harvested on 6 November.

Results

Hutchinson Site: Date of Termination Study, 1995/96 and 1998/99

Winter pea cover crop and grain sorghum results are summarized in Tables 1 and 2 respectively. Soil conditions at planting of the winter peas in 1995 were excellent with good moisture. However, the mid-September planting date was later than desired due to above normal rainfall in late August and early September. After planting temperatures cooled and limited fall growth of the winter peas occurred. Fall ground cover in 1996 ranged from 26 to 36 percent with no significant differences across treatments (Table 1). This compares to a range of 36 to 46 percent for 1999. The winter months of 1996 were cool and dry. This limited growth and delayed the first date of termination (DOT1) from early April to May 16. Date of termination 2 (DOT2) was also delayed by wet conditions in May to June 4. Winter conditions in 1999 were more favorable and growth of the winter peas was much better. The termination dates for 1999 were April 21 (DOT199) and May 19 (DOT299). Winter pea above ground biomass at DOT1 (1996) was about one-half that of DOT2 (Table 1). However, there were no significant differences in dry matter (DM) production within DOTs. Differences in the percent N in the DM existed in the treatments for DOT2. These differences are not related to the treatment but to natural occurrence (no treatments were applied to the cover crop plots prior to termination). In 1999 the differences in DM production by termination date were not as great and those in 1996. However, DOT299 had significantly more DM production that DOT199 (Table 1).

Large amounts of nitrogen were not produced by the winter pea cover crop in 1996. Nitrogen credited to the cover crop ranged from 9.48 to 30.70 lb N/ac. The larger amounts of DM produced in 1999 add considerable amounts of N (table 1) from the winter pea biomass. In 1996, the low levels of N from the winter peas not carry forward to increased grain yield in the grain sorghum crop. Only the no-N treatments with and without the cover crop and the DOT1 no cover crop and cover crop plus 90 lb/a N treatments had significantly lower grain yields (Table 2). Flag leaf N (%) and whole plant N (%) were decreased in the no-N treatments with or without cover crop. The highest flag leaf and whole plant N occurred in the April cover crop plus 90 lb/a N treatment. Thus, the overall effect of the cover crop and N fertilizer on flag leaf and whole plant N and grain yield in 1996 was not always significant or consistent.

It is felt that the increased biomass N and the available water (above normal precipitation) during the growing season resulted in excellent grain sorghum yields for 1999 (Table 2). Grain yields in 1999 ranged from a low of 40.5 bu/ac to a high of 112.3 bu/ac. The lowest yield came from the 0 N no cover crop treatment and the highest from the 60 lb/ac N with cover crop (139 lb/ac N in biomass) treatment.

As with other N rate studies on the South Central Field, the first increment of fertilizer N had the greatest effect grain yield. Sorghum yields in DOT1 were not significantly different by treatment. In DOT2 approximately 30 lb/a N as fertilizer was needed to produce a comparable sorghum yield to the cover crop with no added N. Highest sorghum yields occurred in the DOT1 no-cover crop plus 30 lb/a N and DOT2 cover crop plus 30 and 60 lb/a N treatments. In 1999, the same effect is present. However, in DOT199 yields for cover crop and fertilizer N evened out at the 30 lb/ac N and in DOT299 it took 60 lbN/ac to match the yield of winter peas with no nitrogen.

Hesston Site: Date of Termination Study, 1995/96 and 1996/97

Initial soil nitrate N and available P averaged 36 lb/a and 51 lb/a, respectively, and organic matter was 2.8%. Hairy vetch provided adequate late-fall ground cover (40%) to protect the soil from erosion (Table 3). Rainfall in late April and early May encouraged growth of hairy vetch, which was about 21 in. tall and had reached the 20 to 30% bloom stage on 20 May. It ranged from late bloom to early seed formation stages by June 11. Average dry matter yields were just under 2 tons/a on May 20 and nearly 2.5 tons/a by June 11. The average N contents were 2.73% and 2.59% for the vetch on each date, respectively (data not shown). Consequently, the average amount of N in the above-ground biomass was 105 to 127 lb/a. Disking to terminate hairy vetch growth reduced soil moisture at the surface, particularly on 11 June. Sorghum stands averaged about 8000 fewer plants in the June 11 treatment than in the May 20 date of termination and the no-vetch plots. Leaf N at boot to early heading stage tended to be highest at the higher N rates, and was statistically significant in the absence of vetch and the June 11 date of termination. Sorghum following vetch required 2 to 4 days longer to reach half bloom than sorghum without a preceding cover crop. Averaged over N rates, sorghum yields were 6 to 12 bu/a lower after vetch than where no cover crop had been grown. This negative effect of hairy vetch was accounted for by adjusting sorghum yields for soil P removal by vetch and may also be due to water use by the cover crop prior to sorghum planting. Yields tended to increase with N rate in sorghum after vetch, mainly at the 60 lb/a.

Initial soil nitrate N (0 to 2 ft) and available P (0 to 6 in.) averaged 19 lb/a and 40 lb/a, respectively, with an organic matter level of 2.1% on the site for the 1996/97 plantings. Hairy vetch provided excellent fall ground cover (63%) to protect the soil from erosion (Table 4). On 25 April, vetch was about 16 to 18 in. tall and had not reached bloom stage. A few plants were beginning to bloom by 14 May. Average dry matter yield of hairy vetch was 2.66 tons/a on April 25 and nearly 3.0 tons/a on May 14. The average N contents of vetch were 2.76% and 3.15%, respectively (data not shown). Consequently, the average potential amounts of N in the above-ground biomass were 147 lb/a and 188 lb/a, respectively. Disking to terminate hairy vetch growth did not adversely affect soil moisture at the surface because of ample spring rains, which ultimately delayed planting. Sorghum stands averaged 39,560 plants/a and were relatively uniform across treatments. At low N rates, leaf N at boot to early heading stage was higher in sorghum after vetch than in sorghum without vetch. The highest leaf N values occurred in sorghum following vetch in the 14 May termination date treatment. However, the effects of vetch termination date on leaf N were not always significant or consistent. The overall effect of N fertilizer rate on leaf N was significant. A trend for increasing leaf N as N rate increased was consistent in sorghum without prior vetch. In sorghum following vetch, leaf N did not increase meaningfully above an N rate of 30 lb/a. Sorghum following vetch required 1 to 2 days fewer to reach half bloom than sorghum without a preceding cover crop. Averaged over N rates, sorghum yields were 6 to 10 bu/a more after vetch than where no cover crop had been grown. The positive effects of 25 April and 14 May vetch on the yield of sorghum without fertilizer N were equivalent to those of about 70 lb/a and 89 lb/a of N, respectively. A small, but significant, increase in the number of panicles per plant accounted for most of the treatment effects on yield. The trend for increasing yields at the second termination date may indicate a response to the higher N contribution from the additional vetch.

Summary

The experiment at Hutchinson found that the N contribution from winter peas nearly doubled from 14 to 27 lb N/a with a termination date of May 16 versus June 4. Grain sorghum yields increased from 85 to 90 bu/a with cover crops at the two termination dates, respectively, but this difference was not statistically significant. Overall, the winter pea N contributions were not impressive during these 2 years. The maximum N contributions of 32 lb/a in 1996 and 148 lb/a in 1999 did not result in significant yield increases in the following grain sorghum. However, many farmers who use winter peas will continue to use them despite their low N contribution as compared to vetch, because they feel that they are easier to control in the spring and offer grazing opportunities for livestock on their farms. An on-farm observation study conducted by the South Central Field where there is grazing of the winter peas suggested that taking peas off early in the form of forage can help conserve soil moisture as compared to leaving them until preplant tillage.

The hairy vetch data from the Harvey County Field is encouraging. The vetch provided an overall average of 116 and 168 lb N/a in the above ground biomass in 1996 and 1997, respectively. The N provided by the vetch generally resulted in little to no response to N fertilizer in the plots with vetch, whereas typical yield responses to N fertilizer were observed in the control plots without vetch. The later cover crop termination date in the hairy vetch experiments at Hesston resulted in more total vetch biomass, lower percentage N in the tissue (data not shown), but overall higher levels of N in the above ground biomass. Grain sorghum yields were 6 and 4 bu/a higher in 1996 and 1997 at the second termination date, respectively. Although not statistically significant, this trend may indicate a response to the higher N contribution by the extra vetch. Attempting the termination date experiments pointed out one of the difficulties of handling cover crops in a wet spring, since cover crop kill and subsequent sorghum planting often must be delayed.

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References

Bilbro, J.D., 1989. "Evaluation of Sixteen Fall-seeded Cultivars for Controlling Wind Erosion." *J. Soil and Water Con.* 44:228-231.

Blevins, R.L., J.H. Herbeck, and W.W. Frye, 1990. "Legume Cover Crops as a Nitrogen Source for No-till Corn and Grain Sorghum." *Agron. J.* 82:769-772.

Galvez, L., D.D. Douds, Jr., P. Wagoner, L.R. Longnecker, L.E. Drinkwater, and R.R. Janke, 1995. "An Overwintering Cover Crop Increases Inoculum of VAM Fungi in Agricultural Soil." Am. J. Altern. Agri., 10(4):152-156

Harris, G.H., O.B. Hesterman, E.A. Paul, S.E. Peters, and R.R. Janke, 1994. "Fate of Legume and Fertilizer Nitrogen-15 in a Long-term Cropping Systems Experiment." *Agron. J.* 86:910-915.

Holderbaum, J.F., A.M. Decker, J.J. Meisinger, F.R. Mulford, and L.R. Vough, 1990. "Fall-Seeded Legume Cover Crops for No-tillage Corn in the Humid East." *Agron. J.* 82:117-124.

Huntington, T.G., J.H. Grove, and W.W. Frye, 1985. "Release and Recovery of Nitrogen from Winter Annual Cover Crops in No-till Corn Production." *Commun. Soil Sci. Plant Anal.* 16:193-211.

McCracken, D.V., M.S. Smith, J.H. Grove, C.T. MacKown, and R.L. Blevins, 1994. "Nitrate Leaching as Influenced by Cover Cropping and Nitrogen Source." *Soil Sci. Soc. Am. J.* 58:1476-1483.

Power, J.F., J.W. Doran, and P.T. Koerner, 1991. "Hairy Vetch as a Winter Cover Crop for Dryland Corn Production." *J. Prod. Agric.* 4:62-67.

Schlegel, A.J., and J.L. Havlin, 1997. "Green fallow for the Central Great Plains." *Agron. J.* 89:762-767.

Smith, M.S., W.W. Frye, and J.J. Varco, 1987. "Legume Winter Cover Crops." *Advanced Soil Science*, 7:95-139.

Sweeney, D.W., and J.L. Moyer, 1994. "Legume Green Manures and Conservation Tillage for Grain Sorghum Production on Prairie Soil." *Soil Sci. Soc. Am. J.*, 58:1518-1524.

Sweeney, D.W. and J.L. Moyer, 1995. "Legume and Tillage Effects on Prairie Soil Nitrogen and Penetration Resistance." *Commun. Soil Sci. Plant Anal.* 26:155-168.

Utomo, M., W.W. Frye, and R.L. Blevins, 1990. "Sustaining Soil Nitrogen for Corn Using Hairy Vetch Cover Crop." *Agron. J.* 82:979-983.

Table 1. Winter Pea Cover Crop and Termination Date Effects on Grain Sorghum after Winter Wheat-Cover Crop -- Winter Pea Growth, K.S.U. South Central Field, Hutchinson KS, 1996 and 1999.

Termination Date	N Rate[1] lb/a	Fall Ground Cover[2] %		Winter Pea DM N lb/a		Winter Pea[3] DM Yield N %	Winter Pea[3] DM Yield P %
		1996	1999	1996	1999	1996	1999
April[4]	0	33	46	9.48	103	0.302	3.1
	30	28	36	12.43	94	0.413	2.8
	60	30	36	10.26	83	0.342	2.8
	90	36	40	22.68	109	0.717	3.3
May[5]	0	36	40	19.71	128	0.900	4.6
	30	34	39	32.40	148	1.200	4.7
	60	33	41	23.98	139	1.110	4.8
	90	26	43	30.70	100	1.279	3.9
LSD (P=0.05)		NS	7			0.812	1.2

[1] Nitrogen applied as 34-0-0 after pea termination prior to planting grain sorghum (see Table 2)
[2] Winter pea cover estimated by 6 inch intersects on one 44 foot line transect per plot.
[3] Winter pea oven dry weight, %N, and %P determined from samples taken just prior to termination.
[4] April termination dates 1996 May 16 and 1999 April 21.
[5] May termination dates 1996 June 4 and 1999 May 19.

Table 2. Effects winter pea cover crop and termination date on grain sorghum yield after Cover Crop -- Sorghum Yield, K.S.U. South Central Field, Hutchinson KS, 1996 and 1999.

Termination Date	N Rate[1]	Flag leaf 1996 N	Flag leaf 1996 P	Grain 1996 N	Grain 1996 P	Grain 1996 Yield	Grain 1999 N	Grain 1999 P	Grain 1999 Yield
	lb/a	%				bu/a	%		bu/a
April[2] N/pea	0	2.5	0.38	1.6	0.26	86.5	1.1	0.32	72.6
	30	2.7	0.44	1.6	0.27	93.9	1.2	0.29	90.9
	60	2.8	0.43	1.7	0.27	82.6	1.5	0.32	106.4
	90	2.8	0.44	1.7	0.25	90.4	1.7	0.34	101.8
April[2] /pea	0	2.4	0.40	1.5	0.29	80.2	1.3	0.31	93.5
	30	2.7	0.39	1.6	0.26	85.7	1.3	0.32	97.4
	60	2.7	0.38	1.7	0.27	90.0	1.5	0.33	105.1
	90	2.9	0.41	1.8	0.23	83.8	1.8	0.32	97.9
May[3] N/pea	0	2.1	0.39	1.4	0.30	81.4	1.1	0.34	40.5
	30	2.4	0.39	1.5	0.28	88.1	1.1	0.32	66.6
	60	2.6	0.40	1.6	0.27	90.7	1.2	0.30	93.3
	90	2.6	0.40	1.6	0.26	89.6	1.4	0.31	105.9
May[3] /pea	0	2.3	0.40	1.4	0.29	85.0	1.2	0.31	92.4
	30	2.5	0.40	1.5	0.31	92.4	1.3	0.31	97.7
	60	2.6	0.38	1.6	0.26	92.9	1.5	0.30	112.3
	90	2.7	0.41	1.6	0.25	90.5	1.5	0.32	108.7
LSD (P=0.05)		0.2	0.02	0.1	NS	8.9	0.2	0.04	16.0

[1] Nitrogen applied as 34-0-0 after pea termination prior to planting sorghum on 17, 1996 and 11, 1999 June.

[2] Early April termination. Actual termination 16 May 1996 due to limited growth and 21 April 1999.

[3] Early May termination. Actual termination 4 June 1996 and 19 May 1999.

Table 3. Date of Termination Trial, Hesston, 1995/96

		Hairy Vetch Cover Crop			1996 Grain Sorghum			
Termination Date	N Rate	Fall Ground Cover	Biomass	N	Yield	Leaf N	Leaf P	Half Bloom
	(lb/a)	(%)	(tons/a)	(lb/a)	(bu/a)	(%)	(%)	(days)
No Cover Crop	0	-	-	-	118	2.75	0.345	57
	30	-	-	-	125	2.80	0.344	56
	60	-	-	-	121	2.84	0.345	56
	90	-	-	-	127	2.91	0.355	56
May 20	0	41	2.03	114	103	2.58	0.319	58
	30	40	1.77	87	111	2.64	0.312	59
	60	41	1.95	111	118	2.71	0.331	57
	90	37	1.95	108	113	2.61	0.312	59
June 11	0	36	2.22	115	104	2.55	0.307	64
	30	36	2.43	114	109	2.59	0.312	63
	60	42	2.52	135	123	2.77	0.328	61
	90	42	2.62	145	111	2.74	0.336	61
	LSD	NS	0.54	33	13.1	0.20	0.030	3.2
No Cover Crop		-	-	-	123	2.82	0.347	56
May 20		40	1.92	105	111	2.63	0.319	58
June 11		39	2.45	127	117	2.66	0.320	62
LSD		NS	0.27	17	6.6	0.10	0.015	1.6
	0	39	2.12	115	108	2.63	0.324	59
	30	38	2.10	101	115	2.67	0.323	59
	60	41	2.23	123	120	2.77	0.334	58
	90	39	2.28	127	117	2.75	0.334	59
	LSD	NS	NS	NS	7.6	0.12	NS	NS

Table 4. Date of Termination Trial, Hesston, 1996/97

Termination Date	N Rate	Hairy Vetch Cover Crop: Fall Ground Cover	Hairy Vetch Cover Crop: Biomass N	1997 Grain Sorghum: Yield	1997 Grain Sorghum: Leaf N	1997 Grain Sorghum: Leaf P	1997 Grain Sorghum: Half Bloom
	(lb/a)	(%)	(lb/a)	(bu/a)	(%)	(%)	(days)
No Cover Crop	0	-	-	91	2.60	0.345	59
	30	-	-	97	2.62	0.363	60
	60	-	-	102	2.78	0.395	59
	90	-	-	107	2.91	0.407	59
April 25	0	59	145	103	2.66	0.377	58
	30	60	157	108	2.85	0.394	58
	60	62	148	102	2.80	0.394	58
	90	59	138	105	2.86	0.392	59
May 14	0	66	215	106	2.80	0.400	58
	30	62	155	111	2.93	0.408	57
	60	71	210	111	3.01	0.422	57
	90	61	173	107	2.60	0.395	58
	LSD	NS	68	8.8	0.20	0.022	1.7
No Cover Crop		-	-	99	2.72	0.377	59
May 20		60	147	105	2.79	0.389	58
June 11		65	188	109	2.83	0.406	57
LSD		NS	34	4.4	NS	0.011	0.8
	0	63	180	100	2.69	0.374	58
	30	61	156	105	2.80	0.388	58
	60	67	179	105	2.86	0.404	58
	90	60	155	106	2.79	0.398	59
	LSD	NS	NS	NS	0.12	0.013	NS

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