



## Predicting farmer's inclination towards adoption of anionic mineral mixture in Haryana: A case study

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### ABSTRACT

Milk fever is a critical metabolic disorder in high-yielding dairy animals, causing significant production and economic losses. Anionic Mineral Mixture (AMM) has been identified as a promising intervention to prevent milk fever and enhance milk yield, justifying the need to assess its adoption potential among dairy farmers. This study applied the Adoption and Diffusion Outcome Prediction Tool (ADOPT) to predict the uptake of AMM in Haryana, India. Data were collected from 300 dairy farmers and 10 subject-matter specialists on 22 variables related to adoption behavior. The model predicted a peak adoption rate of 98% in six years, with 50% adoption achieved within 2.7 years. The findings highlight the strong potential of AMM adoption, driven by awareness programs and farmer readiness, though sustainability may be influenced by cost and access once subsidies are withdrawn. Strengthening extension activities, ensuring affordable supply, and continuous capacity building are suggested as the way forward to accelerate adoption and maximize benefits.

**Keywords:** AMM, ADOPT, Diffusion, Dairy farmer, Milk fever, Milk yield

The dairy sector is a crucial part of agriculture in India which contributes significantly to the economy. It accounts for 4.5% of the nation's GDP and 24% of the agricultural sector with a value of approximately ₹10 lakh crore, (Press Information Bureau [PIB], Government of India). India leads the world in milk production supported by a livestock population of 535.78 million, a 4.6% increase over the last census (BAHS, 2019). As the population grows, the demand for milk and dairy products is expected to reach 276.28 million tons by 2028-29 (National Dairy Development Board, Report 2019). This will require rise in annual growth rate from 6.5 to 8.56%, raising per capita milk availability from 394 to 515 g/d by 2025 (Department of Animal Husbandry and Dairying, Annual report 2019-20).

However, dairy animals often face nutritional deficiencies leading to metabolic disorders. One such disorder is milk fever or hypocalcemia which occurs in high-yielding livestock due to insufficient calcium during parturition. The calcium requirement for dairy cows and buffaloes is ten times higher at calving compared to the dry period. A rapid calcium loss through colostrum post-

parturition can result in milk fever affecting productivity and economic performance. The disorder increases the risk of other conditions including mastitis, retained placenta, prolapsed uterus, displaced abomasum, reduced feed intake and impaired rumen function leading to significant economic losses. Incidences of milk fever range from 5% to 25% and in severe cases, can reach 80% causing substantial financial harm to farmers and the dairy industry (DeGaris & Lean, 2008; Reinhardt *et al.* 2011; Buragohain and Kalita, 2016).

To address this, the Indian Council of Agricultural Research-National Dairy Research Institute (ICAR-NDRI) developed Anionic Mineral Mixture (AMM) in 2018. The anionic mineral mixture (AMM) comprised 7,640 mEq of sulfur and 5,080 mEq of chloride as anionic sources, and 1,340 mEq of potassium as the primary cationic component, yielding a total negative dietary cation-anion difference (DCAD) of 11,380 mEq. Additionally, the formulation is supplemented with 10,000 IU/kg of vitamin E. AMM reduces milk fever in lactating cows and buffaloes, combats oxidative stress and enhances reproductive performance and disease resistance (Mani *et al.* 2018, Cariappa *et al.* 2022). Feeding AMM can increase milk yield by 13%, improve fat content and boost animal immunity. While its benefits for milk production are evident, it is necessary to understand farmer adoption rates for effective policy development (Mani *et al.* 2018).

Various frameworks measure adoption behavior but they often rely on qualitative data. To quantify farmer adoption of the Anionic Mineral Mixture, the Adoption and

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Diffusion Outcome Prediction Tool (ADOPT), a web based tool developed by CSIRO in 2017 (Kuehne et al., 2017) was employed offering insights into the future use of AMM in enhancing milk production in India.

MATERIALS AND METHODS

*Location of the study and sampling Plan:* The Farmer FIRST program, led by ICAR–National Dairy Research Institute (ICAR-NDRI) was implemented in seven purposively selected villages of Karnal district, Haryana, India, for an in-depth study. The funding agency of the study had already adopted these villages-Garhi Gujuran, Kamalpur Rodan, Churni Jangir, Nagla Rodan, Samora, Chand Samand, and Dabkoli Khurd for technology demonstration and research interventions. Karnal district was considered ideal for this experiment, as it is home to approximately 2.8 lakh high-yielding female bovines, comprising about 1.1 lakh exotic/crossbred cows and 1.8 lakh buffaloes (Government of Haryana, 2020). The study focused on progressive dairy farmers aiming for better returns. Notably, AMM had not been supplemented to animals in these villages prior to the study, and both project staff and farmers were unaware of the product. Data were collected from farmers owning animals considered at high risk of milk fever incidence, i.e., cows and buffaloes in their second or higher parity, producing more than 10 kg of peak daily milk yield and with at least one month remaining before parturition. These farmers relied on dairy farming for their livelihood and participated in the dairy business school program. They received AMM free of cost. Random sampling selected 300 farmers and data were collected from them. Information on technical performance and benefit potential was collected from 10 scientists from ICAR-NDRI involved in AMM development. The follow-up data was collected from those dairy farmers who fed AMM to their milking animals before 3-4 weeks of calving. A pre-tested interview schedule (supplementary file a) was used to collect data on the selected variables that most often have consistent, predictable and substantial effect on adoption for inclusion in the ADOPT model. Through using ADOPT model, farmer’s inclination in uptake of AMM has been predicted based on the framework depicted in figure 1 (Supplementary file b). The adoption behavior have been predicted with four quadrants: (1) Relative advantage for the population, (2) Learnability characteristics of the innovation, (3) Population-specific influences on the ability to learn about the practice and (4) Relative advantage of the technology were considered for adoption of an innovation. Data was collected on these aspects from the dairy farmers for the 22 primary variables using their current level of knowledge. Subsequently, *ex-ante* predictions were made using the ADOPT model.

The collected data was analyzed to determine the frequency and % of dairy farmers’ responses for every question within each quadrant. After calculating the responses for each statement, the responses with highest frequency were ticked and entered into the ADOPT

software to assess the farmers’ inclination toward adopting AMM. Data analysis techniques such as frequency counts, %, means and standard deviations were used to draw meaningful conclusions from the study.

RESULTS AND DISCUSSION

The diffusion and adoption of innovations are influenced by various factors including psychological, socio-economic and both internal and external elements (Alcon *et al.* 2014; Kassie *et al.* 2013). For instance, reaching the peak adoption level for technologies like the AMM can take over a year to manifest its full benefits in farmers’ fields. According to predictions as depicted in graph 1, the adoption rate of AMM could reach 98% after six years. This high adoption rate is attributed to AMM’s benefits including a 13% increase in milk production and a 10.2% rise in fat % along with improved dry matter intake and body condition score. These predictions should be interpreted cautiously as they are based on the ADOPT model’s numeric outputs. ADOPT also gives the predicted adoption levels for intended technology. It is evident from Table 1 that predicted adoption level of AMM in five and ten years from start is expected to be 91% and 98%, respectively. It takes about 2.7 years’ time to attain 50% of peak adoption (Kuehne et al, 2017; Dhehibi *et al.* 2018; Sendhil *et al.* 2022) in different technologies. This prediction was made when AMM was distributed free of cost to the dairy animals. Adoption of AMM might decrease when dairy farmers need to pay.

Graph 2 illustrates the predicted annual adoption rates for AMM as 6% in the first year, 27% in the second year, 57% in the third year, 79% in the fourth year, 91% in the fifth year and 98% in the sixth year after the first use of innovation in 2022. The adoption curve indicated that once the adoption rate reached 98 % the peak adoption level, it will begin to decline. According to Rogers (2003) the adoption process is categorized into five stages. Innovative dairy farmers are expected to adopt AMM within the first three years. Early adopters are likely to follow between three to five years. The early majority is projected to adopt the technology between five and eight years, while the late

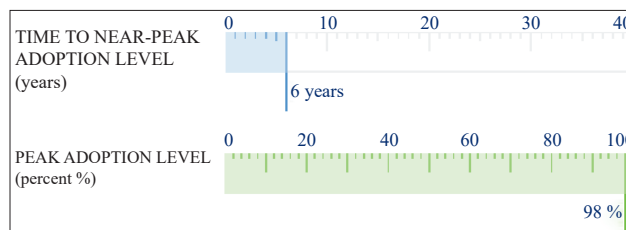


Fig.1 Predicted Adoption level of AMM

Table 1. Predicted adoption levels for AMM

S. No.	State	Five years since the inception (%)	Ten years since the inception (%)	Period to attain 50% of peak adoption (years)
1	Haryana	91	98	2.7

majority is supposed do so between eight and ten years. Finally, the laggards might adopt AMM after ten years. The anticipated adoption level of AMM is 98%. The high rate of adoption may be attributed to AMM's significant benefits including a 70% and 60 % reduction in incidence of milk fever in cows and buffaloes, respectively (Cariappa et al., 2022). Additionally, AMM has led to a reduction in variable costs by ₹2,271 for cows and ₹937 for buffaloes along with an increase in milk yield of 12% in buffaloes and 14% in cows (Cariappa et al. 2022).

*Changing peak adoption level of AMM:* Fig. 1 illustrates the probable factors influencing changes in peak adoption levels. The ADOPT model suggests that altering key

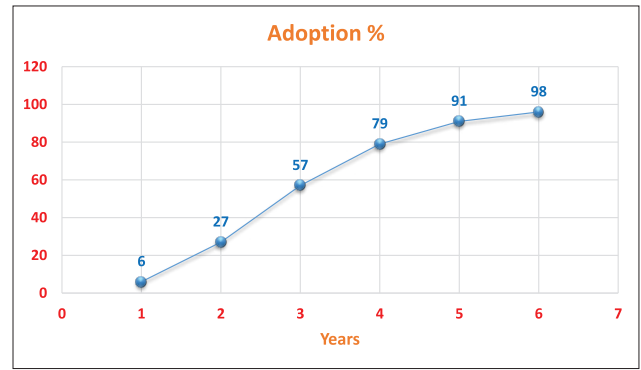


Fig. 2 Adoption level s-curve and yearly adoption of AMM

**CHANGING THE ADOPTION LEVELS**

Many of the factors can be changed by activities such as extension. Based on the data entered, the ADOPT model suggests that changing the following factors would have the biggest effect on adoption.

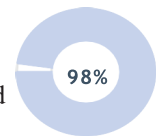
*Changing the peak adoption level*

**MOST SENSITIVE QUESTION**

4 Enterprise scale  
 What proportion of the target households depend highly for their livelihood on the enterprise(s) that could benefit from the innovation?

**YOU'RE RESPONSE**

Enterprise scale  
 A majority of the target households depend highly on the enterprise(s)



**STEP UP RESPONSE**

Almost all of the target households depend highly on the enterprise(s)



**STEP DOWN RESPONSE**

About half currently have a severe short-term financial constraint



**CHANGING THE TIME TO PEAK ADOPTION LEVEL**

**MOST SENSITIVE QUESTION**

6 Short term constraints  
 What proportion of the target households are under conditions of severe short-term constraints?

**YOU'RE RESPONSE**

A majority of the target households depend highly on the enterprise(s)



**STEP UP RESPONSE**

A minority currently have a severe short-term financial constraint



**STEP DOWN RESPONSE**

A majority currently have a severe short-term financial constraint

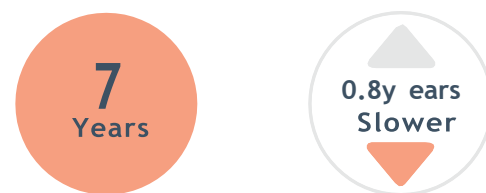


Fig.3 Factors affecting the peak adoption level Sensitivity analysis for AMM to change Time to peak adoption

indicator variables can significantly impact the adoption and diffusion rates based on the data provided. Interventions at the field level such as enhancing extension and outreach activities can boost adoption rates by demonstrating the benefits of adopting AMM. Both formal and informal dissemination of information are crucial in shaping adoption rates. Figure 1 reveals that peak adoption levels can fluctuate based on responses from dairy farmers and experts. For an increase in peak adoption, the most sensitive factor was the enterprise scale, specifically the proportion of target households dependent on the enterprise. In this study, if dairy farmers and experts indicated that “a majority” of households depend highly on the enterprise, the predicted adoption level was 98%. If they had agreed that “almost all” households depend highly, the adoption level would remain at 98%. However, if they had responded that “about half” of the households depend highly, the adoption level would drop to 97%.

*Changing the time to peak adoption level of AMM:* Fig.1 illustrates how the predicted time to peak adoption level can

fluctuate based on dairy farmers’ and experts’ responses. When the adoption level is projected to step up, the most sensitive factor was the existing skills and knowledge among farmers. Specifically, if a significant proportion of the target households face severe short-term financial constraints, the predicted time to peak adoption level is 6.2 years. However, if only a minority of target households faced such constraints, this time would decrease by 0.7 years, reaching 5.4 years. Conversely, if a majority of them were facing severe constraints, the time would increase by 0.8 years to 7 years.

Extension activities including mass campaigns, group discussions and mass media can help in adjusting these perceptions. By increasing awareness and providing essential knowledge and skills, these activities can enhance adoption when innovation is successful (step up). On the other hand, they can also mitigate over-adoption when experts suggest that a technology is no longer beneficial (step down) (Kuehne et al, 2017; Dhehibi et al., 2018; Sendhil et al. 2022).

SENSITIVITY ANALYSIS

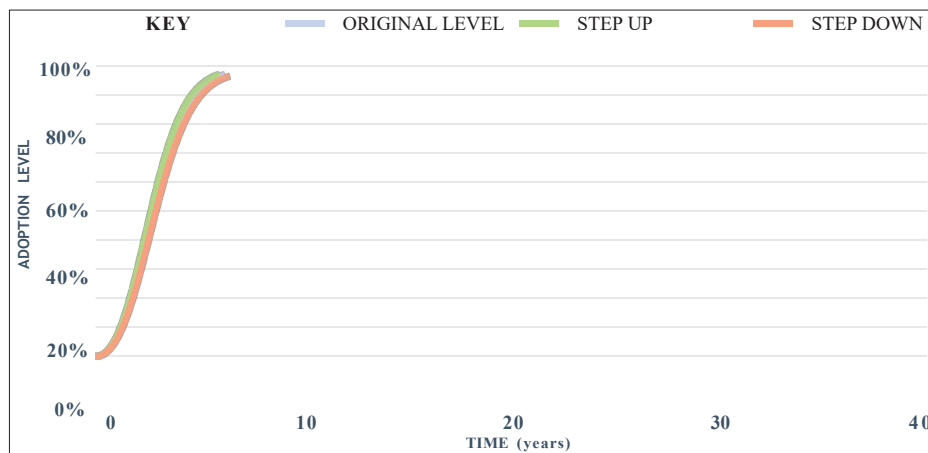
The following charts show the effects on Peak Adoption Level and Time to Peak Adoption of single step changes up and down for all questions.



Fig. 4 Sensitivity analysis for adoption of AMM

### S-CURVE SENSITIVITY

The following chart shows how the S-Curve is predicted to change when a single step change is made to the most sensitive question(s) with respect to Peak Adoption Level



The following chart shows how the S-Curve is predicted to change when a single step change is made to the most sensitive question(s) with respect to Time to Near Peak Adoption.

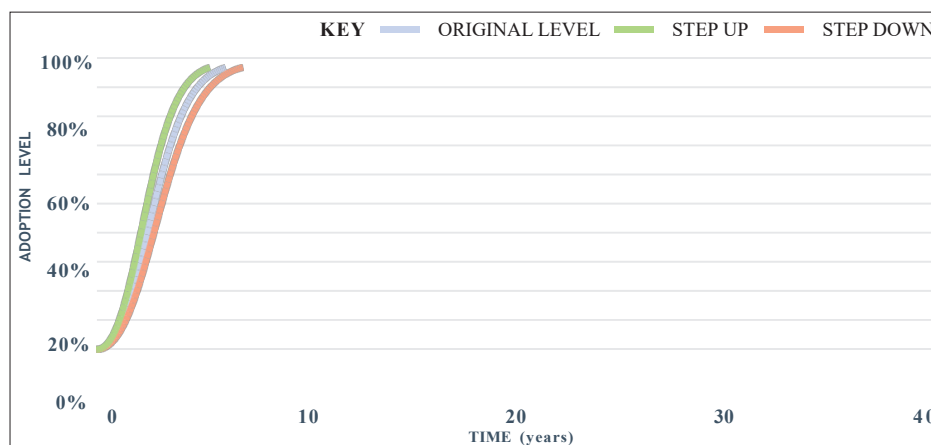


Fig.5 S-curve sensitivity analysis for the adoption of AMM

*Sensitivity analysis to change time to peak adoption of AMM:* Sensitivity analysis (SA) is a vital tool across various disciplines such as economics, engineering, basic and environmental sciences for evaluating the robustness of models and understanding how uncertainties or variations in input parameters affect model outputs. In this study, sensitivity analysis was performed using the ADOPT model software to explore potential changes and errors and their implications for the model's conclusions. The results of the sensitivity analysis (Figure 2) offer valuable insights into how variations or uncertainties in input parameters would influence both the magnitude and timing of adoption outcomes. By analyzing the model's sensitivity to different factors, researchers can pinpoint the variables with the most significant impact on adoption patterns allowing them to prioritize these variables for further investigation or intervention. Figure 2 shows that to step up and step down the time to peak adoption level of AMM, the most sensitive questions were 5, 6, 7, 12. Along with these, question 1, 2, 3,

14, 15, 16, 17, 19, 21 and 22 also contributed to increase or decrease the time to peak adoption level of AMM.

*S-Curve Sensitivity for Peak Adoption Level:* In addition to performing sensitivity analysis, ADOPT also generated S-curve sensitivity figures that showed how incremental changes to the most influential factors such as peak adoption level and time to near peak adoption could affect the S-curve. Similar to the previous sensitivity analysis, this exploration of the S-curve (Figure 3) underscores regional disparities. Several variables, particularly those related to the understanding of the innovation, contributed to differences in adoption and diffusion across regions. The relative advantage of the technology, in terms of economic benefits and productivity gains, strongly influenced farmer decisions. Equally important were the complexity and learnability of the practice, as innovations that were easier to understand and apply were adopted more rapidly. Compatibility with existing farming systems and local practices also played a vital role, since technologies that

integrated smoothly into current management were more readily accepted. Trialability, or the ability to test the practice on a small scale before full adoption, further supported uptake, while the observability of results allowed farmers to see tangible benefits and encourages peer-to-peer diffusion. Beyond these innovation-specific attributes, socio-economic conditions such as herd size, income, and education level significantly shaped adoption behavior. Access to information, extension services, and demonstrations enhanced awareness and learning, while the availability and affordability of inputs such as AMM influenced long-term sustainability. Farmers' risk perceptions and cultural or psychological factors, including tradition, trust in institutions, and influence of progressive farmers, also determined how quickly and widely an innovation is adopted. Together, these variables explained regional disparities in adoption patterns and highlighted the need for targeted extension strategies. Analyzing the S-curve sensitivity at the peak level of innovation adoption provided important insights into why AMM, despite its proven benefits, might face variability in uptake among dairy farmers in Haryana. The sensitivity analysis in this study revealed that factors such as farmers' existing knowledge, short-term financial constraints, and enterprise dependence played a decisive role in determining the speed and extent of adoption. Households with better access to resources and skills showed faster adoption, while those under financial stress required more time to adopt the technology. By addressing these constraints through targeted extension services, awareness programs, and ensuring the affordable availability of AMM, adoption rates can be accelerated. This, in turn, would not only reduce the incidence of milk fever but also improve milk productivity and profitability, thereby directly contributing to the livelihoods of dairy farmers in the region.

The study highlights that milk fever continues to be a major challenge for high-yielding dairy animals, causing substantial economic losses to farmers in Haryana. Adoption of AMM was found to have strong potential in reducing the incidence of milk fever while simultaneously enhancing milk yield and profitability. The prediction results indicated that AMM adoption could reach 91% within five years and stabilize at around 98% in six years, with half of the adoption achieved in less than three years. These findings clearly demonstrate the readiness of farmers to adopt technologies that deliver visible economic and health benefits to their herds. However, adoption is not uniform across all households and is influenced by socio-economic factors, resource availability, and farmers' awareness levels. Therefore, strengthening extension activities, improving farmer training, ensuring continuous availability of AMM at affordable prices, and creating incentive mechanisms will be essential to sustain adoption. By addressing these practical challenges, AMM can emerge as a widely accepted intervention to control milk fever and improve dairy farmers' livelihoods in Haryana and other parts of country.

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