DIAGNOSING
SOIL PHYSICAL PROBLEMS

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Cover picture

This backhoe pit enabled investigators to examine root growth of young pear trees in relation to layers of different texture in this stratified soil.

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PREFACE

Plants live in two environments—one above ground and the other below. The environment above ground is easier to measure and study, so a great deal is known about the climatic effects on plants; the management of the crop by spacing, training, and pruning; and the control of pests and diseases.

The environment below the soil surface is just as important, but its influence on plant growth is more difficult to see. If root systems could be observed as easily as stems and leaves, more thought would be given to **soil preparation** before planting and to **soil and water management** once the plant is established. Plant roots need water, air, and mineral nutrients if the plant is to remain healthy. The soil must provide these almost continuously to the growing plant. It is important, therefore, to understand the relationship between plant and soil.

Part 1 of this series, *Soil Physical Environment and How It Affects Plant Growth*, by William E. Wildman and Kenneth D. Gowans, describes the basic physical relationships of soil particles to each other, and how these affect the movement of air, water, and mineral nutrients. These factors, in turn, affect the growth of roots.

Part 2, *Diagnosing Soil Physical Problems*, by William E. Wildman, outlines methods for examining the soil to assess whether or not observed plant growth problems are related to unfavorable soil physical characteristics.

Part 3, *Managing and Modifying Problem Soils*, by William E. Wildman, Rudy A. Neja, and Jewell L. Meyer, suggests methods of improving the physical environment of soils which have been shown to have unfavorable characteristics.

Parts 1 and 2 should be applicable to all crops and ornamental plants which require well drained and aerated root zones. Part 3 was written largely with tree and vine crops in mind, but the portions dealing with modification of surface compaction and shallow layering apply equally well to field and vegetable crops and shallow-rooted ornamentals. With this in mind, the reader may find the series of bulletins useful in planning new crop or ornamental plantings, and in managing those already established.

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DIAGNOSING SOIL PHYSICAL PROBLEMS

INVESTIGATING PLANT GROWTH PROBLEMS

Plants may grow poorly for many reasons. A plant with a normal root system may grow poorly because its parts above ground may be affected by insects, diseases, nutrient deficiencies, and climatic conditions. On the other hand, its root system may also be affected by insects and diseases, nutrients deficiencies or excesses, nematodes, soil water and air relations, and high soil density. A damaged or limited root system results in poor plant growth if the root's ability to carry out its function of providing plant tops with water and mineral nutrients is sufficiently restricted.

The first step in diagnosing the cause of poor growth is to look for the effects of insects, diseases, or nutrient deficiencies on the top growth. If symptoms are present, laboratory analysis or incubation of plant material may be necessary to make a positive diagnosis. In some cases, treatment of a disease or deficiency may be sufficient to insure good growth. If symptoms are absent on the top growth, it is advisable to look at the root system for clues to poor plant growth. For this purpose, a backhoe is one of the best diagnostic tools available. With it, many pits may be dug in a short time, in a field or orchard. Root systems and soil profiles can be observed and evaluated. Root samples may be collected for disease and nematode tests and soil samples for laboratory analysis.

In addition to diagnosing problems of existing crops, much use is made of backhoe pits to evaluate soils for new crops. By doing this, problems can be anticipated and soil modification treatments applied, if necessary, to provide a better soil environment for future crops.

DIAGNOSING SOIL PHYSICAL CONDITIONS

Soil physical problems usually result in restricted root systems. If these root systems are inadequate to provide plants with water, air, and the mineral nutrients necessary for optimum growth, the plants will then suffer in a manner that may be observed in various ways. Symptoms which may result from a restricted root system are:

1. Slow or stunted vegetative growth.
2. Inadequate shoot growth on perennials.
3. Small leaves.
4. Abnormal leaf color—nutrient deficiency symptoms.
5. Temporary wilting on hot days.
6. Early leaf desiccation or fall.
7. Poor size of crop.
8. Early maturing of crop.
9. Reduced crop yield.

It should be emphasized that any of the above symptoms do not **necessarily** indicate an unfavorable soil physical condition. Some or all of these symptoms may result when a healthy root system undergoes nematode attack, becomes diseased, or deficient in nutrients.

It is therefore valuable to use a multidisciplinary approach in diagnosing plant growth problems.

It is essential to diagnose the cause of potential or present soil physical problems in order to mechanically modify soil profiles for better root growth. If mechanical modification is not feasible, the diagnosis should suggest management practices to alleviate the problems. In either case, examination of the soil profile at several locations may be necessary.

Soil augers and tubes may be used for this purpose, but more information can be gained by digging backhoe pits to the depth necessary to observe all subsoil layers that may have an influence on rooting depth. Such pits are normally 2 to 3 feet wide, 6 to 8 feet long, and 4 to 6 feet deep. Pits in orchards or vineyards should be dug at the dripline of the trees or vines to observe the highest concentrations of feeder roots. Be sure the pit is located away from underground pipelines. **When digging pits more than 5 feet deep, precautions should be taken to prevent caving of the walls.**

OUTLINE FOR MAKING A DIAGNOSIS IN A BACKHOE PIT

1. **Planning a backhoe investigation:**

   It is best to look at freshly dug pits. A skilled backhoe operator can dig a pit as fast as a person can make an examination. Advantages of examining freshly dug pits are: The pit face will not be dried out from exposure to the air. Extra pits can be dug if necessary to define soil problems. Pits can be refilled after examination.

   Pit sites may be marked in advance or the operator may be told where to dig the next pit while the present one is being examined. In either case, the pit should so be located as to be representative of a portion of the field. (As nearly as possible judging from surface topography, plant growth, etc.)

   Be prepared to make a record of significant observations such as depth of notable soil layers, root frequency, etc.; the cover photo shows a typical backhoe pit in a young pear orchard.

2. **Are there obvious layers or changes in soil texture, structure, or color from the surface to the bottom?**

   Pick away at the soil in the sides of the pit with a screwdriver, trowel, or hunting knife (do not use a pocketknife unless the blade locks in the open position). To determine texture, moisten samples from different layers and work the soil by pressing between thumb and fingers. Try to form a ribbon. (See Part 1, page 4.) Sandy soils will not form ribbons. Loam soils form short ribbons that break easily. Clay loam and clay soils form longer and stronger ribbons. Silty soils are slick but not sticky like clay soils. Very dry clay clods may be difficult to ribbon because of their slowness to become thoroughly wetted.

   Try to classify the soil structure of each layer into one of the types mentioned in Part 1, page 5. These are: single-grained, granular, prismatic, blocky, platy, and massive.

   - Single-grained soils (mostly sands) have no aggregation.
   - Granular soils have small aggregates of sand, silt, and clay particles.
   - Prismatic and blocky soils have larger aggregates of clayey material.
   - Platy soils are finely layered, usually with silty texture.
   - Massive soils have no discrete aggregates but the whole mass of soil particles is loosely or tightly bonded together.

   Differences in soil color are not necessarily significant for plant growth, but sometimes suggest past history or soil properties that may affect growth.

   - Dark colors near the soil surface usually indicate a higher organic matter content there. This is often associated with better tilth and higher nutrient content than in the subsoil.
   - Uniform color throughout the profile is typical of young, unweathered soils. Usually the other soil properties are also uniform and the soil is an excellent root environment.
   - Increasing yellow and red colors in the subsoil are typical of older, weathered soils containing free iron oxides. Often associated with these colors is an increased clay content, a more blocky structure and decreased permeability for roots and water.
   - Whitish zones or streaks or a white lacy network following soil cracks may indicate a high content of calcium carbonate (lime) which may induce iron deficiency in certain types of plants, particularly tree crops. A fizz or foam when a drop of 1% hydrochloric acid is added, confirms lime is present. Small white crystals which glitter in sunlight but do not foam with acid are usually gypsum.
   - Blue or gray zones or gray and rust colored mottling indicate poor drainage and lack of good aeration.

3. **What are the patterns of soil moisture?**

   For diagnostic purposes, one can usually learn more about a moist soil than a dry one. Many soils are soft and friable when moist but become very hard when dry. A soil that drains very slowly in the spring may not give a clue to this characteristic after it has dried in the summer. When examining a

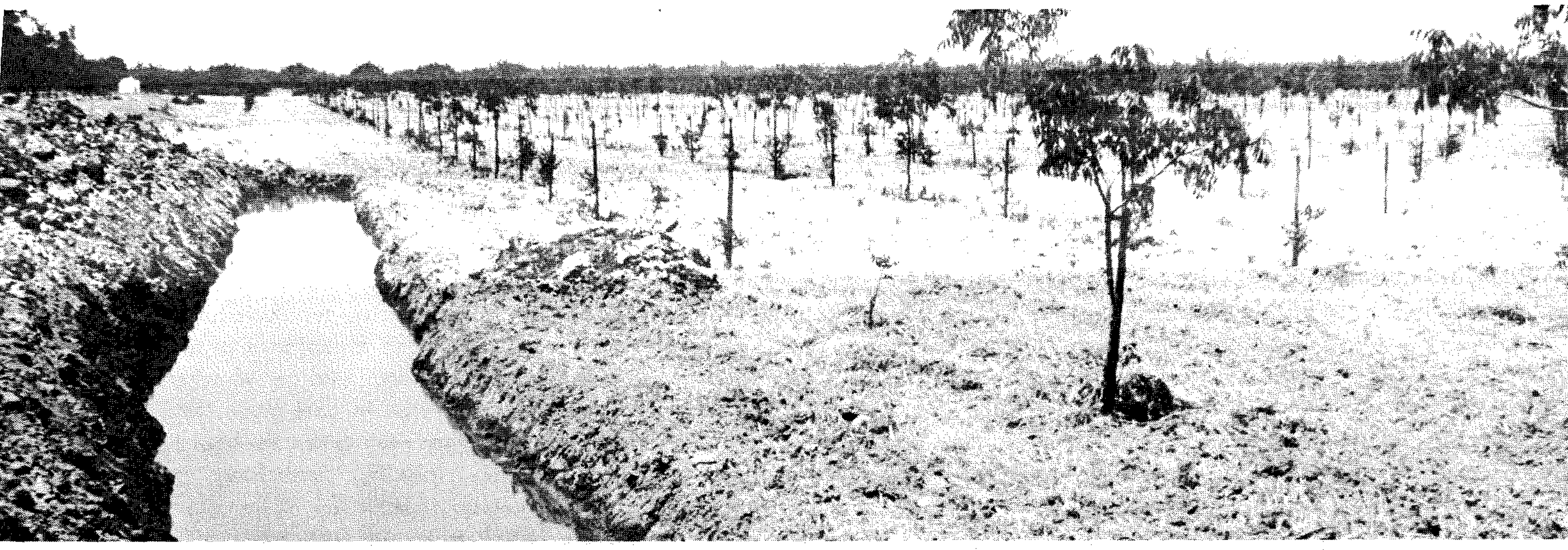


Figure 1. A trench dug in a young walnut orchard filled with water from a high water table. The trees have only a few inches of aerated soil around their roots and will die unless drainage is provided.

moist soil look for zones of excessive wetness in the side of the pit and try to determine why they are wet. A restricting layer below the wet zone may have held that water up. In extreme cases, you may find a saturated zone (perched water table). Free water runs out of the saturated layers and with time, will fill the bottom of the pit with water (see figure 1).

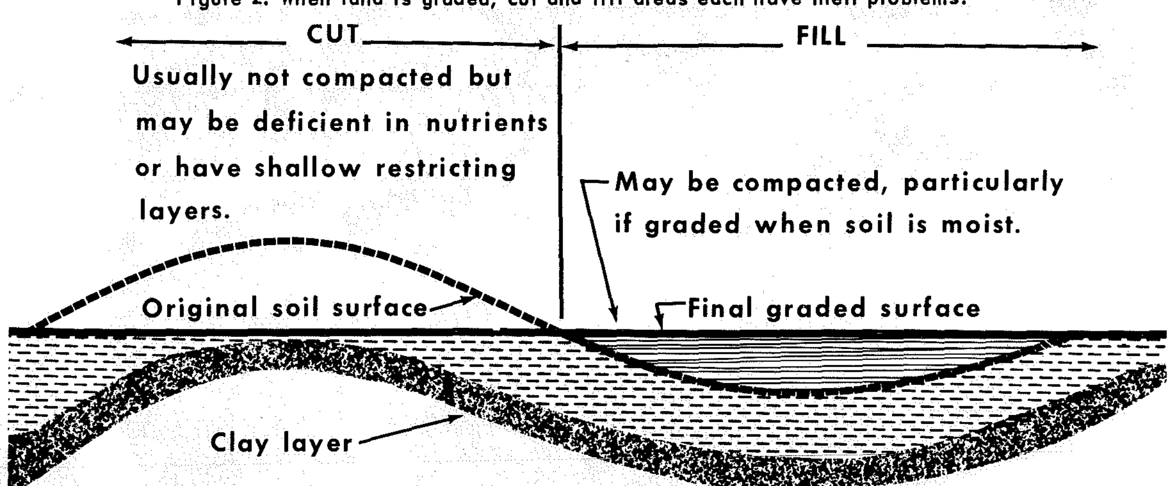
In a well irrigated, permeable soil—several days after irrigation—soil moisture normally is lowest at the surface and increases with depth. However, if the subsoil being examined is dryer than the surface, one of several possibilities is indicated:

- Percolation is normal but not enough irrigation water has been applied. This is an irrigation management problem.
- Percolation through the surface soil may be restricted by compaction or surface sealing, not allowing water to reach the subsoil. Improvement of the surface should be considered.
- The subsoil may be so dense that it does not accept water readily. Deep subsoiling may bring about improvement. (See Part 3, *Managing and Modifying Problem Soils.)*

4. **Was the field cut or filled in a land grading operation?**

Examine the sides of the pit for evidence of buried surfaces (indicating a fill) or subsoil layers closer than normal to the surface (indicating a cut). Cut areas (see figure 2) may uncover restricting or infertile subsoil layers close to the surface of the graded soil. Plant nutrients, zinc in particular, may be in deficient supply in cut areas, since it normally is present in much smaller amounts in the subsoil than near the original soil surface. However, cut areas may provide better water penetration than fill areas. Fill areas are often compacted excessively during the grading process, and unless loosened by subsoiling or deep plowing, provide an unfavorable medium for root growth. Moreover, fills over crop or weed

Figure 2. When land is graded, cut and fill areas each have their problems.



residues may promote anaerobic decomposition of these organic materials. Within a few weeks after land grading, anaerobic decomposition turns the soil blue or gray and releases gases and organic compounds toxic to plant roots. Anaerobic decomposition in soils gives off an unmistakable odor of sewer gas.

5. **Is there evidence of compaction—originating from previous cropping—within the surface two feet?**

   Pick away at the pit side with a small tool and note its firmness. You can often establish an upper and lower boundary of a compacted layer just by the slight differences in resistance to the tool. For best identification of compaction, the soil should be uniformly moist but not wet. Horizontal plates of compact soil about 1 inch thick may often be found near the upper boundary of the compact layer and just below the zone of surface tillage. The lower boundary may be more diffuse, with the compact layer grading into soft, friable soil. Figure 3 illustrates a typical case of surface compaction.

   Compaction can also be detected by soil tubes or penetrometers either pushed or driven into the soil. Resistance to the tube is very noticeable in the compact zone, and decreases as the zone is passed. An auger will not readily detect compaction.

6. **Is the soil stratified?**

   Observe the textures of the different layers, their thickness, their continuity, their hardness and porosity, and the abruptness of the boundaries between them. Notice whether roots tend to grow better in one layer than in another, and whether they cross the boundaries without any kinking, branching, or change in direction. Check for differences in moisture between layers that might indicate poor aeration above a boundary. The more abrupt the boundaries and the greater the textural change between layers, the more problems can be expected (figure 4). For reasons that are not fully explained, roots seem to grow from a coarse (sandy) layer into a fine textured soil more easily than from the fine textured soil into the coarse one. Roots will grow more uniformly if abrupt soil boundaries are broken up and stratified layers are mixed.

7. **Is there a claypan in the subsoil?**

   Clay increases in the subsoil are not usually difficult to detect. The greater the increase in clay in a subsoil layer the more obvious it becomes in appearance and feel, and the more restrictive it may be for root growth.

Figure 3. Soil compaction to a depth of two feet was easy to spot in this pit. Soil below the two-foot-depth was loose and friable. Roots of the dormant grapevine had not grown as well as they would have if the compacted layer had been thoroughly loosened before planting.

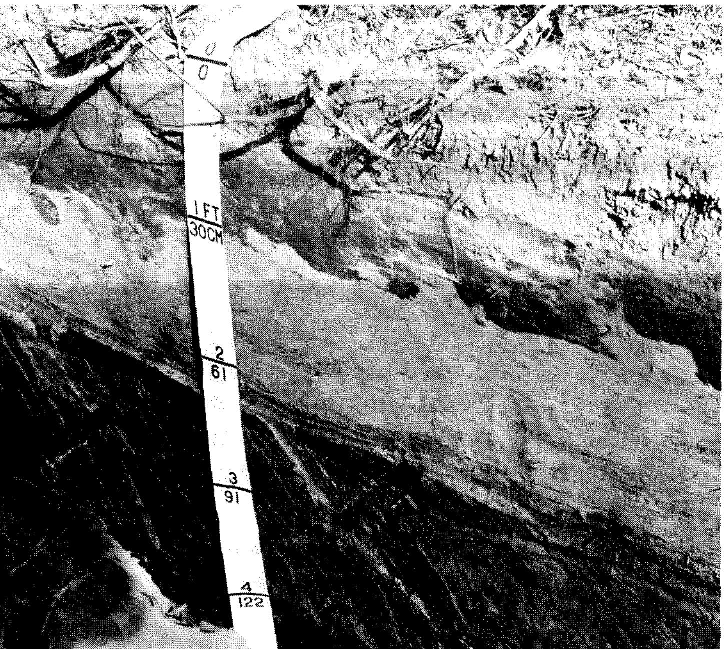


Figure 4. In this excessively stratified soil, young pear roots spread laterally in the sandy loam surface soil but did not enter the loose sand at one foot depth. Here the problem was not compaction, but disruption of the normal water, air, and nutrient relations at the abrupt boundary between the layers. When the soil layers were mixed by a trencher (see cover photo), roots grew well in the uniform soil and entered the silty soil below the white sand.

Try to locate the upper and lower boundaries of the zone of increased clay content. The upper boundary may be either abrupt or gradual; the lower boundary is usually gradual.

Use your picking tool to locate differences in looseness and cohesiveness. A loam or sandy loam surface soil will be easily picked away in small fragments but a clay loam or clay subsoil is tougher, more plastic, harder to pick away, and will tend to come out in larger chunks or blocks.

Cracks between blocks are often coated with a smooth layer of clay which is darker in color than the interior of the block. Look for roots growing along cracks between blocks but not in the interior of the block. These roots may be flattened, indicating that the crack is squeezed shut when the clay swells with wetting. Roots in claypans are often kinky because of the tortuous path they must follow in soil cracks.

Observe whether some roots go all the way through the claypan. If you find deep roots from nonirrigated plants, do not count on attaining the same depth of rooting with irrigated crops. Because single water applications are heavier, irrigation is much more likely than rainfall to produce temporary, poorly aerated zones in claypan soils. Figure 5 shows a typical claypan soil.

Figure 5. This claypan soil has a sandy loam with a porous massive structure to 15 inches deep, then an abrupt clay layer with prismatic and blocky structure. Young almond tree roots have been able to grow in cracks in the upper few inches of the claypan, but are in danger of being killed if this layer becomes saturated because of a wet winter or a careless irrigation. Soil below the claypan contains less clay, but is so dense that roots cannot penetrate any deeper.

8. **What is the nature of the soil beneath the claypan?**

   Check the texture, looseness, and density or porosity of the soil below the clay pan. This may be difficult because the soil is often dry under claypans and may seem very dense and hard. Even if the texture is a loam or sandy loam, the soil may be slightly cemented, or too densely packed for good root growth or water drainage. It helps to squirt a little water on the wall of the pit, let it soak in for a few moments, then examine the soil for looseness and water penetration. To test for cementation, place a clod in a shallow dish and add about a quarter inch of water to the dish. Allow the clod to become completely soaked and add more water, if necessary, to maintain a quarter inch in the dish. If the clod disintegrates while wetting, it is not cemented; if it maintains its shape after being completely soaked, and remains brittle while breaking between the fingers, it is partially cemented, and probably not a good root or drainage medium.

9. **Is there a hardpan in the subsoil?**

   A hardpan is a hard layer that may be of varying degrees of cementation. It usually has an abrupt upper boundary, an abrupt or gradual lower boundary. Unlike a claypan, it does not soften when wet. There may be a claypan just above the hardpan in the profile. When they are wet, it is easy to tell the difference between the two. If there is any doubt, the wetting test given in the previous paragraph should be used. Hardpan soils occur extensively along the east side of the Sacramento and San Joaquin Valleys, and in some other scattered locations. The hardpan soil shown in Figure 6 is typical of those in the San Joaquin Valley.

10. **What is the nature of the soil beneath the hardpan?**

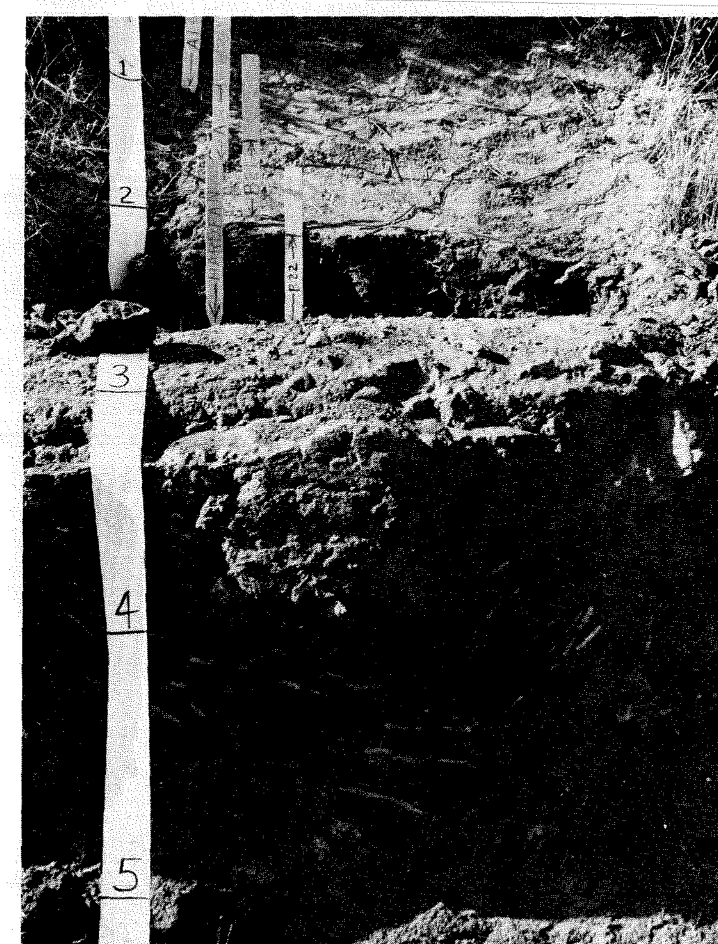
    If the soil beneath the pan is permeable, the effective depth of the root zone above the pan can sometimes be increased by subsoiling through the pan to obtain improved drainage. To assess the permeability, dig an auger hole beneath the pan and place a few inches of water in it. If the water drains away in a few hours, the soil is reasonably permeable. If it does not, it may be of questionable value to break the pan by deep subsoiling.

CONCLUSION

Diagnosis of soil physical problems can lead to improved management of existing crops, and to modification of soil profiles to provide a better environment for future crops. In examining a soil profile, one should note its uniformity at varying depths; the color, texture, structure, and denseness of soil layers; compaction from previous cropping practices; root growth in relation to soil layering and depth; problems associated with land grading; and the moisture regime of the profile.

Management of existing crops may often be improved by reducing compacting influences and altering irrigation frequency and quantity. Soil profiles may be modified by various types of deep tillage. These methods will be discussed in Part 3 of this series: *Managing and Modifying Problem* soils.

Figure 6. This hardpan soil shows the typical profile for the San Joaquin series. The sandy loam A horizon gradually increases in clay at 18 inches deep, becoming extremely clayey from 24 to 30 inches deep. An abrupt cemented hardpan extends from 30 to 48 inches, returning to a slightly packed sandy loam below. Depth to the hardpan may be more shallow in some cases, and the thickness of the hardpan itself can be either thinner or thicker, depending on the soil location.



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