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## Review of soil acidity and liming guidance

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# 1. INTRODUCTION

In responding to the AHDB invitation to review current guidance on soil acidity and liming in the Nutrient Management Guide (RB209), the Agricultural Lime Association (ALA) have carefully studied each section of the guide in the relation to soil acidity and pH, whilst looking at reference to the important role of calcium as a major plant nutrient.

Ameliorating soil acidity has been viewed as a liming materials principal function but fine, reactive, calcium and its chemical bases are an essential source of this essential secondary macronutrient. In this paper ALA have responded by studying the current guidance in relation to calcium and identifying those areas where there may be omissions or points that might provide the user with a better appreciation of the subject.

The aim of this paper is to gauge the opinion of the Crop Nutrient Management Partnership on the ALA analysis. By taking measure of the comments into account ALA would propose to respond with detailed proposals on liming and calcium aimed at providing users with a comprehensive understanding of the subject to both appreciate and make more informed decisions.

# 2. ABSTRACT

Agricultural Lime has and remains a farmer's principal input to neutralise soil acidity, in the drive to maintain and increase levels of crop production. It also has a key role in continued environmental sustainability and underpinning the fundamentals for a healthy soil. An informed approach to the appropriate choice and application of liming products certainly warrants an increasingly important role in future farming practices.

History has taught us that neglecting soil comes at a price, the 1937 Land Fertility Act was introduced to address such a situation, and as such underpinned agricultural development for the next 37 years. This legacy was short lived, as new agricultural technologies and practices evolved, some of 'yesterday's knowledge' including the practice of pH maintenance and regular liming were overshadowed.

The closure of the 'Aglime' subsidy also saw the end of the comprehensive agricultural lime databank, leaving the UK amongst the minority of European countries devoid of any liming data and reliant instead on 'estimations'. Evolution and consolidation coupled with annually reduced tonnages and liming interest resulted in mineral producers withdrawing from the costly logistics of lime testing leaving the task to farmers, advisors or agricultural merchants. This natural transition has resulted in the bulk of agricultural liming work now being commissioned by agricultural advisors and merchants as an appendix to their wider remit.

Of more concern is the fact that the market has experienced minimal regulatory intervention and control measures with the primary key driver being price, not surprisingly the repercussion of this is that the market is principally serviced by screened or coarse grade products.

It is against this background ALA initiated the AgLime Quality Standard (AQS). The key objectives were to re-awaken awareness of the benefits of maintaining optimal soil pH levels and promote farmers and growers to become more questioning and informed both about the products they bought but also about the efficacy and value they delivered. If in the process AQS made users more informed on regulatory standards there remained potential that the standard of UK agricultural liming products could be improved.

Of the two sources of information providing a measure of current liming practices, the British Survey of Fertiliser Practice (BSFP) and the Professional Agricultural Analysis Group (PAAG) Survey, it is concerning that the most recent PAAG report highlighted that throughout the surveys 25 years year history mean soil pH levels have recorded steady decreases in both arable and grassland samples, indicating a need to address liming on significant proportions in both farming systems.

The first chapter in the 1953 book “The Use of Lime in British Agriculture” written by Gardner and Garner is titled “Liming as an Agricultural Problem”. In this chapter the authors describe the lead up to the ‘Land Fertility Scheme’ 1937 – 1976. It concludes with a quote from the then MAFF 1950 Agricultural Expansion Programme pamphlet with conclusions from six National Agricultural Advisory Service Working Parties, “Despite all that has been done in recent years, (through the AgLime Subsidy) lime deficiency remains one of the greatest obstacles to increased production” The Working Parties pointed out “that in order to establish a satisfactory lime status over the country as a whole, application must be maintained over a considerable number of years at about twice the rate applied in 1946-47 (2.8mt)”, - current (2019) estimates put UK applications at 1.5 – 1.8mt.

Guidance and information on liming features in Section 1, Principles of nutrient management and fertiliser use. The three soil acidity and liming pages provide a broad outline of the subject, however, there appears limited expansion on the subject since the AgLime subsidy era. The predominant emphasis on agricultural liming focuses firmly on the acid neutralisation properties as their singular and distinctive function, reference to the function and role of calcium as one of the three secondary plant nutrients is minimal. All the references to lime point towards ground limestone as the basis for all recommendations whereas this does not replicate the market situation where coarser screened products based principally on price supply the majority of the UK market.

# 3. Review of the Nutrient Management Guide (RB209)

## 3.1. Principles of nutrient management and fertiliser use

**Page 5 – The basis of good practice** – regular soil analysis includes only 4 elements – pH, P, K, and Mg, encouragement for best practice should be to widen the scope to include the major secondary nutrients including calcium. High response crops – while calcium is an essential element for all plants, the following crops have been found to be especially responsive - apples, broccoli, brussel sprouts, cabbage, carrots, cauliflower, celery, cherries, citrus, conifers, cotton, curcurbits, melons, grapes, legumes, lettuce, peaches, pears, peppers, potatoes, tobacco, tomatoes, wheat, soya, maize, oilseed rape and barley.

**Page 6 – Greenhouse gases** – a balanced soil pH should be included as a major contributory factor to the reduction of Greenhouse Gas (GHG) emissions for a reduction of nitrous oxide emissions and carbon sequestration. There also needs to be emphasis on calcium replacement through the process of nitrogen acidification, agriculture is an important anthropogenic source of nitrous oxide, which has a global warming potential approximately 300 times higher than that of carbon dioxide.

The nitrous oxide reduction path, in soils is mainly driven by soil pH and is progressively inhibited when pH is lower than 6.8 (Henault et al, 2019). During field trials in this study liming acidic soils to neutrality decreased soil nitrous oxide emissions and studies estimated liming could potentially decrease emissions by over 15%.

Reference – 'Think Soil' chart – Page 14.

**Page 12 – Soil structure** – there is no mention of the benefit of calcium cations on soil structure and the resultant improvement in soil aggregation. It is also essential to note the importance of these same cations in providing plant cell strength, crop and animal health with a potential reduction in pesticide usage.

Calcium promotes soil structure improvement, creating the healthy, aerated soil farmers need. Calcium opens up the soil, allowing water to be better absorbed, promoting better nutrient availability and reducing the risk of erosion and flooding biodegradation of soil-applied pesticides that has long been correlated with soil pH above ca 6.5-7.5 (Warton and Matthiessen, 2005).

**Page 13 – Soil acidity and liming** – there is no mention of hydrogen and aluminium toxicity. The pH availability bar chart would help to reinforce this point.

There is no listing of common generators of soil acidity - including:

- Acidic precipitation – rainfall is slightly acidic between pH 5 and 5.6
- Deposition of acidifying atmospheric gases or particles (sulphur dioxide, ammonia and nitric acid)
- The application of acidifying fertilisers such as elemental sulphur and ammonium fertilisers
- Crop nutrient offtake
- Microbial activity and plant roots producing organic acids
- Leaching of the nitrates that are not taken up by the plants
- Organic manures

**Page 13** – warns overuse of lime is wasteful and costly. This is outdated as all surveys clearly suggest UK farmland is under limed and requiring significant attention to soil pH monitoring to ensure pH levels are increased to optimal efficacy levels with a positive message for farmers – calcium for increased profitability.

The studies led by Dr Jonathan Holland of the James Hutton Institute together with Harper Adams University and Rothamsted Research found that maintaining optimal pH levels through regular liming is a beneficial long-term capital investment for growers and the analysis proves that the trend away from liming is putting a dent in overall farm income (Holland and Behrendt, 2020, Holland et al, 2019).

The studies also showed that higher rates of lime gave the best overall economic return on both sites, but maintaining regular applications was seen to be more important than the rate of lime in any single year and that almost all crops were positively affected in respect of yield by increasing pH. Surveys in the UK have shown 41% of soils in UK are below pH 6.5.

**Page 14 – Lime recommendations** – the liming calculation should be in shown as an equation not in words. In Table 1.2 the term ‘Liming Factor’ is used - what is this factor and how is this derived?

The AHDB lime application recommendations are very cautious in comparison to other calculators which might question the application maintaining a mean pH throughout the liming cycle.

There is no mention of the effect on pH of the other cations e.g. Ca, Mg, K, Na, or $NH_4$. Studying the lessons from the PAAG survey analysis there should be more emphasis placed on a neutral – slightly alkaline soil pH as a benchmark as the cornerstone of a farm soil management plan, and not looking at a whimsical liming 5 t/ha once every 5 years. The + or – 0.5 variation on Page 15 is not sound advice in this context for liming applications.

**Page 15 – Example 1.1** – needs readdressing and modification as it is misleading unless reactivity is included. For comparison see: [Lime Comparison | Calculators | soilquality.org.au]

In the examples, all references are to ground limestone and this is where the user may be misled, even the now 'dated' 1991 Fertilisers Regulation lists 25 different classifications of liming products from carbonate, oxide, hydroxide, silicate, mixed limes, sands and shells, and unclassified (anything goes), with agricultural lime being very traditional and local, tuning the grower into identifying the suitable and effective product requires wider explanation.

ALA are encouraging efforts to introduce UK growers to established European standards for reactivity (neutralising value + fineness) as a wider and more definitive measure for the efficacy, effectiveness and true value and benefit of a liming product.

**Page 25 and 26 – Soil sampling** – The guidance is basic information with no reference to the secondary nutrients and calcium.

**Pages 27-34 – Target soil indices** – Again it is basic information, the section on nutrient descriptions completely misses calcium as a crucial secondary plant nutrient.

**Page 40 – Analysis of fertilisers and liming materials** – there are no figures for the calcium content in the liming products, even Limex has full analysis without a calcium content. There is no inclusion of calcium sulphate based nitrogen fertilisers e.g. Singletop or Anhydrite (calcium sulphate) in the sulphur based fertilisers.

Throughout the section liming products and materials are described as universally consistent products, with very limited distinction or explanation for material properties, qualities, and value. Neutralising Value (NV) is the principal determining factor for liming materials with no reference to the importance of fineness (NV + fineness = reactivity = speed of action = efficacy = value = return on investment). An introduction to the principles of soil cation exchange capacity and how this interacts with nutrients and the structure of a soil would be of great benefit to users of the guide.

Conversion tables for elements do not have multipliers for calcium. The inclusion of a plant nutrient chart highlighting the impact on soil and plant health and development including deficiency symptoms would be very beneficial to users.

### 3.2. Organic materials

There is no mention of calcium content of organic manures which are commonly higher than magnesium, there is no reference or detailed inclusion of micro-nutrients. The section should include the potential influence from the incorporation of bedding materials and use of hydrated lime slurry and its calcium content.

### 3.3. Grass and forage crops

**Page 5** – in the introduction the emphasis is on the importance of a balanced soil structure with specific emphasis on nitrogen as a basis for quality and yield, there is no mention calcium or a broader spectrum of soil analysis.

The pH target of 6.0 – 6.2 must be questioned for swards applied with high rates of nitrogen when later recommendations in the section are as high as 300 kg N/ha, these levels will encourage higher rates of nitrous oxide losses. Additionally, there is enough research published to show how fertiliser efficiencies improved when the pH is greater than 6 which should be enough encouragement to low input grassland farmers to use low rates of lime annually rather than buying expensive fertiliser.

The section omits the potential for pH to be high due to other cations such as potash, particularly where high volumes of slurry are used. There should be an encouragement to look at soil, slurry and forage tissue in a wider context and see where antagonisms are occurring. Calcium is frequently low in forage analysis due to high potash and high rates of nitrogen.

**Page 18** – grass staggers and the preventative use of magnesium lime is mentioned, however there is no detail regarding calcium in this section, or the important balance that should be in place between calcium and magnesium. The omission of calcium is very important not least because of its improvement to digestibility and subsequent output efficiency.

No warning is given about the effect of using other pH altering cations such as magnesium required for animal health that can negatively affect soil structure and calcium. A pH test is not a calcium test.

## 3.4. Arable crops

This section does cover primary, secondary, and micro plant nutrients; however it completely misses calcium as one of the three secondary nutrients. Calcium is the key essential nutrient for all plant and organic life, its role in strong plant growth, strength and development of cell walls and membranes is crucial, calcium promotes plant synthesis and the intake of nutrients adequate levels of soil calcium provide a basis for the potential reduction in herbicide usage and better-balanced production.

Deficiencies of calcium can result in restrictive development especially at the young growing points resulting in stunted growth. There are pointers that calcium also acts a ‘plant-messenger’ warning of nutrient deficiencies and pathogen attacks. Calcium both as an essential plant nutrient and stabiliser in the soil merits inclusion and should be highlighted.

Other cations in this section not considered as affecting soil pH include magnesium and potash. Soil acidity occurs naturally in higher rainfall areas and can vary according to geology, clay mineralogy, soil texture and buffering capacity. Agricultural production also increases acidity through unbalanced nitrogen cycling (excessive use of nitrogen fertilisers and nitrogen leaching), organic matter decay and continued removal of high yielding crops and animal materials including grains, wool and meat.

Again, only Basic Soil Analysis is considered in this section.

### 3.5. Potatoes

This section is very light on calcium due to concerns regarding liming and production of potato scab having a negative impact on skin finish and crop sample. It is known that low Exchangeable Calcium (Caex) in the soil leads to bruising and rots, and that Internal Rust Spot (IRS) can likewise be commonly linked to soils low in Caex. However, there are other calcium based products frequently used in potato crops – e.g. calcium nitrate, Calcifert Sulphur and Polysulphate.

### 3.6. Vegetables and bulbs

Nutrient sampling in this section highlights the essential secondary nutrients magnesium and sulphur and a number of micro-nutrients but omits calcium, which in a crop that demonstrates the most visible deficiencies should be highlighted.

In high value crops like vegetables diseases like clubroot can exact big yield losses, but there is no mention of clubroot containment with the practice of maintaining above average pH levels. The application of higher rates of liming materials in specific field areas affected with clubroot problems should be emphasised as a method of containment.

With high value crops like vegetables consideration should be given to sampling and mapping soil pH separately to a nutrient suite analysis in a consolidated sample.

**Page 18** - it would be useful to list calcium and magnesium in the crop removal figures which in some crops can be quite significant amounts.

**Page 21** - in the guidance for Leaf analysis crops listed include cauliflower, calabrese, onions and carrots, but not the leafy (and calcium rich) crops like lettuce. There is no mention in the vegetable section for the improvement of the crop storage and keeping qualities when calcium levels are optimised.

**Page 40** – The potential problem of Blossom End Rot in courgettes could be attributed to low concentrations of calcium, low concentrations of calcium particularly in all leafy vegetable crops could be a problem. Tip burn and the lack of calcium in young developing leaves does not appear to be factored in when it is very common leafy green vegetable crops.

### 3.7. Fruit, vines and hops

The introduction moves from lime to sulphur and micro-nutrients but there is no mention of calcium and magnesium which has the potential to be a problem particularly in soft fruits.

**Page 14 –** indicates excessive potassium can affect storage quality. It is the lack of calcium that affects storage (either through not enough reserve or insufficient amounts being suppressed by too much potassium) and promotes significant fruit loss issues such as Bitter Pit and softening of fruit leading to unmarketable fruit.

**Page 18 – Table 7.10 –** calcium is second only to potash in the table for nutrient solution for strawberry production. With calcium being a particularly important nutrient for cell wall strength and plant growth there remains a potential at fruit filling that should the plant have insufficient reserves of calcium fruit splitting and spoiling of the crop could result, as calcium is not a very mobile nutrient adequate reserves should be factored in. This is again highlighted by the omission of calcium on **Page 19 Table 7.11** where there is no mention of calcium in the table of leaf analysis given the important function of calcium in the growing points and leaf function.

Guidance for the concentration of dry matter content in strawberries and the average nutrient content in apples is supported by the most extensive guidance for the importance of calcium in any of the seven sections of RB209.

Potassium - high applications reduce calcium uptake in apples, which are extremely susceptible to poor calcium uptake and translocation within the tree.

## 4. Summary and conclusions

Future revisions of RB209 would deliver more benefit and value to users of the guide by expanding the range and diversity of information on agricultural lime. The historical name and terminology of the word lime has been long been viewed as a universally regular product with the principal function to address and correct soil acidity and neutralisation, whereas the dividends calcium and its chemical bases contribute to both soil and plant life and health are of equal importance and measure as the major nutrients.

Soil health will be one of the three central tenants of the new environmental land management schemes and the provision of a more comprehensive understanding of liming products, the classifications, specifications, and the importance of how all these elements interact would provide a clearer understanding and appreciation.

As has been highlighted in the previous comments agricultural lime has to be viewed as a material and product with more than one function, it is also important to recognise that pH is a logarithmic scale and that not maintaining a constant mean neutral soil pH will lead to reduction in soil micro-bacterial activity and overall soil health and functioning.

The problems and limitations created with acidic soils are well documented, but the role and function of calcium is less well documented. In addition to its nutritional function in plant growth and development calcium plays an important role interacting with both macro and micro-nutrients enabling greater functionality across a wider spectrum of plant functions.

As has been highlighted in preceding pages adequate and essential plant calcium is essential not only for the health of plants building resistance to pests and disease, but as an essential element for the growth and development of good quality marketable yields.

As previously stated evidence of both the BSFP and PAAG seem to indicate the practice of liming appears to be more reactive rather than proactive indicating a need for a more robust approach to soil management planning, the reasons for which may include;

- Soil acidity takes time to manifest itself but quickly escalates it may therefore be mistaken for a range of other nutrient deficiencies
- A lack of appreciation and understanding that pH is a logarithmic scale and declining pH levels are accelerating nutrient lock-up
- Agricultural economics, agricultural lime is a capital investment spread over several years, as indeed are the reciprocal benefits. Targeting pH 6.5 will not ensure soil pH levels will be maintained at adequate levels throughout a liming-cycle, resulting in a reduction of soil health, microbial activity, efficacy and efficiency

As from the points above one size does not fit all, and tailored recommendations are required for individual crop and soil combinations.

Lime has been a very traditional market but the ‘traditional’ practice of 2 tonnes per acre every XX years is not the best application of science and certainly not the efficient return on the capital investment with screened and coarse materials. Coarser materials will help to influence your bank balance, but not necessarily on your soil pH.

A healthy soil environment provides the benefits of a good soil mix and aeration for root development in addition to better water holding capacity through dry and droughty periods. Growers will in future need to have a serious focus on the fundamentals of soil management and health and to factor in the serviceable importance of the practice and application of lime as a regular practice, providing as it does the long-term benefits to both profitability and overall soil health.

In the drive for ‘net-zero emissions’ ambitious targets have been set to reduce GHG emissions, agricultural practices are an important anthropogenic source of nitrous oxide, which has a global warming potential approximately 300 times higher than that of carbon dioxide. The nitrous oxide reduction path, in soils is mainly driven by soil pH and is progressively inhibited when pH is lower than 6.8 (Henault et al, 2019). During field trials liming acidic soils to neutrality decreased soil nitrous oxide emissions and studies estimated liming could potentially decrease emissions by over 15%.

Maintaining optimal soils pH’s through the practice of regular liming both improves the structure, aeration, and drainage of the soil which encourages greater levels of biological activity resulting in healthy soils. Healthy and efficient soils will assist in building soil carbon levels as a result of the increased yields and residue returns to the soil. Then greater carbon sequestration capacity in limed soils helped to reduce global warming through more efficient and effective use of nitrogen fertilisers helping to offset the effects of climate change.

The focus of the new environmental land management schemes is on the environment, clean air, water, mitigating the effects of climate change. As a result, the farmers’ basic asset – the soil and managing its health will be important. Whether it be through rewilding to encourage wildflowers and flora and fauna or ensuring the soil is maintained in optimal condition to withstand the changes to our weather patterns from climate change it will be increasingly important that physically and ultimately financially that soil is managed to build a thriving, healthy and living environment that both provides and utilises its resources efficiently and effectively.

## 5. REFERENCES


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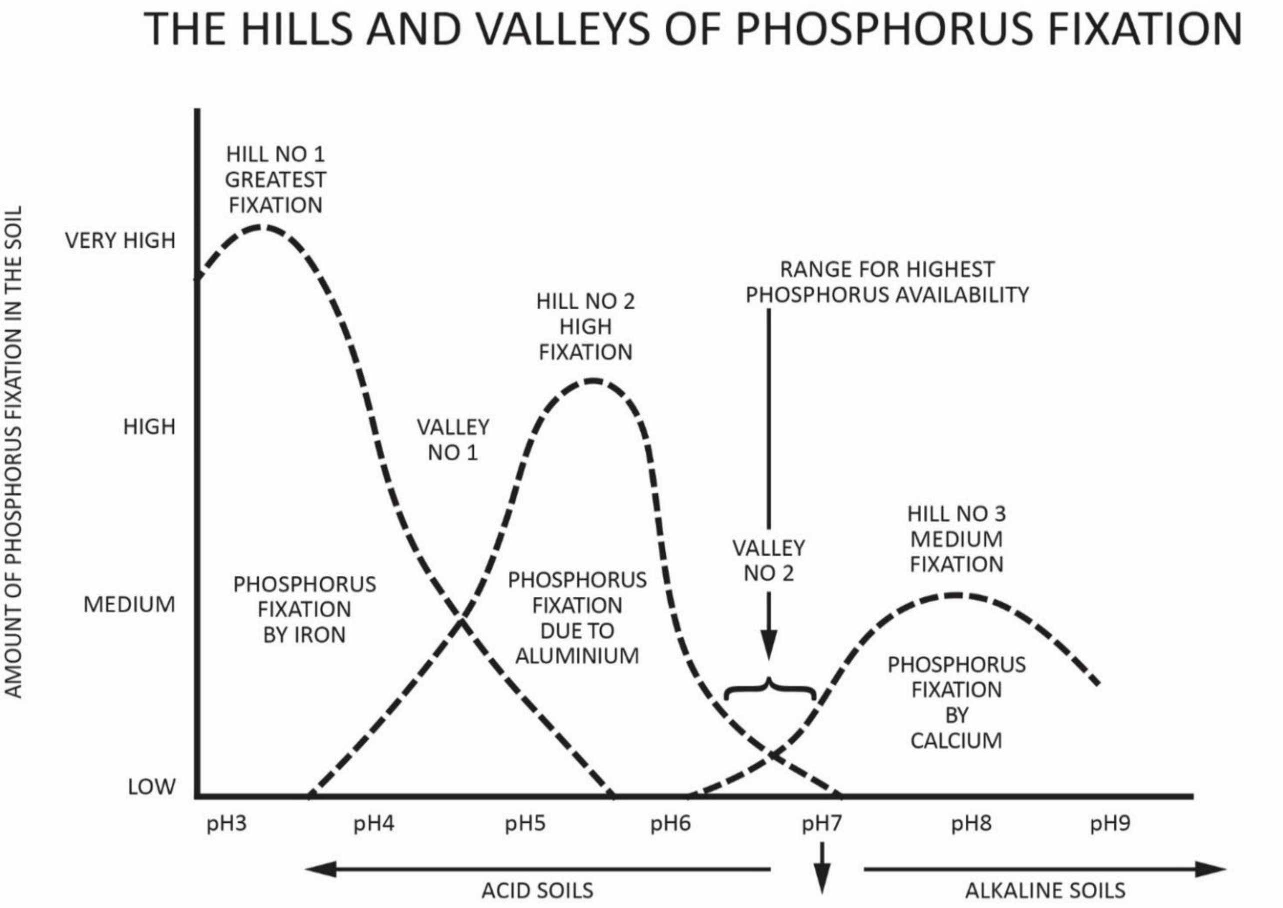
AQS – AgLime Quality Standard – https://aglime.org.uk/downloads/AQS_Outline.pdf

Soil Quality Organisation – Australia – Lime Comparison | Calculators | soilquality.org.au

## 6. Appendix




| | Kg $CaCO_3$ required to neutralise each Kg N |
|---|---|
| Ammonium Sulphate | 5-7 |
| Ammonium Nitrate | 2-3 |
| Urea | 2-3 |
| Calcium Ammonium Nitrate | 1.5-2.5 |
| Calcium Nitrate | 0 |


## *Look after your soil and in return it will look after you*

There are 19 essential elements that are required to be present in soil for healthy plant growth

### pH and Fertiliser Efficiency

| Soil Acidity | | Nitrogen | Phosphate | Potash | % Fertiliser wasted |
|---|---|---|---|---|---|
| Extremely acid pH 4.5 | | 30% | 23% | 33% | 71.34% |
| Very strong acid pH 5.0 | | 53% | 34% | 52% | 53.67% |
| Strongly acid pH 5.5 | | 77% | 48% | 77% | 32.69% |
| Medium acid pH 6.0 | | 89% | 52% | 100% | 19.67% |
| Neutral pH 7.0 | | 100% | 100% | 100% | 0% |