Effect of **"Pro-Soil Foundation 1-0-1™"** upon Early Root Development of Wheat *(Triticum aestivum)* in Harper County, Kansas

Research Performed
By
Advanced AgroData
Lawrence, KS

Member
American Society of Agronomy • Crop Science Society of America • Soil Science Society of America

Abstract: *Based upon reports from wheat growers, Pro-Soil Foundation 1-0-1™ (PS or PSF), manufactured by Pro-Soil Ag Solutions, Inc., has shown to increase wheat yields at a significant level, at times even with a reduction in applied nitrogen. Reports have also included statements indicating in many instances larger root systems. This project was initiated to study the effects of PS upon early root development of the wheat plant itself, and to weigh whether PS does have a positive effect upon wheat roots prior to winter dormancy*

The key messages from the Pro-Soil Foundation™ biological fertilizer treatment in this study are: *(1) Treatment with Pro-Soil Foundation™ biological fertilizer had a large, and significant, effect on the size of the root system; increasing both root depth and mass.(2) Treatment with Pro-Soil Foundation™ biological fertilizer had an even more significant effect on plant population; increasing both the number of vigorous wheat plants per foot of row as well as the total vegetative biomass. (3) Treatment with Pro-Soil Foundation™ biological fertilizer suggested more rapid residue decomposition.*

Materials and Methods: Field preparation for the research was identical across the entire field. The wheat variety is *Overly*, and planting rate was 70 pounds of wheat seed per acre. Prior to planting the field was divided into **nine alternating replications** for both control and *Pro-Soil Foundation*™ treated wheat. The *Pro-Soil Foundation*™ was applied at 12.8 ounces per acre, as part of the pre plant nitrogen application. The entire field received 20 units N, with the source being liquid 28%. Additional fertilizer was applied with the drill, and included 50 pounds/acre of pel-lime, and 30 pounds/ acre of 11-52-0. The wheat was planted on October 6. Soil type is a silt loam, and according to soil maps is consistent across the field.

WHEAT ROOT SAMPLES: NUMBER OF REPLICATIONS

Sample sites were measured, and flagged, in each strip on 11/2/06, at 150', 300' and 450' in to the field. Initial *Pro-Soil Foundation*™ treated wheat replications #1, #3 and #5 at each of the three sites, *providing a total of nine wheat samples from both control and Pro-Soil Foundation™ treated wheat.*

On 12/14/06 research samples were again taken from both control and *Pro-Soil Foundation*™ treated wheat replications #1, #3, #5 and #7, for a total of 12 wheat samples from both control and *Pro-Soil Foundation*™ treated wheat. All samples were taken at a 12" depth, and width was 6.7" on 11/2, and 10" on 12/14.

Figure 1: Bagged Wheat Root Samples

Once collected, research samples were labeled, and placed into plastic bags, water was then added to soften the soil and samples were allowed to sit overnight. They were then placed upon a screen, with water applied to wash soil from the roots. They were then placed back into the bags, and again water was added to soak overnight. After a second washing, the plants were then placed in moist paper towels to avoid excessive drying. They received one additional washing, and then the longest root was measured, as well as the longest leaf. The total number of wheat roots, leaves and tillers were recorded, and then the root and vegetative parts of the plant were divided and weighed. Both the roots and vegetative parts were then allowed to dry for three weeks and then reweighed.

Observations: A true comparison of individual wheat plants was somewhat difficult to achieve **due to a significant increase in plant population.** This was consistent across most comparisons, and population at each sample site is shown in Table 1.

In the nine control samples taken on 11/2/06 there was a total of 74 plants (14.8 per foot of row) and the Pro-Soil had a total of 102 plants (20.4 per foot of row), for an increase in plant population of 37.84%.

At the time of the second sampling on 12/14/06, this difference had decreased somewhat but there was still a significant increase in the Pro-Soil samples. The twelve control samples had a total of 121 plants (12.1 per foot of row) and the Pro-Soil had a total of 152 plants (15.2 per foot of row), for an increase of 25.62%.

Table 1: Number of Plants Per Sample.

Sample	Control		PS Foundation™	
ID	11/2	12/14	11/2	12/14
1A	6	15	10	12
1B	8	9	8	8
1C	7	13	9	15
3A	9	8	9	10
3B	8	12	12	13

SEMINAL WHEAT ROOTS

At the first sample date, the only roots present were those coming out of the wheat seed kernel itself (seminal roots).

The number and size of seminal roots is usually determined by the vigor of the seed kernel of the wheat itself, and usually ranges up to six per seedling. Even so, there was a small increase in both the number and length of the roots from the seedlings treated with Pro-Soil Foundation. (Table 2)

WHEAT DEVELOPMENT STAGE (ZADOKS SCALE)

The average development stage, using Zadoks scale, was between 13 and 14, again with a slight difference in favor of the wheat plants from the Pro-Soil sites. This data is shown in Table 2.

Figure 2: Trimmed Crown/Nodal Wheat Roots

By the second sample date, 12/14, crown root formation was well underway. Soil fertility, and other factors such as physical limitations, will have an impact upon both the number and length of these later roots (crown/nodal).

When taking these samples it was apparent that there were roots being trimmed, probably more from a lateral standpoint than depth. (Figure 2) ***Even so, there was again a slight increase in both the number of roots and the average length with samples from Pro-Soil treatment sites.*** This data is also shown in Table 2.

Additionally **tillering was well underway, with an average development stage of 22 to 24 on the Zadoks scale.** (Table 3)

Table 2: Average Root and Leaf Numbers, Length, and Weight. (Nov. 2 Sample Date, 6.7" Sample Width):

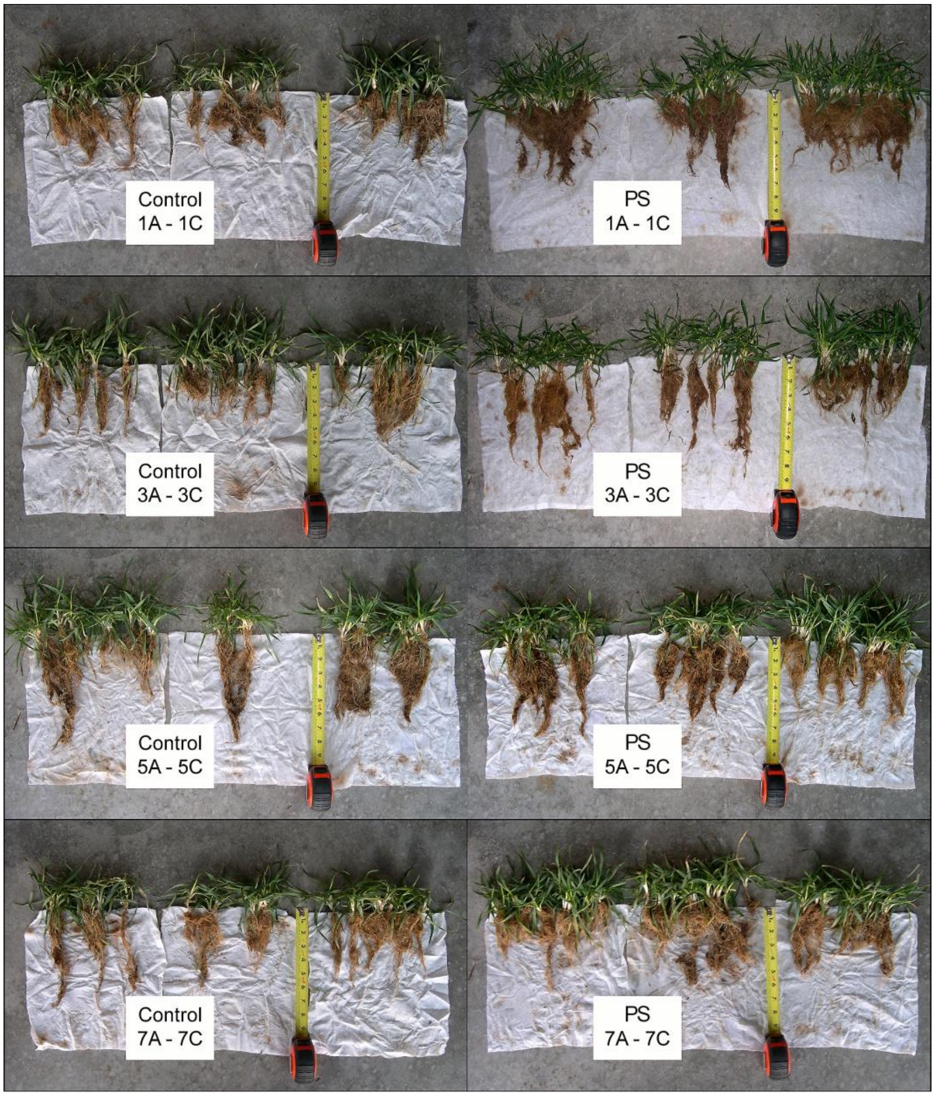
	Control				PS Foundation			
	Rep 1	Rep 3	Rep 5	Average	Rep 1	Rep 3	Rep 5	Average
# Plants	21	27	26	24.67	27	34	41	34.00
# Roots/Plant	4.74	4.99	4.35	4.69	4.93	4.65	5.07	4.88
Ave Length (mm)	117.85	120.03	125.52	121.13	127.03	123.92	123.75	124.90
Ave Weight (gm)	.25	.32	.34	.30	.32	.25	.32	.29
Total Root Wt (gms)	5.20	8.50	8.90	22.60	8.50	8.50	13.10	33.20
Dry Root Wt. (gms)				2.50				4.50

# Leaves/Plant	2.93	3.02	2.98		2.98	2.92	3.02	3.19		3.04
Leaf Length (mm)	159.71	169.41	170.77		166.63	169.12	170.55	169.43		169.70
Ave Weight (gm)	.33	.33	.30		.32	.33	.26	.37		.32
Total Leaf Wt (gms)	7.00	9.00	7.70		23.70	8.90	8.90	15.10		35.10
Dry Leaf Wt (gms)					3.60					5.40
Total Plant Wt (gms)	12.20	17.50	16.60		15.43	17.40	17.40	28.20		21.00
Total Dry Wt. (gms)					6.10					9.90

Table 3: Average Root and Leaf Numbers, Length, and Weight. (Dec. 14 Sample Date, 10” Sample Width):

	------------------------ **Control** ------------------------					---------------------------**PS Foundation**------------				
	Rep 1	Rep 3	Rep 5		Average	Rep 1	Rep 3	Rep 5		Average
# Plants	37	30	27	27	30.25	35	36	44	37	38.00
# Roots/Plant	8.37	9.44	10.26	9.76	9.46	8.65	9.70	9.65	10.69	9.67
Ave Length (mm)	152.72	170.28	207.20	168.56	174.69	185.81	184.72	177.81	184.70	183.26
Ave Weight (gm)	.72	.79	1.16	.97	.91	2.24	1.14	1.49	1.71	1.64
Total Root Wt (gms)	26.80	23.80	31.30	26.30	114.20	78.40	40.90	65.70	63.10	248.10
Dry Root Wt. (gms)					24.60					79.30
# Tillers/Plant	3.00	3.73	4.30	3.59	3.66	3.83	4.03	3.80	4.30	3.99
# Leaves/Plant	8.65	10.67	12.70	10.52	10.63	11.57	10.92	11.07	12.05	11.40
Leaf Length (mm)	138.86	106.28	104.84	104.62	113.65	153.25	143.80	155.62	157.85	152.63
Ave Weight (gm)	.84	1.49	1.97	1.35	1.41	1.61	1.24	1.39	1.63	1.47
Total Leaf Wt (gms)	31.20	44.60	53.30	36.50	163.70	56.40	44.60	61.00	60.40	222.40
Dry Leaf Wt (gms)					38.50					51.00
Total Plant Wt(gms)	58.00	68.40	84.60	62.80	277.90	134.80	85.50	126.70	123.50	470.50
Total Dry Wt. (gms)					63.10					130.30

Figure 3: Pictured below are the samples taken on December 14.



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Results: **Although there was certainly some variation from one sample site to another, there was a definite trend toward increased root (Graphs 1 & 2) and vegetative mass, as well as more advanced vegetative development.**

Wheat Root Counts

As to root counts on November 2, the control averaged 4.695 seminal roots per plant and the Pro-Soil treatment averaged 4.883 roots per plant, an increase of .188 roots per wheat plant (4.00%). On December 14, the control averaged 9.458 roots (seminal and crown) per plant and the Pro-Soil treatment averaged 9.671, for an increase of .213 roots per wheat plant (2.25%).

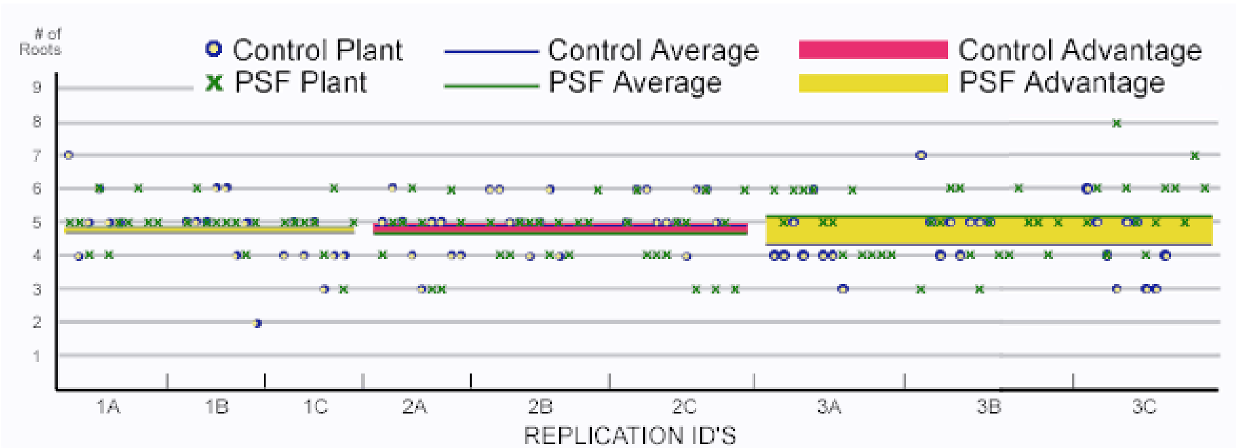
Wheat Root Length

At both sampling dates the root length was also increased. On November 2, the control averaged 121.134 mm length, and the Pro-Soil treatment averaged 124.898 mm; an increase of 3.11%. On December 14, the control averaged 174.691 mm and the Pro-Soil treatment averaged 183.261 mm; an increase of 4.91%. ***In addition, it appeared generally that the roots from the Pro-Soil treatment samples were somewhat more developed as to small feeder roots*** (see photos in Figure 3.)

Although the average increase per plant, from either date, is not highly significant in itself, **the difference in total root mass is significant due to the much higher population in the Pro-Soil treatment samples** (Graph 3).

> "Although the average increase per plant, from either date, is not highly significant in itself, **the difference in total root mass is significant due to the much higher plant population** in the Pro-Soil treatment samples."

Graph 1:
Number of Roots (Seminal) per Plant, by Replication ID's (November 2 Sample).



Graph 2:

Number of Roots (Seminal & Crown) per Plant, by Replication ID's (Dec. 14 Sample).

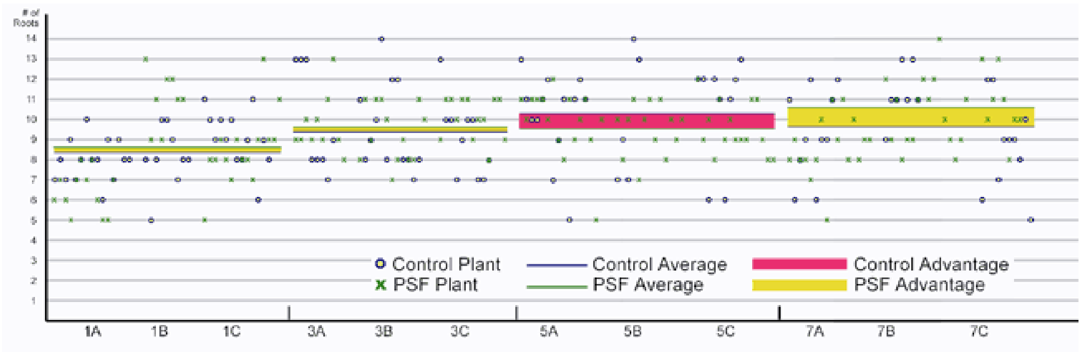


Table 4: Plant Mass per Foot of Row.

	11/2/06		12/14/6	
	Control	**Foundation**	**Control**	**Foundation**
Root (gms)	4.520	6.640	11.420	24.810
Vege. (gms)	4.740	7.020	13.642	22.240
Total (gms)	9.260	13.660	25.062	47.050
Diff. (gms)		+ 4.400		+ 21.988
Diff. (%)		+ 47.52%		+ 87.74%

INCREASED WHEAT PLANT BIOMASS/ VIGOR

Again, **the higher plant population is responsible for a majority of the increase in biomass per foot of row, 47.52% greater on 11/2, and 87.74% greater on 12/14 (Table 4).**

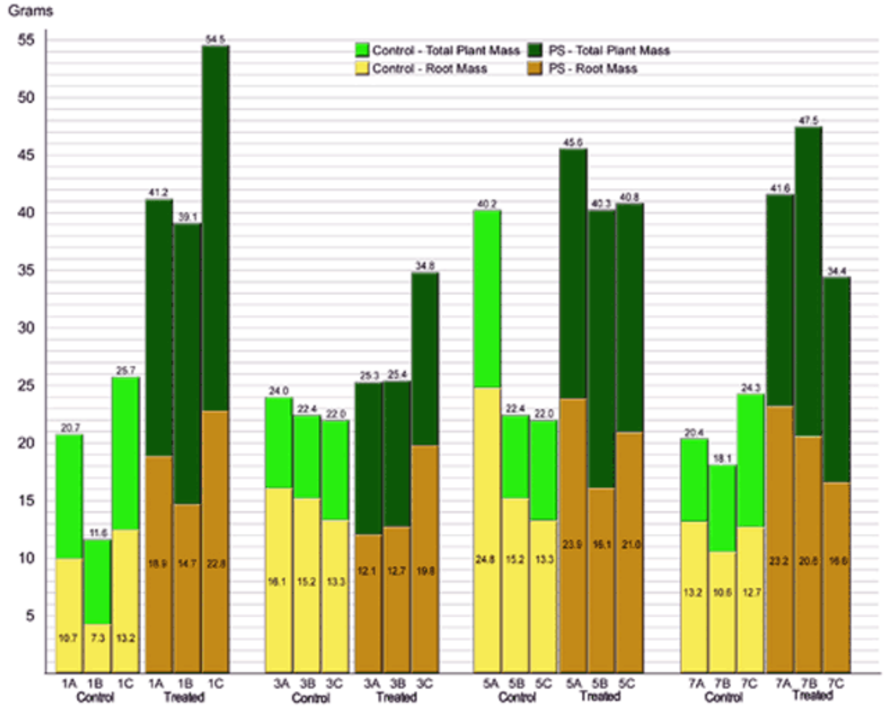
This is interesting, in that *under normal circumstances it is expected that as plant population increases individual plant size will tend to decrease, due to competition,* assuming equal amounts of plant nutrient, water and other environmental factors. *This was not the case with the plants from the Pro-Soil areas of treatment, which would suggest **additional vigor** due to materials either in Pro-Soil itself directly, or by indirect means resulting from other soil/plant activity.* The label lists small amounts of copper, iron and zinc, as well as kelp extract and humic acid, which in numerous scientific studies have each shown to be of benefit to increase plant vigor.

When washing the roots, it was observed that there was noticeable plant residue from the previous wheat crop. This residue was present in all of the samples taken, but ***appeared to be decomposing more rapidly in the soil with the Pro-Soil treatments.*** *Additionally, the roots from plants with the Pro-Soil treatment were more difficult to wash clean, due to what appeared to be a more distinct rhizosphere surrounding the root itself.*

PERCENTAGE OF TOTAL WHEAT PLANT MASS CONSISTING OF ROOTS

Total root mass for the control samples was 114.20 grams, and for the Pro-Soil samples it was 248.10 grams. Total plant mass for the control samples was 277.90 grams, and for the Pro-Soil samples it was 470.50 grams. This computes to **41.09% of total plant mass in the control samples consisting of roots. In the Pro-Soil samples the percentage of roots by weight was 52.73%.**

Graph 3:
Total Root and Plant Mass by Replication (December 14 Sample).



Graph 3 illustrates the total root mass (in grams) as well as the total plant mass, roots and vegetative tissue.

FIELD WEIGHT VS. DRY

Of similar interest was the percentage of dry matter in the sample plants, as compared to the "field" weights prior to drying. The control plants, once dried, had a total weight from all replications of 63.1 grams, or 22.71% of the original field weight. *The Pro-Soil plants had a dry weight of 130.3 grams, or 27.69% of the original field weight, which is 4.988 points higher than the control. This equates to a **21.97% increase in dry matter per unit of field weight.***

CONCLUSIONS: From most any standpoint the results were positive, and at the very least supports the claim that *PS-Foundation 1-0-1*™ is beneficial in helping to provide larger root mass in wheat. But there also appears to be other areas of benefit that in this study were even more significant, specifically the increase in plant population. Seeding rate should have been very close to identical, as the grower did not change his seeding rate at any time across the field. In addition, care was taken to avoid any samples being taken from an overlap of seeding.

Also of interest was the difference in percentage of root mass, when compared to total plant mass, between the control and PS-Foundation 1-0-1™ treated samples. Although nitrogen, and water, will have a positive effect upon vegetative development, **it is well known that efficiency of any one nutrient is to a large degree dependent upon all of the other nutrients.** Whether or not the higher percentage of vegetative plant parts in the control samples, as compared to roots, would indicate a greater percentage of nitrogen/water is not known as tissue analysis was not performed.

I suspect this might be the case though based upon the dry weights. ***With a 22.97% increase in dry weight percentage, this would indicate that the plants grown in the Pro-Soil treated areas either have a greater source of mineral nutrient and/or carbon in the soil environment itself, or that by some method were better able to take these nutrients in from the soil environment.*** If so, the question then becomes where this additional mineral source came from. It is unlikely that, by chance alone, the Pro-Soil areas of the field had better mineral nutrient availability. In addition, the applied fertilizer was consistent across the entire field, so this is not the probable source. Yet another possibility would be that the Pro-Soil plants were nitrogen/ water deficient, but this is a low probability simply because they were growing as well if not better than the control plants, again, even at higher populations.

Based upon visual observation, I believe that there are two possible answers to improved sources of mineral/carbon nutrients.

1. One involves the residue from the previous wheat crop. As mentioned it appeared to be decomposing much more rapidly in the soil surrounding the Pro-Soil samples, than that surrounding the control samples. If so, this would provide an additional source of virtually all nutrients, and could account for a more vigorous plant containing higher percentages of dry matter.
2. The other possibility involves the rhizosphere surrounding the roots themselves. By definition, the "rhizosphere is the narrow region of soil that is directly influenced by root secretions and associated soil microorganisms. It is teeming with bacteria that feed on sloughed-off plant cells, termed *rhizodeposition*, and the proteins and sugars released by roots. The protozoa and nematodes that graze on bacteria are also concentrated near roots. Thus, much of the nutrient cycling and disease suppression needed by plants occurs immediately adjacent to roots."

When washing the samples, the soil separated fairly easily from the roots of the control plants. *When washing the Pro-Soil samples though, it was much more difficult and often required an additional washing with running water.* If there was greater activity of microorganisms in the rhizosphere of the Pro-Soil plants, this would almost certainly improve overall nutrient availability to the growing plants, thus increasing the potential for greater dry mass. It would be interesting to perform a bioassay to determine if this is in fact the case.

The final comment deals with yield potential, as this is, after all, what a grower is interested in. Whether or not an actual yield increase is achieved will to a large degree depend upon weather and other management practices in the spring. ***Based upon the results from this study though, one would expect that the Pro-Soil treatment has set the stage for increased potential yield.***