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An Economical and Farmer-Friendly Seed Invigoration Protocol for Improving Longevity and Productivity of Short-Lived Medicinal Plant Andrographis Paniculata

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Abstract:

Andrographis paniculata Nees, commonly known as Kalmegh, is an important medicinal plant belonging to the family Acanthaceae. It is widely cultivated for its medicinal properties, particularly due to the presence of andrographolide, an important bioactive diterpenoid compound. However, inconsistent seed germination, variation in seed maturity, loss of seed vigour during storage and poor field establishment can create difficulties for commercial cultivation.The present study proposes an economical, simple and farmer-friendly seed invigoration protocol to improve seed germination, physiological quality, storage longevity, seedling vigour and subsequent crop productivity of A. paniculata. The proposed investigation will evaluate selected low-cost treatments, including hydropriming, controlled drying, potassium nitrate priming and selected seed-storage conditions. Untreated seeds will serve as the control.

The experiment will assess germination percentage, mean germination time, seedling length, seedling dry weight, seedling vigour indices, field emergence, plant growth, biomass production and andrographolide content. Seed viability and vigour will also be monitored during storage at predetermined intervals. The proposed protocol aims to identify an affordable and reproducible treatment that can be adopted by small and marginal farmers without requiring sophisticated laboratory facilities.

Keywords: Andrographis Aaniculata, Kalmegh, Seed invigoration, Seed priming, Seed longevity, Seed viability, Seedling vigour, Sustainable Agriculture.

Introduction:

Medicinal plants play an important role in traditional healthcare systems, pharmaceutical industries and the development of herbal medicines. Among these plants, Andrographis paniculata Knees is considered an important medicinal species because of its therapeutic and pharmacological potential.

The plant is commonly known as Kalmegh or King of Bitters. It is widely distributed in tropical and subtropical regions, particularly in India and Southeast Asian countries.The major bioactive constituent of this plant is andrographolide, which has attracted considerable scientific interest because of its biological and pharmacological activities.

Despite its medicinal and economic importance, successful cultivation of Kalmegh is sometimes restricted by problems associated with seed germination, seed quality, seed maturity and storage conditions.Seed

quality is one of the most important factors determining successful crop establishment. Seeds with low physiological vigour may show delayed germination, uneven emergence and poor seedling development.

Seed invigoration is a pre-sowing technique that involves controlled hydration or other suitable treatments to initiate early metabolic activities without allowing radicle emergence. It can improve germination uniformity and seedling establishment when appropriately optimized.Previous research has demonstrated that polyethylene glycol osmopriming can improve the germination performance of A. paniculata. Abdullahi et al. (2021) reported a maximum germination percentage of 71.5% with PEG-8000 at −0.8 MPa under their experimental conditions.

Similarly, Shruti et al. (2024) investigated hydropriming, halopriming and osmopriming under different salinity conditions and reported beneficial effects of priming, particularly with potassium nitrate. Saraswathy et al. also reported that hot-water treatment at 50°C for five minutes increased germination from 62% to 84% in their experimental material.

These studies indicate that seed treatment can be useful for improving germination. However, a practical protocol integrating seed invigoration,post-treatment drying, storage longevity, field establishment, crop productivity and economic feasibility requires further systematic evaluation.Therefore, the present investigation is designed to develop a simple, economical and farmer-friendly approach for improving the physiological quality and productivity of Kalmegh.

3. Review of Literature:

3.1 Seed germination and quality

Seed germination is a complex physiological process involving water absorption, enzyme activation, respiration and mobilization of stored food reserves. The physiological condition of seeds determines the speed and uniformity of germination.

In A. paniculata, seed maturity is particularly important. Solikin and Nurfadilah (2017) investigated seed maturity and storage duration and found substantial differences in germination between immature and mature seeds. Their study reported 98.50% germination in mature seeds stored for twelve months under the investigated conditions. This finding suggests that seed longevity should not be generalized without considering seed maturity, initial quality and storage conditions.

3.2 Seed priming and invigoration

Seed priming is a controlled hydration technique that permits pre-germinative metabolic activities while preventing visible radical emergence.

The major methods include:

- Hydropriming using water.
- Halopriming using inorganic salt solutions.
- Osmopriming using osmotic agents.
- Hormopriming using plant growth regulators.

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- Biopriming using beneficial microorganisms.

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Abdullah et al. (2021) demonstrated the potential of osmopriming in improving germination and seedling growth of A. paniculata.

3.3 Seed maturity and storage longevity

Seed storage behaviour depends on initial seed quality, moisture content, temperature, relative humidity and packaging materials.

The study by Solikin and Nurfadilah (2017) highlights the importance of physiological maturity and storage duration in maintaining Kalmegh seed germination.

Consequently, the present study will examine whether appropriate invigoration.

3.4 Seed storage and deterioration

Storage conditions strongly influence seed viability and longevity. Excessive moisture and unsuitable temperatures can accelerate deterioration.

Seed maturity, initial seed quality, packaging materials and storage environments should therefore be considered while developing an effective seed-management protocol. procedures can maintain seed quality during subsequent storage.

Objectives of the Study:

The major objectives are:

1. To evaluate the effects of economical seed invigoration treatments on germination of Andrographis paniculata.

2. To determine the effects of seed treatments on seed viability and physiological vigour.

3. To investigate the influence of invigoration treatments on seed storage longevity.

4. To assess seedling growth and field emergence.

5. To evaluate the effects of treated seeds on plant growth and biomass productivity.

6. To estimate the andrographolide content of plants raised from treated seeds.

7. To identify an affordable and farmer-friendly seed invigoration protocol.

8. To calculate the economic feasibility of the proposed treatment.

Hypotheses:

H_{01}: Seed invigoration treatments have no significant effect on seed germination.

H_{02}: Seed invigoration treatments have no significant effect on seed longevity and physiological vigour during storage.

H_{03}: Seed invigoration treatments have no significant effect on field emergence and plant productivity.

H_{04}: Seed invigoration treatments have no significant effect on andrographolide content.

Materials and Methods:

6.1 Experimental material

Healthy and mature seeds of Andrographis paniculata will be collected from a reliable source or authenticated seed-production plot. The seeds will be cleaned manually to remove immature, damaged and diseased seeds.

The initial seed quality will be determined through standard germination, moisture content and seed vigour tests. The botanical identity of the plant will be authenticated by a qualified botanist or relevant institutional authority.

6.2 Experimental design

The laboratory experiment will be conducted using a Completely Randomized Design (CRD) with three or four replications.

A subsequent field experiment will use a Randomized Block Design (RBD), preferably with three replications.

6.3 Seed storage experiment

To evaluate seed longevity, treated and untreated seeds will be stored under different controlled storage conditions.

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Suggested storage intervals:

- Initial assessment.
- 3 months.
- 6 months.
- 9 months.
- 12 months.

At each interval, germination percentage, mean germination time and seedling vigour will be recorded.

Packaging materials such as moisture-proof containers and conventional storage bags may be compared.

The storage experiment should distinguish between the effects of initial priming and the effects of storage itself. Primed seeds should not automatically be assumed to have longer storage life than untreated seeds.

6.4 Field experiment

A field experiment will be established to evaluate the practical effects of seed invigoration treatments on crop establishment and productivity.

Healthy seedlings obtained from the laboratory germination experiment will be transplanted into prepared field plots. The experiment may follow a Randomized Complete Block Design (RCBD), with three or four replications.

The following growth parameters will be recorded:

- Plant height (cm).
- Number of branches per plant.
- Number of leaves per plant.
- Root length (cm).
- Fresh biomass (g).
- Dry biomass (g).
- Flowering time.
- Seed production per plant.

6.5 Seed invigoration procedure

The following procedure is proposed:

- Select healthy and mature seeds.
- Remove dust and foreign materials.
- Divide the seeds into experimental treatment groups.
- Soak seeds in the respective treatment solutions for predetermined durations.
- Maintain suitable temperature and controlled hydration.
- Remove the seeds after treatment.

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- Wash seeds where necessary, particularly after chemical treatments.
- Surface-dry the seeds.
- Redry primed seeds to their original moisture content if the intended treatment requires dry storage.

Treatment Description:

- T_0 Untreated control
- T_1 Hydropriming with distilled water
- T_2 Hydropriming with clean drinking water
- T_3 Potassium nitrate (KNO_3), 1% solution
- T_4 Potassium nitrate (KNO_3), 2% solution
- T_5 PEG-8000 osmopriming at an optimized water potential
- T_6 Hot-water treatment at 50°C for 5 minutes

The proposed treatment concentrations and durations will first be tested in a pilot experiment. The treatments will be optimized for seed lot, moisture status and germination response before the main experiment. Farmer-friendly priority: Hydropriming and appropriately optimized KNO_3 treatment will receive particular attention because of their potential practical applicability. Hot-water treatment will be tested separately because excessive temperature or exposure can damage seeds.

Development of an Economical and Farmer-Friendly Protocol:

The main practical outcome of the proposed research will be the development of a simple seed invigoration protocol that can be implemented by farmers.

The following operational sequence is proposed:

1. **Proposed seed management protocol**
   Select mature, healthy and physically sound seeds.

2. **Seed cleaning**

   Remove immature seeds, dust and foreign materials.

3. **Seed invigoration**

   Apply the selected optimized hydro priming or osmopriming treatment.

4. **Drying**

   Re dry treated seeds appropriately before storage, if required.

5. **Storage**

   Store seeds in suitable moisture-resistant packaging under validated conditions.

6. **Nursery sowing**

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Sow seeds in properly prepared nursery beds or seedling trays.

7. **Field transplantation**

Transplant healthy seedlings at the recommended growth stage.

8. **Productivity assessment**

Monitor plant growth, biomass and medicinal compound production.

The final soaking concentration, duration, drying level and storage conditions must be established experimentally before this protocol is recommended to farmers.

Novelty and Research Significance:

The principal research contribution is the integration of seed invigoration, storage evaluation and field productivity into a single experimental framework for a paniculata.The proposed study differs from a conventional seed priming experiment because it will investigate multiple stages of the seed-to-crop production process.

Its potential scientific contributions include:

- Identification of economical seed invigoration treatments.
- Evaluation of seed physiological quality during storage.
- Development of a practical seed management procedure.
- Assessment of the relationship between seed vigour and field establishment.
- Evaluation of biomass and andrographolide productivity.
- Development of a farmer-oriented cultivation technology.

Conclusion:

The proposed investigation focuses on developing an economical and farmer-friendly seed invigoration protocol for improving the seed quality, storage longevity and productivity of Andrographis paniculata.Although earlier studies have demonstrated the positive effects of different seed priming methods on Kalmegh germination, an integrated approach combining seed invigoration, post-treatment drying, storage assessment, field performance and medicinal quality remains an important area for further research.

The proposed work will provide an opportunity to identify affordable seed treatment practices that may improve crop establishment, reduce seed wastage and support sustainable cultivation of this economically important medicinal plant. The successful development of such a protocol could benefit small and marginal farmers, medicinal plant growers, seed producers and researchers working in medicinal plant agronomy. Seed priming represents a promising approach for improving germination performance and early seedling development. However, successful implementation requires careful optimization of treatment concentration, hydration duration, drying conditions and storage environment.The integration of laboratory germination studies, storage experiments and field evaluation will provide a comprehensive understanding of the relationship between seed physiological quality and crop productivity. The ultimate objective is to identify a

practical, affordable and scientifically validated seed-management technology that can be adopted by medicinal plant growers, nursery operators and small-scale farmers.The proposed research may contribute to the sustainable cultivation and commercial production of A. paniculata and strengthen the scientific foundation for medicinal plant seed management.

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