TECHNICAL NOTES

U.S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE

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FERTILIZER PLACEMENT FOR CEREAL ROOT ACCESS

Dr. Steven E. Petrie, agronomist for Unocal Chemicals Division in Boise, Idaho, has given us permission to issue his presentation given at the 6th Annual Conservation Tillage Workshop held in Paso Robles on May 1-2, 1985.

The success of conservation tillage systems depends on maintaining profitability for the grower. One way to do this is to reduce variable production costs while maintaining yields.

Proper fertilizer placement can help maintain yields and reduce nutrient availability to weeds. Weed control is a major cost in most conservation tillage systems so we need to be aware of every opportunity that can reduce weed problems.

As Dr. Petrie points out, you need to know how the plant's root system grows in order to get the most return for your fertilizer dollar.

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FERTILIZER PLACEMENT FOR CEREAL ROOT ACCESS

Dr. Steven E. Petrie, CPAg[1]

Proper fertilizer placement often increases fertilizer efficiency, improves yields, and reduces per acre costs to produce a crop. Interest in band application of fertilizers is increasing as growers seek ways to increase yields and profits while reducing costs. Determining the optimum fertilizer placement requires knowledge of the reactions that occur when fertilizer granules or solutions come in contact with the soil. In addition, it requires knowledge of how a cereal plant grows and develops if the most efficient and practical placement scheme is to be used.

Band application of acid forming fertilizers can increase the availability of phosphorus (P) and micronutrients by reducing the soil-fertilizer contact and thus slowing the tie-up of these nutrients. In addition, the acidity in the fertilizer band increases the availability of the P and micronutrients. A considerable body evidence has been generated over the last several years which shows clearly that band applications are generally superior to broadcast applications for P and micronutrients. This is particularly true in minimum and no-till cropping systems which do not allow for incorporation of fertilizers.

Recently, several different grain drills and fertilizer applicators have been developed which have the ability to place fertilizer in bands. Depending upon the equipment these bands can be (1) with the seed, (2) below the seed, (3) beside the seed, or (4) below and beside the seed either 2" x 2" or 2" x 6". Evaluating the most efficient application system requires a thorough knowledge of the root development patterns of cereals. Fortunately, Dr. Betty Klepper and her colleagues at the Columbia Plateau Conservation Research Center at Pendleton Oregon have learned much about how a wheat plant grows and develops. Although their work has been centered on wheat the principles apply to other cereal crops as well.

Cereal seedling development is a remarkably orderly process with roots, leaves and tillers appearing in a predictable sequence, barring adverse environmental stress. Cereal plants have two types of roots; seminal roots and nodal roots. The seminal roots develop from the base of the young shoot (coleoptile) where it emerges from the seed while the nodal roots grow from the crown of the plant. We will discuss each of these in turn.

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The first seminal root to emerge from the seed is the primary root and it tends to grow straight downward from the seed. Next, a pair of seminal roots energe from the seed at about the same time the coleoptile begins to grow. These seminal roots appear on opposite sides of the plant and grow outward and downward from the seed, generally at about a 30 degree angle from the horizontal. These roots continue growing outward for 2 to 3 inches and then they turn and begin growing downward (Fig. 1).

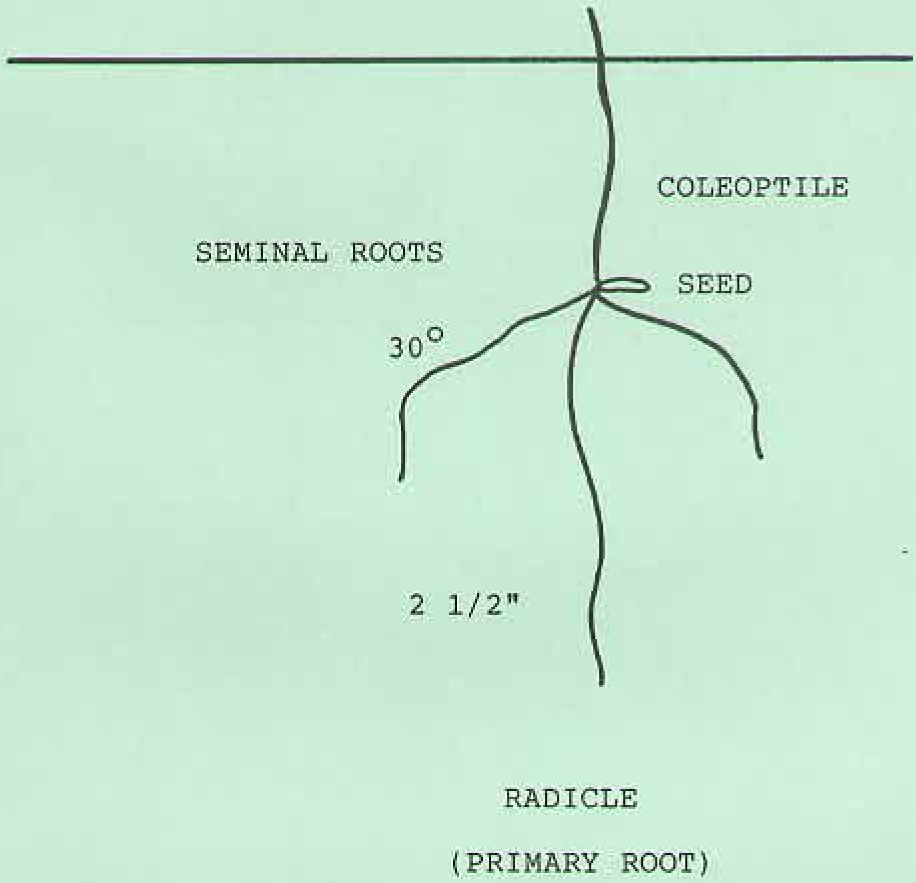

Fig. 1. Early cereal seminal root development.

Between the 1- and 2-leaf stage a second set of seminal roots then appears and grows outward about 4 inches before turning and growing downward (Fig. 2). A third set of seminal roots may also appear. If fertilizer is to be readily available to the young seedling it must be placed so that the developing roots will intercept the fertilizer band.

The actual number of seminal roots that develop depends upon both genetic and environmental factors. Plants that develop in poorly prepared seedbeds or from poor seed are often missing some of the seminal roots.

The seminal roots supply the plant with water and nutrients as the first three leaves develop and grow. The seminal roots branch before tillering with the length of the branches depending upon soil conditions. Longer branches occur in loose, friable soils. Environmental stresses such as cold soils, diseases, or low nutrient levels will limit the early root development.

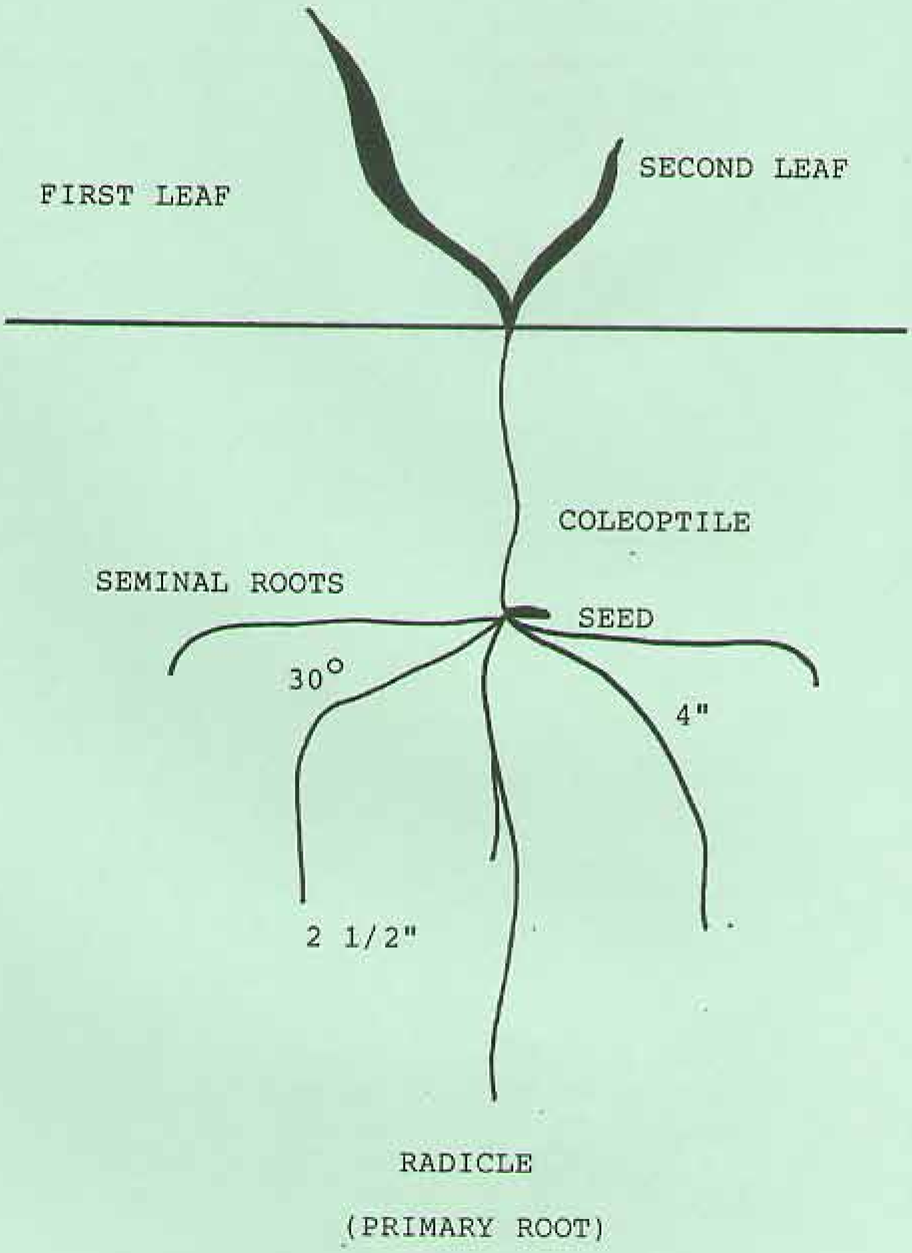

Fig. 2. Cereal root development at the 1- to 2-leaf stage.

As the fourth leaf develops the first tiller emerges from the axil or base of the first leaf and the first crown roots appear (Fig. 3). The crown roots develop in a pattern similar to the seminal roots; they grow outward for a few inches and then begin to grow downward.

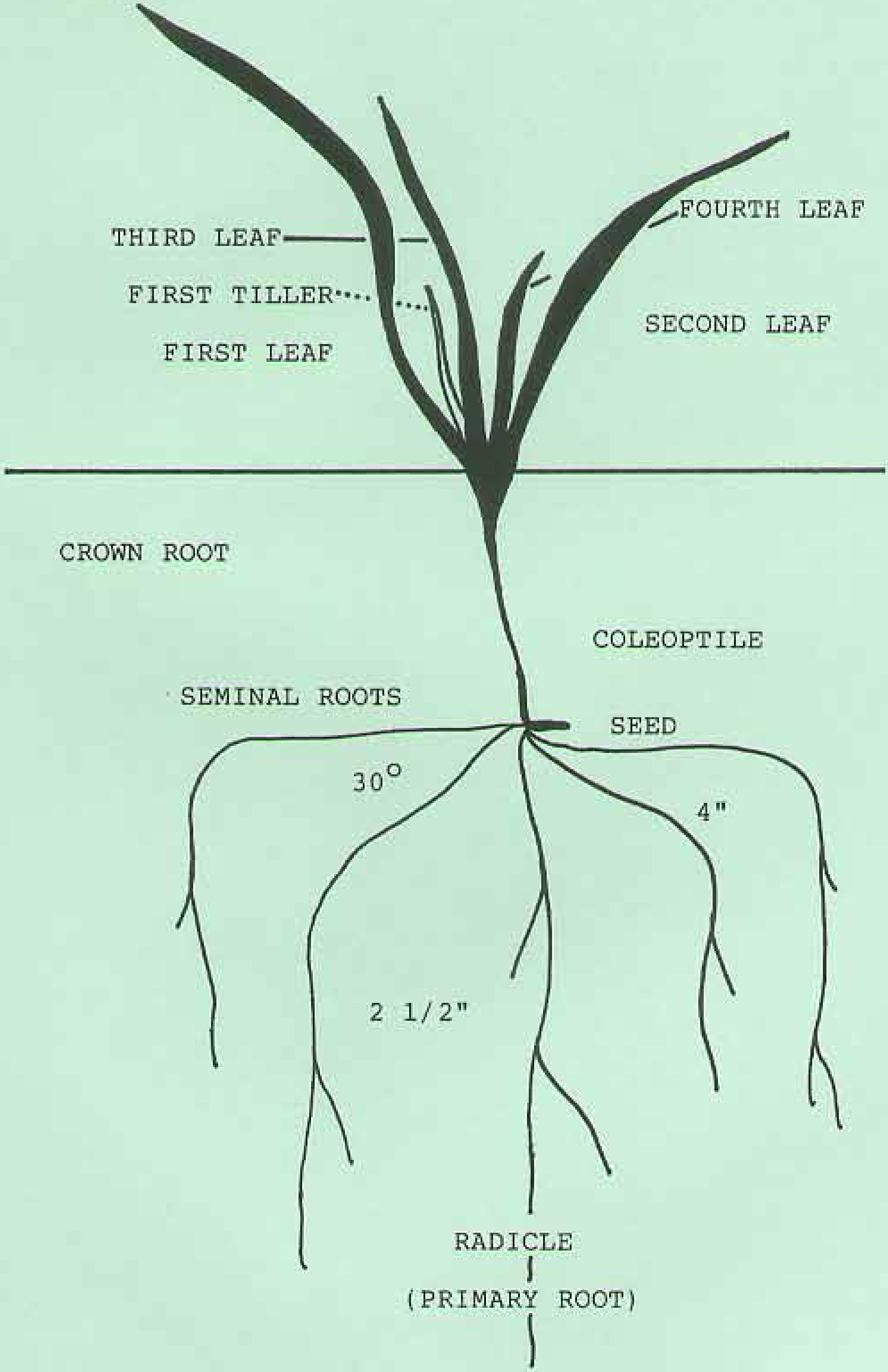

Fig. 3. Early crown root development in cereals.

As the fifth leaf emerges the second tiller begins to grow from the base of second leaf. The sixth leaf is accompanied by the emergence of the third tiller from the base of the third leaf. This pattern of leaf and tiller development continues until the plant stops tillering. Each tiller that develops is accompanied by the development of more crown roots. In addition, each tiller produces its own crown roots after it has about three leaves. Eventually these crown roots comprise the majority of the plant roots and may extend into the soil for 3 to 5 feet or more.

Ultimately, the crown roots explore the soil between the rows but this does not occur until after tillering has begun. Until then the area between the rows is a favorable site for weed germination and growth. Broadcast fertilizer that falls between the rows is unavailable to the roots until after tillering but is available to germinating weeds.

Fertilizer can be placed in any of several locations within the seedbed including; (1) with the seed, (2) below the seed, (3) beside the seed, or (4) below and beside the seed either 2" x 2" or 2" x 6". Although there are advantages and disadvantages to each of these placement schemes not are all equally available to young cereal seedlings early in their growth. These placement options are shown in Fig. 4.

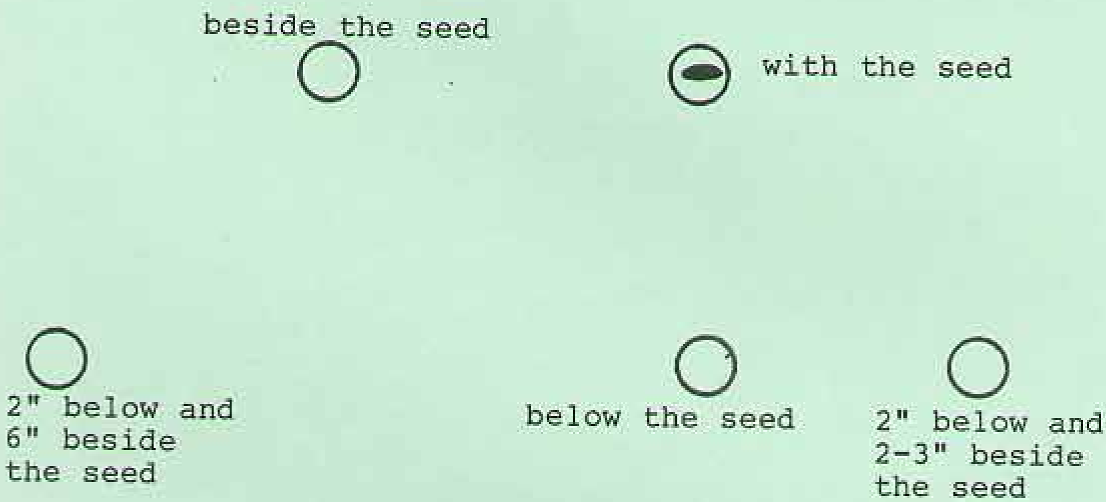

Fig. 4. Fertilizer placement options.

Applying the fertilizer directly with the seed at planting is one method of placing the fertilizer. It is readily available to the young seedling and the seed and fertilizer can be placed with only one opener which minimizes soil disturbance and lowers the power required. It is not possible to apply the entire fertilizer program with the seed because of the potential for fertilizer injury. As a rule of thumb the total N and K2O applied directly with the seed should not exceed 30 lb/A. In addition, DAP (18-46-0 or 16-48-0), ammonium thiosulfate (Thio-Sul) or urea should not be applied in direct contact with the seed. Applying the fertilizer directly with the seed results in a relatively shallow placement and this fertilizer may become unavailable as the soil dries out. Roots cannot grow and take up nutrients from dry soil. It has also been found that applying N and P together in a deep band results in higher yields than placing the P with the seed and the N sepa- rately. Nonetheless, under cold wet conditions cereals may bene- fit from fertilizer banded with the seed at planting because root development is severely limited.

Fertilizer may also be banded directly below the seed using the same opener. This fertilizer is available to the young seedling before emergence is evident. Higher rates of fertilizer can be used but caution is still in order. Researchers have found that a 2" separation is required in a silt loam soil and a wider separation may be necessary in coarse textured soils. Assuming that the minimum 2" separation can be maintained agronomically reasonable rates of fertilizer can be applied in this manner. Planting in rocky ground may result in the seed and fertilizer being placed closer than 2" when the opener, shoes and spreaders are deformed.

Placing the fertilizer beside the seed is another option. This placement does not allow for early seminal root access because of the downward growth patterns of the seminal roots. The same cautions concerning rates of fertilizer that can be safely applied below the seed would apply to this placement system. Because this is a shallow placement the fertilizer may not be available as the soil dries out later in the season.

Placing the fertilizer below and beside the seed (2" x 2-3") offers excellent fertilizer availability to the early seminal roots with little chance for fertilizer damage. This placement scheme also fits well with the paired row concept. The shallow band placed between the rows is available to the cereal seedlings and not available to the weeds germinating between the rows.

If the fertilizer is placed further from the seed in a 2" x 6" band it will be less available to the seminal roots as they grow out and downward from the seed. The fertilizer will be available to the crown roots later as they develop but nutrient stress may have already limited the yield potential. This fertilizer will also be more available to germinating weeds.

Does placing the fertilizer really make a difference in fertilizer availability and cereal yields? Research conducted in the dryland region of the Pacific Northwest shows that correct fertilizer placement can indeed increase fertilizer efficiency and cereal yields.

Banding the N, S, and P fertilizer 3" below the seed resulted in greater yields of both winter and spring wheat grown under both conventional and no-till cropping systems in Washington where the average rainfall was 16" (Table 1). The fertilized treatments received 60 lbs P2O5 banded 3" below the seed; 90 lbs N/A and 18 lbs S/A were either banded with the P or broadcast on the surface at seeding. Banding the fertilizer resulted in a 4 bushel yield advantage in winter wheat for conventional tillage and a 12 bushel advantage for no-till cropping in a 4 year study. The same trend existed for spring wheat with banding increasing yields 10 bushels for conventional tillage and 9 bushels for no-till.

Table 1. Effects of banding fertilizer on wheat yields in WA.

Fertilizer Placement	Yield			
	Winter Wheat		Spring Wheat	
	Conventional	No-Till	Conventional	No-Till
	bu/A			
None	21	19	18	18
Broadcast	44	38	36	32
Band	48	50	46	41

Another trial in Washington (15" rainfall area) examined the effect of fertilizer placement on no-till wheat (Table 2). Again the P was banded 3" below the seed and the N and S were either banded or broadcast. Winter wheat yields were 3 bushels greater and spring wheat yields were 9 bushels greater where the fertilizer was banded.

Table 2. Effects of fertilizer placement on no-till wheat yields in Washington.

Fertilizer Placement	Winter Wheat	Spring Wheat
	bu/A	
None	13	12
Broadcast	55	27
Band	58	36

Several other experiments could be cited but the trends are clearly evident. Band application of fertilizer resulted in higher yields of both winter and spring wheat grown under both conventional and no-till cropping systems.

Banding the fertilizer too far from the seed can reduce the availability to the young seedling. Research with both winter and spring wheat shows the benefit of having the fertilizer band close to the seed and in a position to be intercepted by the seminal roots as they develop (Table 3). Placing the fertilizer 2" below the seed was substantially better than placing the fertilizer 2" below the seed mid-way between the 16" rows.

Table 3. Effect of band placement on no-till wheat yields in Washington.

Fertilizer Placement	Yield	
	Winter Wheat	Spring Wheat
	--------------bu/A--------------	
2" below the seed	56	44
2" below the seed between the rows	43	33

Extensive research indicates clearly that fertilizer sources are generally equivalent in terms of nutrient availability. Harold Houlton at the Northern Montana Experiment Station has conducted a number of trials evaluating various N and P fertilizers. In a three year trial with fallow spring wheat he found that anhydrous ammonia, urea, solution 32, and ammonium nitrate all produced similar yields (Table 4).

Table 4. Comparison of N sources, 3 year average of fallow spring wheat trials.

N Source	Yield		
	Min	Ave	Max
	-----------bu/A----------		
NH_3	24	52	37
Urea	22	51	36
Sol'n 32	23	50	36
Am. Nit.	24	49	36

In a three year trial comparing N sources for recrop spring wheat, similar results were obtained (Table 5). The yields are lower because of reduced soil moisture storage but there were no yield differences between the various N sources.

Table 5. Comparison of N sources, 3 year average of recrop spring wheat trials.

N Source	Yield Min	Yield Ave	Yield Max
	-----------bu/A----------		
NH_3	8	41	21
Urea	9	34	18
Am. Nit.	9	32	18

Houlton also conducted trials comparing various N-P materials and again, found no differences between the N-P materials (Table 6). This study used recrop spring wheat and all treatments received 70 lb N/A as NH_3 to supply adequate N and balance the N contained in the different materials.

Table 6. Comparison of various N-P materials.

P Source	P Rate (lb/A) 20	45	Average
	-----bu/A----		
10-34	35	38	37
18-46	36	38	37
11-52	36	37	37

SUMMARY

Correct fertilizer placement can markedly increase fertilizer efficiency and cereal yields particularly under reduced tillage systems. Recent developments in fertilizer placement technology have been coupled with an increased understanding of cereal root development. Cereal roots develop in an orderly and predictable pattern and fertilizer placement systems can be modified to take advantage of this by placing the fertilizer where it will be most available to the crop. Banding the fertilizer below and beside the seed allows for early seminal root interception of the fertilizer band and increased seedling vigor. Nitrogen and P fertilizer sources are essentially equal in terms of supplying nutrients to the crop.

ADDITIONAL READING

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