The Effects of Various Phosphorus on "No-Till" Barley Production

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Executive Summary

This project proposes to study various sub-surface phosphorus placements and their effects on the growth and yield of cereal grains using a no-till farming system, through use of a specially modified piece of planting and fertilizing equipment, designed specifically to apply seed and fertilizer at the same time

A randomized complete block design with six replications will study the effects of various possible combinations of phosphorus placement on nitrogen and phosphorus uptake as determined by measurement of actual uptake of nitrogen and phosphorus using a "difference" method, by analyzing measurements of biomass production at various growth stages, measuring and analyzing yield components *(number of headed tillers, number of kernels per spike, kernel weight, and grain:residue ratio)*, and analysis of grain yield measurements.

Determining optimum phosphorus placement, along with potential yield and economic advantages in no-till farming systems will help bring grower adoption of this technology a step closer to fulfillment, which will help stop the unnecessary loss of thousands of tons of productive soil from "HEL" (Highly Erodible Lands) sites every year and significantly reduce soil pollution of surface water streams.

Proper soil fertility is a key factor to plant growth and ultimately to economic crop yields and quality. Proper placement of plant nutrients, important to any farming system, becomes a critical factor when the system in question is "Conservation Tillage." Conservation tillage is a farming system which seeks to reduce soil erosion to the absolute minimum possible for the specific conditions encountered.

Conservation tillage in its ultimate form, "no-till," means planting a crop into the residue of a previous crop without disturbing or mixing the soil with tillage operations. Adoption of conservation tillage practices, including no-till, is essential if goals of reducing non-point source water pollution, reversal of the trend toward decreasing soil productivity, and maintenance of a sustainable, profitable agriculture are to be attained. While a no-till farming system allows soil erosion and associated problems of decreased soil productivity and non-point source water pollution to be brought under control, it is not without some attendant problems of its own. A major problem is the efficient and accurate placement of fertilizers in very much less than optimum conditions as compared to conventional farming systems where fertilizers can be easily placed or mixed in the soil with a variety of tillage operation options.

In the case of nitrogen, which is quite mobile in soil moisture, no-till systems do not present major difficulties from the standpoint of fertilizer availability to the crop. Phosphorus, however, presents a very different situation -- phosphorus is quite immobile in the soil; i.e., while it does diffuse in the soil very slowly, phosphorus sources tend to be restricted to their original soil positions as far as plant availability is concerned. In addition, phosphorus is easily adsorbed to clay particles in the soil and to other ions in the soil solution, particularly calcium ions, which often renders the phosphorus unavailable for plant use.

Phosphorus cannot be broadcast on the soil surface with no-till systems as there is no "tillage" option to mix it in the soil, and as previously mentioned, it is immobile --- when broadcast, phosphorus is placed out of the "root zone" and remains so during the entire growing season. Since phosphorus is essential for early root development, initiation of reproductive processes, and optimization of yield, an easily available, ample supply is critical to the success of a no-till planting. It thus becomes obvious that some means of sub-surface application is necessary. Not only is it important that phosphorus be placed sub-surface but it must also be placed in such a manner that there is maximum opportunity for crop roots to encounter and uptake it.

While the literature includes a number of studies of phosphorus placement in cereal grain systems using conventional tillage; there are few using no-till methods. Studies using no-till techniques have not utilized equipment that allows continuous placement of phosphorus fertilizer in relative proximity to the seed. In prior studies phosphorus has been applied in one, or a combination of, three available methods: (1) broadcast on the soil surface, (2) applied in the seed row with the seed at the time of seeding, or (3) applied with an applicator prior to planting either at seeding depth or as a "deep band." Each of these methods has shortcomings in terms of no-till. Broadcasting leaves immobile phosphorus stranded on the soil surface. Placement of phosphorus with the seed has the advantage of close proximity and availability to the seedling; however, as roots develop downward they grow away from this source. It is also possible to cause seedling damage due to high salt content in close contact with tender seedlings. Preplant fertilizer applications often do not coincide exactly with planting patterns. Fertilizer shanks and grain drill row spacings do not often coincide, and even if they do it is virtually impossible to have separate field applications match exactly.

This project proposes to study various sub-surface phosphorus placements and their effects on the growth and yield of cereal grains grown using a no-till farming system, through use of a specially modified, uniquely designed, piece of planting and fertilizing equipment, designed specifically to apply seed and fertilizer at the same time by Dr. C. J. Baker, Director, Agricultural Machinery Research Centre, Massey University, Palmerston North, New Zealand. This piece of equipment, the "Cross-Slot" no-till planter, was modified by Dr. Keith Saxton, USDA-ARS and myself, to place fertilizer at various locations, including (but not limited to) with, below, and to the side of the seed, in close proximity to the seed but with a soil barrier between seed and fertilizer.

Determining optimum phosphorus placement, along with potential yield and economic advantages in no-till farming systems will help bring grower adoption of this technology a step closer to fulfillment, which will help stop the unnecessary loss of thousands of tons of productive soil, from often "HEL" (Highly Erodible Lands) sites, every year and significantly reduce soil pollution of surface water streams.

Information developed as a result of this investigation will be made available to the grower community and to agricultural support entities in the form of field meetings during the investigation, and to "FREP" and the public at large as annual reports and a final report of the investigation will be issued as a University of California Cooperative Extension publication.

Objectives

This project proposes to study, through use of a uniquely designed piece of planting and fertilizing equipment, various sub-surface phosphorus placements and their effects on the growth and yield of cereal grains grown using a no-till farming system.

Workplans and Methods

Demonstration of the Effects of Phosphorus Placement on "No-Till" Barley Production.

The purpose of this task is to document the effects of various phosphorus (P) placements on the production of barley, using "no-till" planting methods, by analyzing plant uptake of nitrogen (N) and (P) during the growing season, and by analyzing yield differences.

Prior to establishment of this experiment, baseline soil samples will be gathered from the selected site in the following manner:

1. Two random locations within <u>each treatment</u> plot will be sampled at three depths -- 0"-6", 6"-12", and 12"-18".
2. Samples from each plot will be combined for each depth and thoroughly mixed.
3. Composited soil samples will be sub-sampled and *approximately half will be* sent to the DANR Analytical Lab at U.C. Davis for determinations of:

   Nitrogen
   Phosphorus
   Organic matter
   pH
   Soil texture
   Potassium
   Sulfur
4. The remainder of the composited samples will be taken to Cal Poly, SLO and dried at ≅ 140°F, for 72 hours, to determine pre-plant soil moisture.
5. Rainfall records will also be kept throughout the duration of the experiment.

Soil nitrogen will be determined using the Total Kjeldahl Nitrogen (TKN) method, soil phosphorus will be determined through the use of the Sodium Bicarbonate (Olsen) method, and potassium, sulfur, soil texture, organic matter, and pH, will be determined using the standard methods employed by the DANR Analytical Lab. Results of these analyses will provide baseline data for determining P and N uptakes. (see appendix # 1)

1. Two random locations within <u>each treatment</u> plot will be sampled at three soil depths -- 0"-6", 6"-12", and 12"-18".

2. Samples from each plot will be combined for each depth and thoroughly mixed.

Soil samples were taken in the manner prescribed under *subtask 1.1.1 - 1.1.2* in November of 1995 and again in November of 1997 since this trial was conducted on two different sites. Soil samples were taken following the field protocol submitted in an earlier report using a hydraulically operated "Giddings" soil probe. The samples were split as described under *subtask 1.1.3 - 1.1.4* with one half of the sample being sent to the DANR Analytical Lab at U.C. Davis.

3. *Composited soil samples will be sub-sampled and approximately half will be sent to the DANR Analytical Lab at U.C. Davis for determinations of:*

    Nitrogen
    Phosphorus
    Organic matter
    pH
    Soil texture
    Potassium
    Sulfur

1994-95: Baseline soil analyses, completed on April 4, 1995, determined that this is a quite homogeneous loam soil from the surface to 45 cm of depth. There was an increase in soil pH from 7.4 to 7.6 as depth increased from surface to 45 cm in depth. Organic matter decreased from approximately 1.50% in the 0-15 cm depth, > 0.87% at 15-30 cm, > 0.75% at the 30-45 cm depth. Nitrogen also tended to decrease with increasing soil depth, from 0.096% to 0.057%, or approximately 45 to 60 pounds per acre in the top 15 cm of soil. Sulfur tended to remain stable with increasing depth at approximately 12.6 ppm, while Potassium showed a slight decline from 292 ppm to 240 ppm as soil depth increased. Soil analysis also indicated approximately 13 ppm phosphorus, or ≅ 26 pounds per acre, at the 0-15 cm soil depth, using the Sodium Bicarbonate Test. Soils testing in the range of 12 - 18 ppm phosphorus may or may not show benefits from added fertilizer phosphorus.
(*See Appendix I – Table I*)

1996-97: Baseline soil analyses, completed on January 13-14,1997, determined that this is a fairly homogeneous loam soil from the surface to 45 cm of depth, with a tendency to become higher in sand as depth increases. Soil pH increased from 6.7 to 7.4 as soil depth increased. Organic matter decreased from approximately 1.72% in the 0-15 cm depth, > 1.17% at 15-30 cm, > 0.61% at the 30-45 cm depth. Nitrogen also tended to decrease with increasing soil depth, from 0.131% to 0.059%, or approximately 60 to 80 pounds per acre in the top 15 cm of soil. Sulfur in the surface 15 cm was approximately 13.6 ppm and tended to remain stable at approximately 6.25 ppm between 15 and 45 cm. Potassium was high to very high throughout this soil with the 0 - 15 cm layer at 537 ppm to the 30 - 45 cm layer at 257 ppm.

Soil analysis also indicated approximately 21 ppm phosphorus, or ≅ 42 pounds per acre, at the 0-15 cm soil depth, using the Sodium Bicarbonate Test. Soils this high in phosphorus often do not show any benefit from the application of additional phosphorus.

4. The remainder of the composited samples will be taken to Cal Poly, SLO and dried at ≅ 140°F, for 72 hours, to determine pre-plant soil moisture. (*See Appendix I – Table II*)

The remainder of the composited soil samples were taken to the Soil Science Department at California Polytechnic University, San Luis Obispo, California, in both 1994-95 and 1996-97, where soil moisture determinations were conducted.

1994-95: Oven drying of the composited soil samples for 72 hours at ≅ *140°F,* indicated that there was 14.44% soil moisture, by weight, in the 0-15 cm soil depth, 10.60% in the 15-30 cm layer, and 11.48% in the 30-45 cm soil layer. The texture of this soil, 44.7% sand - 31.3% silt - 24.0% clay, indicates that can be classified as a loam soil.

In a loam soil this translates to ≅ 34 mm of water from the surface to 15 cm of depth, 22 mm from 15-30 cm, and 27 mm from 30-45 cm of soil depth, or a total of ≅ 18 mm of available soil moisture at planting time. Only approximately 16 mm of moisture in the top 15 cm of soil depth was actually available for plant growth, none of the moisture in the 15 - 30 cm layer was likely to be available, and only about 2 mm in the 30 - 45 cm layer was available because of the clay content in this soil texture.

In **1996-97,** the trial site was moved to an adjacent field because of a change in leasee of the previous site. Textural classification of this site was slightly different from the previous site with the surface 15 cm being a sandy clay loam - 51% sand - 28% loam - 21% clay. The remaining 30 cm of soil depth being classified as sandy loam - 58% sand - 26% loam - 16% clay.

Moisture content of 0 - 15 mm soil depth was 14.11%, 15 - 30 mm equaled 13.62%, and the 30 - 45 mm soil layer contained 13.23% soil moisture. These soil moisture percentages for the corresponding textural class indicate that available soil water at planting was as follows: 0 - 15 cm ≅ 15 mm, 15 - 30 cm ≅ 13 mm, and 30 - 45 cm ≅ 12 mm, or a total of ≅ 40 mm of available soil water in the top 45 cm of soil at time of planting.

These trials had sufficient soil moisture for germination and emergence at time of planting in both 1994-95 and 1996-97.

5. Rainfall records will also be kept throughout the duration of the experiment. (*See Appendix I – Table III*)

Also before planting this trial, the entire trial area will be "Para-tilled" using a "Howard Paraplow™." This is a piece of equipment which loosens the soil to a depth of approximately

14" without inverting the soil and with very little disturbance of surface residues. This operation will be necessary to ensure that tillage pans from previous years of conventional tillage practices do not interfere with uniform soil penetration by planting equipment or that tillage pans do not interfere with root penetration in shallow fertilizer placement treatments. "Para-tilling" will be carried out in a manner which is perpendicular to the direction in which planting will occur.

Subtask 1.2 was not necessary in either 1995 or 1997 since an adequate amount of rainfall had occured in both years to eliminate the need to remove hard soil layers prior to planting. Also in both years, because of excessive rainfall during optimal planting time, it was determined that establishing the trial at all was a priority over any deleterious effects that might be caused by past tillage pans.

It will be necessary between late October and early December (depending on weather conditions in eastern Washington) to travel to the USDA Conservation Field Station at Pullman, Washington, to pick up the modified "Cross-Slot"™ planting equipment.

1994-95: This represents a departure from the instructions in G. 2) "Budget Itemization - Travel, however, the grower cooperators have offered to use their Ranch Company truck (ten wheel Kenworth™ flatbed) at a greatly reduced rate, compared to a "common carrier" to facilitate both pickup and return of the planting equipment. Picking up of the planting equipment was accomplished in late November - early December of 1994 and the equipment was returned WSU - USDA in the spring of 1995.

1996-97: Unfortunately it was not possible to utilize the White Ranch truck this year, so a “common carrier” was used to transport the planting and fertilizing equipment from and return to the WSU - USDA Conservation Field Station at Pullman, Washington.

With the modified Cross-Slot planting system, it is possible to place fertilizer virtually anywhere within an area described by a 5 inch square continuous column with the seed positioned in one upper corner and fertilizer placed at any position within the column, as shown below:

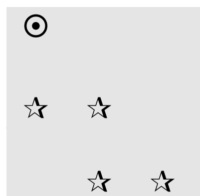
-----soil surface-----

• = seed placement

Fertilizer can be placed anywhere in the shaded area.

Fertilizer placements chosen for testing are: (1) close proximity to the seed, but with a soil barrier between seed and fertilizer, (2) 2.5" directly below the seed, (3) 2,5" below and 2.5" to the side of the seed, (4) 5.0" below and 2.5" to the side of the seed, and (5) 5.0" below and 5.0" to the side of the seed. as shown below.

-----soil surface-----



⦿ = seed and possible fertilizer placement

⦿ ☆= fertilizer placements chosen as most likely

Individual plots will be 10' in width and 50' in length. Since phosphorus and nitrogen can be independently placed, the above configuration lends itself easily to a series of seventeen treatments with seed being placed in the same position in each plot (1.5" to 2.0" deep). If we use the numbering system shown above these treatments are as follows:

Trt	**N location**	**P location**	**Trt**	**N locatio n**	**P locatio n**
1.*	0	0	10.	3	1
2.	3	0	11.	3	2
3.	0	3	12.	3	3
4.	2	1	13.	3	4
5.	2	2	14.	3	5
6.	2	3	15.	1	1
7.	2	4	16.	5	5
8.	2	5	17.	4	4
9.	2	0			

*= Check Treatments -- No fertilizer application

1994-95: Two variances to subtask 1.4 have occurred, neither of which should negate the results of this trial: (1) Due to weather conditions in the Northwest, as mentioned in *subtask 1.3*, and to the much above normal rainfall in the Shandon area during the months of December 1994 through February 1995, planting was delayed until the last day of February 1995. While this planting date is later than hoped for and somewhat beyond the optimal planting dates, it should not pose undue problems, provided that rainfall continues at a normal pace for the remainder of the crop year. (2) Due to unforeseen space limitations it has been necessary to reduce the number of replications in the trial from six to four. While six replications could have given a greater number of "degrees of freedom" for use in statistical analysis and thus possibly increased trial precision, the use of trials with four replications, or even three replications, is probably more common for "field" trials and should not interfere with accurate analysis.

The trial site was planted with 95 Lbs./Ac. of UC-337 barley and each plot within the trial, except for check plots, received identical amounts of nitrogen and phosphorus fertilizer (≅ 40 Lbs./Ac. N and 20 Lbs./Ac. P_2O_5.) The only differences between treatments being the various placements of the fertilizer.

Aside from the above-mentioned variances, establishment of the trial is as described in *subtask 1.4*. A copy of the plot map is included with this report. (*See Appendix I – Table IV*)

1996-97: Subtask 1.4 was accomplished on February 5, 1997, considering that the months of December and January were exceptionally wet and soil conditions would not allow planting at an earlier date. The trial site was planted with 95 Lbs./Ac. of UC-337 barley and each plot within the trial, except for check plots, received identical amounts of nitrogen and phosphorus fertilizer (≅ 40 Lbs./Ac. N and 20 Lbs./Ac. P_2O_5.) The only differences between treatments are the various placements of the fertilizer.

Data gathered from this trial will include biomass production at the following growth stages, *(1) elongation, (2) boot, (3) anthesis, and (4) ripe*. Plant tissue from these samples will be analyzed for total **phosphorus**, (*after Miller, R.O. "Quantitative Analysis: Phosphorus, Sulfur, Potassium, Calcium, Sodium, Boron, Zinc, Manganese, Iron, and Copper in Botanical Materials*) and total **nitrogen** (*after Miller, R.O. "Total Nitrogen Botanical Materials -- Combustion Method - Modified Dumas"*). Yield components *(number of headed tillers, number of kernels per spike, kernel weight, and grain:residue ratio)* will also be collected and analyzed, as will grain yield measurements. A cost/benefit analysis will be made after harvest, if indeed there are significant treatment effects. (*See Appendix II – Tables I – IV & Appendix IV*)

1994-95: Because lateness of planting caused a compression of growth stages, and due to illness of the P.I., it was decided that plant samples would be collected from the "tillering" and "anthesis" growth stages. "Tillering" samples were collected from a meter of row in each treatment plot on April 17, 1995 and "anthesis" samples were similarly collected on May 10, 1995. Dryweight production was determined on these samples using drying facilities at Cal Poly, SLO, Soils Department. After biomass determinations were completed, the dried samples were submitted to the U.C. Davis Analytical Laboratory for nitrogen and phosphorus analysis.

It was not possible to gather either grain yield or yield component data on this trial due to destruction of the site by a unexpected invasion of ground squirrels when a neighboring field was sprayed, destroying the local food source and leaving the trial site as the only "green" food in the surrounding area. Laboratory results for nitrogen and phosphorus uptake and biomass production were subjected to statistical analysis using a Randomized Complete Block Analysis of Variance *(after Little and Hills 1978 "Agricultural Experimentation Design and Analysis" Chap. 5 pp. 53-60*) to determine significant differences due to treatments applied. It was necessary to discard one replication of data from the analysis due to excessively uneven growth, resulting in an inordinately high overall "coefficient of variation" for the trial. As stated earlier, field trials with three replications are quite common and in this case permitted greater confidence in results of the analysis.

1996-97: Stand establishment and early growth were excellent; however, there was no further rainfall for the season after this trial was planted. Whole plant samples were taken at mid-elongation (March 6-7, 1997) and anthesis (April 14-15, 1997), dried in ovens at the Cal Poly Crops Department for 48 hours at 100° F and the dry weights were tabulated. All biomass samples were subsampled and subsamples were submitted to the University of California, Davis, Analytical Laboratory for nitrogen and phosphorus analysis.

As the crop year progressed and it became apparent that there would be no further rainfall, it became necessary to depart from the strictly rain fed program, as described in the original proposal, if the trial was to be taken to maturity. During the week of April 21-25, 1997, approximately 1 inch of water was applied to the test site using a temporary sprinkler irrigation system, since the site is more than a mile from any water system. Plants at this time were in the early fill stage (approximately "milk" stage) of growth.

Due to this irrigation, the trial was carried to maturity and harvested during the week of July 14-18. Yield component measurements were determined for heads/unit area, kernals/head, weight/1000 kernals, and harvest index. Final biomass samples and grain samples were submitted to University of California, Davis, Analytical Laboratory for nitrogen and phosphorus analysis.

It was also necessary to eliminate one of the four replications of this trial from the analysis for 1996-97, because of a severe infestation of "perennial bindweed” (*Convolulos arvensis*) in approximately 80% of one replication which reduced grain production, both biomass and yields, to virtually zero. Laboratory results for nitrogen and phosphorus uptake of biomass and grain samples were again analyzed using a Randomized Complete Block Analysis of Variance (*after Little and Hills 1978 "Agricultural Experimentation Design and Analysis" Chap. 5 pp. 53-60*). In addition, overall grain yields, heads/unit area, weight/1000 kernals, and harvest index were subjected to the same analysis procedures to determine significant differences attributable to treatment affects. (*See Appendix II – Tables V – XVIII*)

Data will be analyzed using a Randomized Complete Block Design Analysis of Variance, *after Little and Hills 1978 "Agricultural Experimentation Design and Analysis" Chap. 5 pp. 53-60.* Trial results will be summarized and an interpretive summary will be submitted along with remaining invoices.

Summary and Conclusions:

Analysis of the 1994-95 trial data indicates that there were significant advantages in both biomass production and fertilizer phosphorus up-take from germination to anthesis, attributable at least in part to placement of fertilizer phosphorus. As expected, a greater percentage of biomass production and phosphorus uptake occurred between tillering and anthesis than occurred between germination and tillering. Treatments which placed phosphorus fertilizer either 2.5” below and 2.5” to the side of seed placement (*treatment 3+3*), or, 2.5” directly below the seed (*treatment 2+2)* resulted in significantly increased phosphorus up-take and significantly increased biomass production. It was also evident that placement of fertilizer nitrogen relative to fertilizer phosphorus, and to the seed, influenced both phosphorus up-take and biomass production.
(*See Appendix III – Charts I & II*)

Treatments with nitrogen placed directly with phosphorus were generally superior to treatments where nitrogen and phosphorus were physically separated in the soil -- as long as phosphorus was no deeper than 2.5” below the seed and no further than 2.5” to the side of seed. Phosphorus placement with, and around, a nitrogen placement of 2.5” below and 2.5” to the side of seed (*treatments 3+1………3+5*) tended to be superior to either phosphorus placement plus nitrogen placements together (*treatments 1+1………5+5*), or phosphorus placement with, and around nitrogen placements 2.5” directly below the seed (*treatments 2+1………2+5*).

Inability to carry this trial to harvest precluded conclusions relating to later growth stages or effects on yields and yield components. **It was, however, apparent that nitrogen placement appeared to be at least as important as phosphorus placement**

Results of the **1996-97** study appear to be very similar in both biomass production and phosphorus uptake between germination and anthesis, as is readily apparent when comparing graphs I through IV. (*See Appendix III – Charts I – IV*)
Total biomass production at harvest time indicates that placements *2+2, 3+2, & 3+3* were significantly more productive than placements *0+0, 0+3, 1+1, 2+0, 2+1, 2+3, 2+5, 3+0 & 5+5*. **Since all treatments except *0+0, 0+3, 2+0, & 3+0* received exactly the same amounts of nitrogen and phosphorus fertilizer, this indicates again that phosphorus placement does significantly effect biomass production.**

Total phosphorus uptake at harvest presents a more difficult picture with three treatments (*1+1, 2+1, & 3+4*) showing an actual loss of phosphorus between anthesis and maturity. Treatments *1+1* and *2+1* had phosphorus placed in direct contact with seed and may have suffered some phytotoxic effects; especially treatment *1+1* which also had nitrogen applied in contact with the seed. Another possible explanation could be that phosphorus became positionally unavailable as the soil began to dry from the surface downward; on the other hand, the fact that the un-fertilized check continued to accumulate phosphorus (*and at a rate comparable to the best treatments*) would tend to make one question that explanation. It was not possible to explain the loss of phosphorus at harvest in treatment *3+4,* in view of the fact that other treatments with phosphorus in the *x+4* position continued to accumulate phosphorus through maturity.

While a substantial amount of biomass was generated after anthesis (*47.4%*), relatively little additional phosphorus (*10.5%*) was taken up. This tends to support some earlier reports, although only the three treatments mentioned previously actually lost phosphorus as was generally reported for many years. More recent work tends to indicate that when phosphorus is not placed with the seed, or surface applied, uptake often takes place through maturity.

In addition to overall plant growth and phosphorus uptake there were also significant differences in grain yields which can be attributed the fertilizer placement. It is important to reiterate the fact that all treatments, except the various checks, were fertilized with exactly the same amounts of the same fertilizer materials, with only the placements being varied.

Differences apparent during vegetative growth stages did not necessarily continue through grain production in all cases. Grain yield differences did indicate significant treatment effects, with obvious benefit from some fertilized treatments over the un-fertilized checks. This was not universal however, with treatments *1+1, 2+1, 3+0, 3+1, & 5+5* all having yields lower than the check, and treatments *1+1, 2+1, & 5+5* being significantly less productive than the un-fertilized check. It is, again, very difficult to explain how or why treatments *0+0 and 0+3*, one un-fertilized and the other having only phosphorus applied, should have greater grain yields than most of the fertilized treatments. It might be possible to lay such anomalies to either phytotoxic effects of some treatments or to fertilizer placements which were less efficient because of positional aspects; however, the general relative agreement of grain yields with the vegetative growth results tends to make one skeptical. On the other hand, it is clear that treatments *2+2, 3+2, & 3+3* are significantly superior to the un-fertilized check and further are superior to all other placements in this study, with only treatment *2+3* being in the same significance class. (*See Appendix III -- Charts V, VI*)

Analysis of “yield components” indicated that there were no significant differences in kernals per head, 1000 kernel weights, test weights, or harvest index across all fertilizer placements. (*See Appendix III – Chart VI*)

The only yield component indicating significance was heads per unit area. Treatments *2+2, 3+2, 3+3, 3+4, & 4+4* all produced significantly more heads per unit area than the un-fertilized check. Further, the best treatment, *3+3*, also produced significantly more heads per unit area than treatment *1+1*, the most common current fertilizer placement position. Treatment *3+3* (phosphorus and nitrogen placed together 2.5” below and 2.5” to the side of the seed) produced 62% more heads per unit area than did the check, 35% more than *1+1* (phosphorus and nitrogen placed together with the seed), 15% more heads than treatments *2+2* (phosphorus and nitrogen placed together 2.5” below the seed) or *3+4* (phosphorus 5.0” below and 2.5” to the side of the seed, nitrogen 2.5” below and 2.5” to the side of the seed), and 8% more heads than treatment *3+2* (phosphorus 2.5” directly below the seed, nitrogen 2.4” to the side and 2.5” below the seed.

It appears important that both nitrogen and phosphorus be in fairly close proximity, but not in contact, with the seed. In fact, an overall conclusion that can be supported by this study would indicate that placement of nitrogen fertilizer in relation to the seed may be as important, or even more important, to phosphorus uptake than the placement of phosphorus itself. In all cases in this study, the significantly superior treatments combine nitrogen and phosphorus within a zone from 2.5” below the seed

to 2.5" below and 2.5" to the side of the seed. This seems particularly true for most efficient phosphorus uptake.

It would appear that placement of phosphorus and nitrogen together 2.5" to the side and 2.5" below the seed (treatment *3+3* in this study) could be recommended as an optimal or BMP (Best Management Practice) placement for both nutrients.

In fulfillment of (Task E1. Subtask 1.6) an economic analysis was performed on selected treatments and groups of treatments. (*See Appendix IV – Tables Ia, Ib, Ic.*)

Determining the value of the grain, over a range of prices, produced without the use of any fertilizer (*0+0*) and comparing that to the value of grain produced over all fertilized treatments (*1+1…………………..3+5*), less cost of fertilizer, indicated that increased production resulting from use of fertilizer would not pay for the fertilizer used, even at $7.00/CWT. This same comparison of the unfertilized check vs. treatments with nitrogen only (*2+0, 3+0*), resulted in even less cost effective findings. When comparing the unfertilized check vs. treatments with nitrogen and phosphorus placed together (*1+1……………...5+5*), similarly poor economic resultswere noted.

However, when the top three yielding fertilizer placements (*3+2, 2+2, 3+3*) were compared with the unfertilized check treatment, each placement showed returns that were greater than the cost of fertilizer, even at $4.00/CWT. Thus, treatment *3+2* returned an additional $1.69/Ac above fertilizer costs @ $4.00/Cwt, $6.27 @ $5.00/CWT, $10.85 @ $6.00/CWT, and $15.43 @ $7.00/CWT. Treatment *2+2* returned $3.29/Ac @ $4.00/CWT, $8.27 @ $5.00/CWT, $13.25 @ $6.00/CWT, and $18.23 @ $7.00/CWT. The highest yielding placement in this trial, *3+3*, returned $8.37/Ac above fertilizer costs @ $4.00/CWT, $14.62 @ $5.00/CWT, $20.87 @ $6.00/CWT, and $27.12 @ $7.00/CWT.

It further appears that if the fertilizer materials used in this study were applied, it would take approximately 416 Lbs/Ac of additional production to break even. If 19-9-0, a commonly available dry fertilizer, were applied, it would take 458 Lbs/Ac of increased yield to pay for the fertilizer.

Considering the fact that all treatments used the same rate and cost of fertilizer, it can be assumed that any differences noted were due, in large part, to the fertilizer placement position. The above returns indicate that fertilizer placement can have significant economic, as well as biological consequences.

One must be cautious, however, when making recommendations based on limited information. In the opinion of this investigator, additional studies should be conducted for added confidence in recommendations. Further, similar studies should be conducted in an irrigated location where moisture during the growing season would be less of a critical factor. Also, it would be easier, and quicker, to verify the validity of these studies, even though the information developed might still be of more use to dryland growers.

Develop and Conduct Grower Meetings and Field-day on Fertilizer Best Management Practices. The purpose of this task is to make information about phosphorus placement best, management practices developed by this project available to growers, sellers of fertilizer inputs, researchers, and all interested parties.

Plan grower meetings and field-days, pre-meeting and field-day publicity, design evaluation methods, and produce meeting and field-day materials. Task products will be two grower meetings and one field-day, evaluations of meetings and field-day and a final project report.

Hold grower meetings in Paso Robles and San Luis Obispo during March and April 1995 and a field-day in Shandon in May 1995. The grower meetings will describe the project and present data gathered to date. The field-day will present updated data and for the field trial and information on fertilizer placement techniques developed for best management practices, and the efficient use of fertilizers.

It has not been possible to adhere to the projected schedule of grower meetings and field-days as originally scheduled; however, **a field-day was held in the spring of 1998 during the last year of this study. There were approximately 30 growers in attendance and feed-back was very positive**. There were **also two "Poster Papers" presented based on preliminary findings**. Summary information developed from this study will be presented to growers at a **field-day May 20, 1999**, and two grower meetings will be presented in **September of 1999** which will also include final information and potential recommendations.

Prepare evaluations of grower meetings and field-day and submit final draft report consisting of data gathered, data analysis, and summary of findings to CDFA.

At this writing (March 1999) evaluations of grower meetings and field-days have not been conducted.

Project Management, Evaluation and Outreach

The project leader will assume overall responsibility for the planning and execution of all phases of this project. White Ranch personnel will perform basic field operations at the direction of Kenneth White, Farming Manager, after consultation with the project leader. The project leader will oversee and direct all field preparation operations, planting, sample gathering, and harvest operations -- and will physically assist wherever and whenever necessary. The project director will share draft information as to plot plans, plot design, and data analysis with Dr. Keith Saxton, USDA-ARS, and with Dr. Stuart Pettygrove, UCCE-DANR, prior to implementing same The project leader will oversee, or perform, all data analysis as well as prepare the necessary reports.

The outcomes of this project will be assessed based on results developed from the analysis of data generated by the field trial. Since the only difference between treatments will be fertilizer placement, it is expected that a measure of progress will be yield, or yield component differences due to treatments.

Potential barriers to adoption of practices disclosed by this project are that there are no commercial planting systems currently on the market that have the fertilizer placement versatility of the experimental planter used in this project. I believe, however, that this situation would be rapidly rectified if results from this project are significant.

Survey questionnaires will be developed and presented at the grower meetings and at the field-day to ascertain the perceptions of the participants at these events about the practices demonstrated, grower perceptions and feelings about this type of applied research, and the potential of such practices and research in helping to reduce soil erosion and improve water quality.