IOWA PHOSPHORUS AND POTASSIUM SOIL-TEST INTERPRETATIONS WERE UPDATED IN 2023: CHANGES AND REASONS *

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ABSTRACT

The Iowa State University phosphorus (P) and potassium (K) soil-test interpretations for crops were updated in 2023 because the previous update had been in 2013 using data until 2012 and research since then indicated a need for some changes. The general goal of the guidelines since the 1990s has been to accomplish long-term profitability from fertilization and low risk of yield loss while maintaining or improving crop production sustainability. This has been attained by emphasizing crop response-based P and K rates to maximize yield in most conditions for the low-testing interpretation categories and suggesting build-up rates for at most 2 years, suggesting removal-based maintenance using prevailing crop yields (not yield goal), and suggesting P-K starter for specific conditions. The categories Very Low, Low, Optimum (maintenance), High, or Very High have been defined based on decreasing probability of yield response of approximately 80, 55, 25, 5, and 1%, respectively. Changes to the interpretation categories for P tests (Bray-1, Mehlich-3 colorimetric and ICP, Olsen) and K tests (ammonium-acetate or Mehlich-3 with dry and moist or slurry sample handling procedures) were that borders between the Very Low, Low, and Optimum interpretation categories were increased slightly but the Optimum category was made much wider by a larger increase of the boundary with the High category. Changes were justified by the new research to maintain the criteria for the categories' definitions, better awareness of very high soil-test small-scale spatial variability in most fields, and large bias among soil-test laboratories. Suggested fertilization rates for Very Low and Low categories were increased due to increased crop yield to maintain the criterion of attaining maximum yield in most conditions. Fertilizer placement guidelines did not change.

INTRODUCTION

Field research on P and K fertilization and relationships between soil-test values and yield response is continuously conducted in Iowa to assure that management guidelines are kept current. The last update of Iowa State University P and K guidelines (publication PM 1688) was in 2013 including soil-test and yield response data by 2012. Improved crop genotypes have been introduced in agriculture and crop yields continued increasing. Field-response trials with corn and soybean from 2013 until 2020 involved 799 site-years for P and 724 site-years for K, encompassed 36 Iowa soil series with predominant crop production, and soil (6-inch depth) pH was 4.9 to 8.1 and organic matter was 1.5 to 10% across P and K trials. The new results were combined with results of previous trials from which lowest yield levels were excluded (489 site-years for P and 240 site-years for K). This article summarizes changes and shows new

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relationships between corn and soybean soil-test results for selected soil-test methods. The criteria for establishing guidelines, updated soil-test interpretation categories, and suggested fertilization rates are included in the revised Extension publication PM 1688 (Mallarino et al., 2023).

WHAT DID NOT CHANGE?

The fundamental concepts for the interpretation and rate guidelines did not change. The general goal since the early 1990s has been to accomplish long-term profitability with minimal risk of yield loss while maintaining or improving crop production sustainability and water quality. This has been attained by emphasizing crop response-based P and K fertilization rates to maximize yield in most conditions for the Very Low and Low interpretation categories, suggesting build-up rates for at the most 2 years, suggesting removal-based maintenance using prevailing crop yields (not yield goal) only for the Optimum category using provided P and K concentrations in harvested crop parts, and suggesting P-K starter only for specific conditions. The categories Very Low, Low, Optimum, High, or Very High have been defined based on decreasing probability of yield response of approximately 80, 55, 25, 5, and 1%, respectively.

Recent research confirmed that the Bray-1 soil P extractant is unreliable in highly calcareous soils and either the Olsen or Mehlich-3 P extractants should be used, different soil-test interpretations are needed for any soil P test (but especially the most widely used Mehlich-3 extractant) when using the colorimetric or inductively-coupled plasma (ICP) measurements of extracted P, and K tests by the ammonium-acetate or Mehlich-3 K extractants are much more reliable when using the field-moist or slurry sample handling procedure than the common dried sample procedure especially in soils having moderately poor to very poor drainage. New research confirmed that with all tillage systems, equivalent responses typically occur for broadcast and planter-band P and K applications when using comparable rates. New research for deep banding was not repeated but extensive previous research had shown that deep-band P is not better than broadcast P for corn or soybean whereas deep-band K is a must with ridge-till but only occasionally is beneficial with no-till or strip-till (Mallarino, 2019).

WHAT WAS CHANGED?

One important change was that the recommended P and K fertilization rates for the Very Low and Low interpretation categories were increased to preserve the concept of assuring maximum yield for most conditions because of increased yield levels and P and K removal (see suggested rates in PM 1688, Mallarino et al., 2023). The most important change, however, was that the boundaries of the interpretation categories were adjusted in attention to the new research results to preserve the probabilities of response for each category defined since the early 1990s. The boundaries between the Very Low, Low, and Optimum categories were increased slightly but the Optimum category was made much wider by a large increase of its boundary with the High category. This was justified by the observed yield responses, further recognition of the inherent uncertainty of soil-test results mainly due to high small-scale spatial variation despite using improved dense soil sampling methods, and large bias among soil testing laboratories despite improvements from many years of proficiency soil testing programs.

Figure 1 shows the relative grain yield responses of corn and soybean to P fertilization for a wide range of soil-test values using the Bray-1 tests using the standard colorimetric measurement of extracted P. A handful of trials on highly calcareous soils, where the Bray-1 underestimated plant-available P were excluded and, therefore, the data approximately apply to the Mehlich-3 test with a colorimetric P measurement since these tests are statistically equivalent except in highly calcareous soils. For reference, the figure includes the previous interpretations in 2013 and the new interpretations. The bargraph shows that the probabilities of response across both crops are higher than 80% for Very Low and around 60%, 25%, 5%, and 0% for the Low, Optimum, High, and Very High categories, respectively.

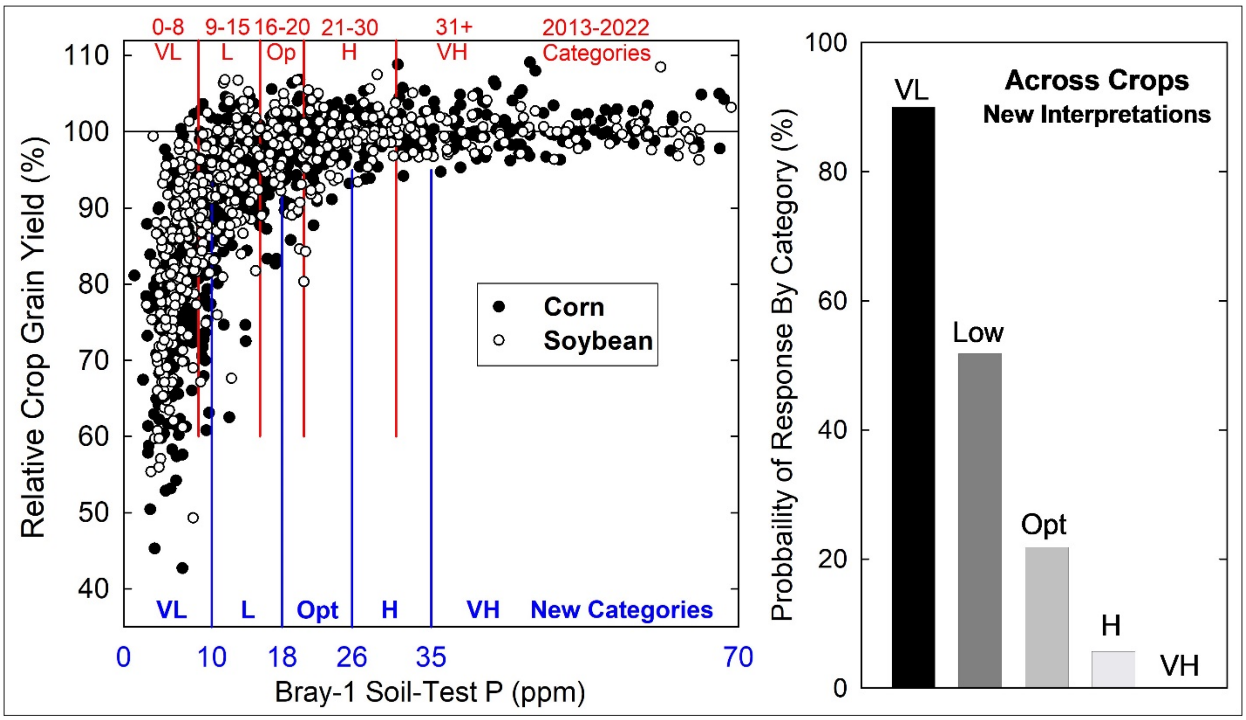

Fig. 1. Relationships between Bray-1 colorimetric soil P and relative corn and soybean grain yield response showing old and new categories and the probability of response across both crops for each new category (VL=Very Low, L=Low, Opt=Optimum, H=High, VH=Very High).

Figure 2 shows the relationships between corn and soybean yield increases and soil-test P and the new interpretation categories. The observed variability is common for P trials and results from different environmental conditions, soil-test spatial and temporal variability, and experimental error. Yield increases frequently were very large in the Very Low category, moderate in the Low category, very small in the Optimum category (on average around 4 bu/acre), and varied around zero for the high-testing categories. Therefore, recommended removal-based P or K rates for the Optimum category will maximize yield in most conditions although may not optimize profitability and producers can reduce it mainly with unfavorable prices or unsafe land tenure. Fertilization, other than the usually low starter rates, will not offset the costs of fertilizer and its application.

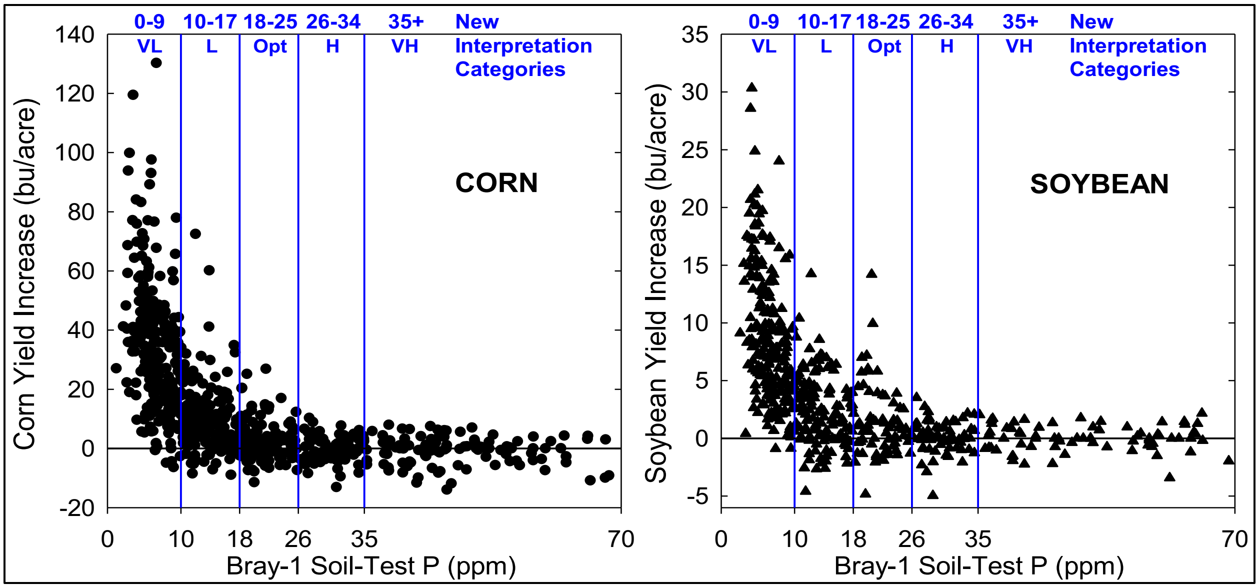

Fig. 2. Relationships between corn and soybean grain yield increases from P fertilization and Bray-1 soil P indicating the new interpretation categories.

Figure 3 shows relationships between relative grain yield responses and soil-test K by the ammonium-acetate test (statistically equivalent to the Mehlich-3) using the dry and field-moist or slurry sample handling procedures (Gelderman and Mallarino, 2012). Interpretation changes for K and the reasons were like those for P.

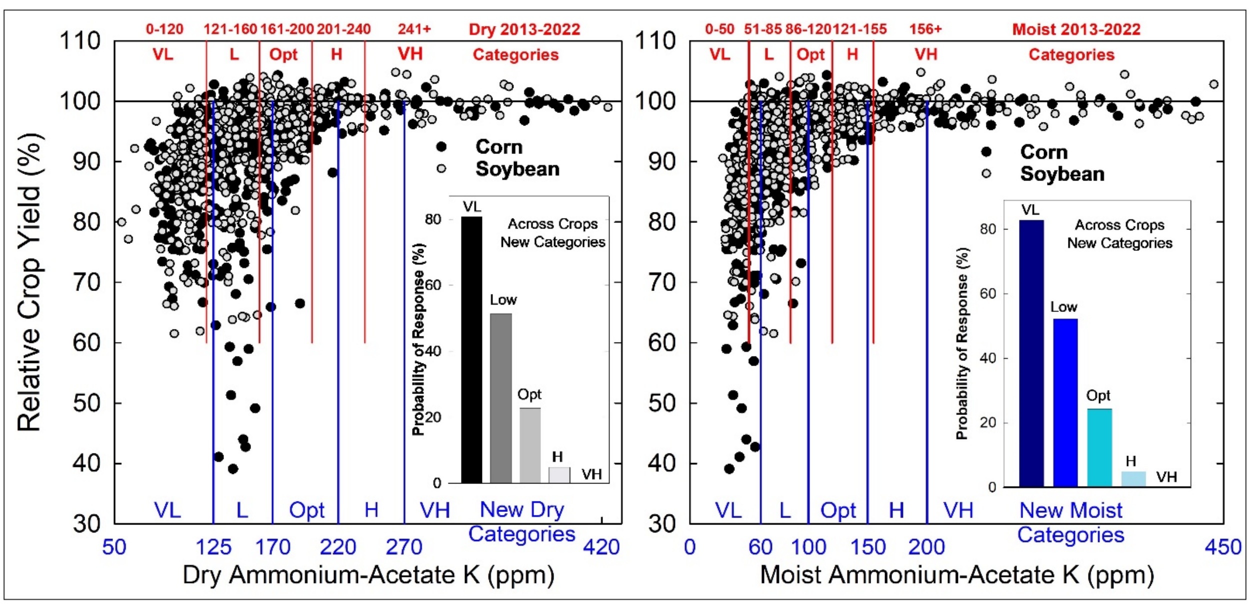

Fig. 3. Relationships between ammonium-acetate soil-test K using dry or moist sample handling procedures and relative corn and soybean grain yield responses showing the previous and new categories. Bargraphs show probability of response across both crops for each new category.

Yield increases from K fertilization related to soil-test values for both sample handling procedures in Fig. 4 show the usually much higher K response variability than for P observed in Iowa and other states. But the data show well the better performance of the moist (or slurry) K test as well as unlikely and very small yield responses in high-testing soils which seldom would offset costs of fertilizer application.

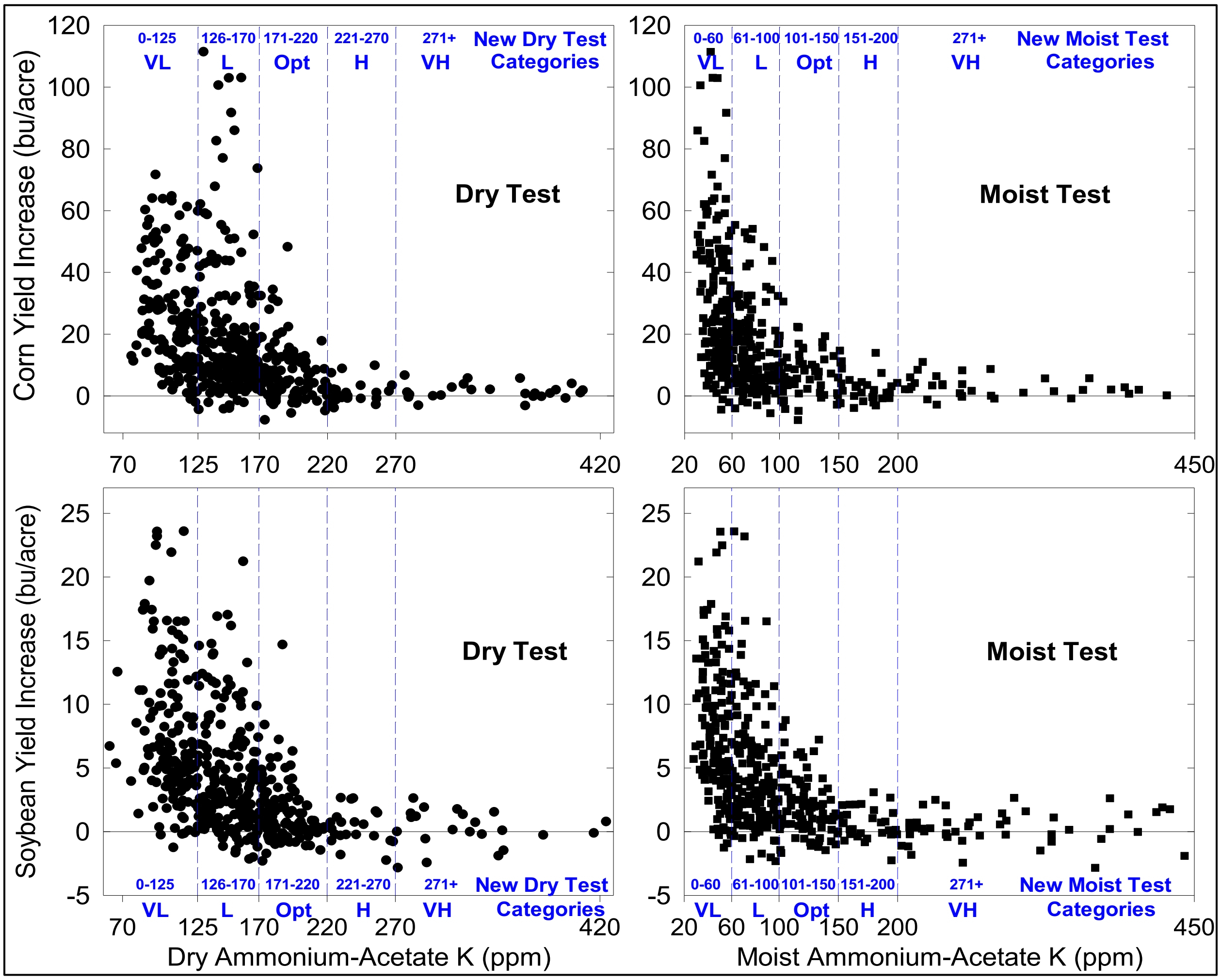

Fig. 4. Relationships between corn (top two graphs) and soybean (bottom two graphs) grain yield increases from K fertilization and ammonium-acetate soil K using dry or moist sample handling procedures indicating the new interpretation categories.

Figure 5 confirms that the moist K test is much more reliable than the dry test and results in more accurate K fertilization management for many soils. This is the case for soils with moderately poor to poor drainage even with tiles present such as the Iowa series Canisteo, Clyde, Coland, Colo, Edina, Haig, Harps, Kalona, Marcus, Okoboji, Taintor, Webster, and Zook. Research suggested that alternating dry and saturated soil moisture is the main reason for the dry test bad performance, although soils had slightly higher organic matter and smectite clay dominance than others. The meaning of a moist K test value for yield response was similar across soils but not for the dry test and its use complicates good K management.

New data in Fig. 6 confirm that soil K cation saturation is not good to decide K fertilization and using the recommended 2 to 5% range by some consultants would result in unneeded fertilization and reduced profitability in many fields.

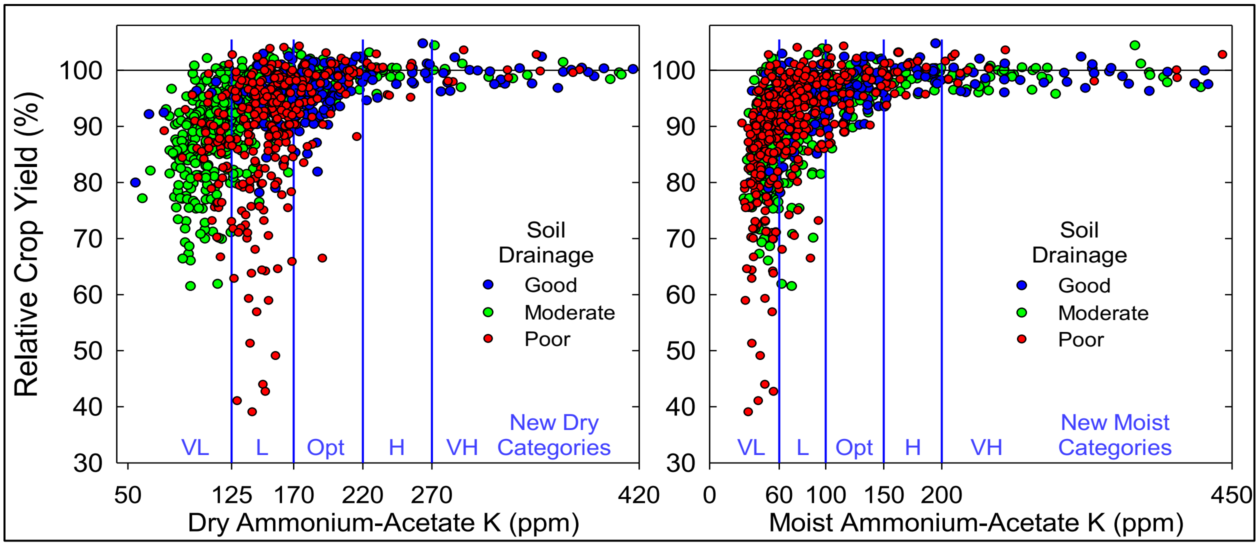

Fig. 5. Relationships between ammonium-acetate soil K with dry or moist sample handling procedures and relative corn and soybean grain yield response for soils with different drainage.

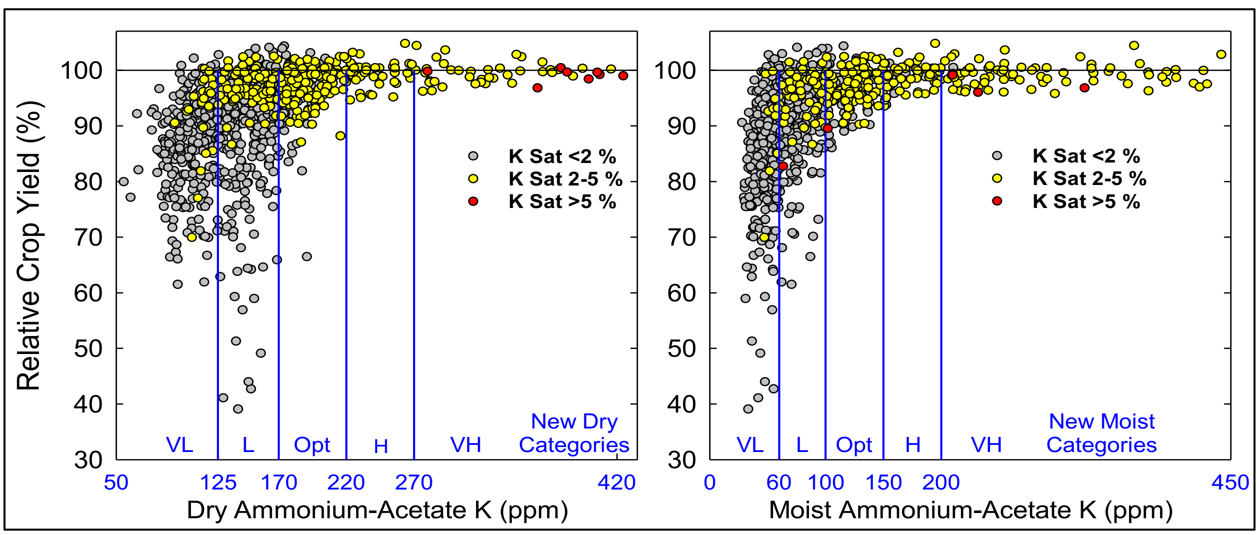

Fig. 6. Relationships between ammonium-acetate soil K with dry or moist sample handling procedures and relative corn and soybean yield response for soils with different K saturation.

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