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(REVIEW ARTICLE)

Effect of abiotic factors and nutrition elements on pollen germination and pollen viability

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Abstract

Pollen viability and germination are essential components of the flowering plant reproduction. Numerous physiological, metabolic, and environmental elements interact in a complicated way to affect these processes. The germination and viability of pollen grains are greatly impacted by environmental factors such as temperature, humidity, light, and air pollution. Modest humidity and ideal temperature encourage healthy germination, whereas high temperature or extended exposure to harsh environments frequently results in decreased viability. Pollen tube growth and fertilization effectiveness is physiologically influenced by the age and genetic composition of pollen grains, as well as the general health of the plant. For example, fresher, younger pollen grains usually have higher germination and viability rates than damaged or older grains. Biochemically, successful fertilization depends on the pollen's essential nutrients, carbohydrates, and proteins as well as the activation of enzymes needed for pollen tube formation. Furthermore, the way that stigma and pollen interact- for example, through compatibility factors and surface receptors on the stigma- can either promote or prevent pollen germination. It has been demonstrated that abiotic stressors like drought lower pollen's capacity to germinate, which affects plant reproduction and agricultural output. This review highlights the significance of pollen viability and germination processes for plant reproductive success by summarizing the current understanding of these aspects.

Keywords: Abiotic Factors; Nutrients Elements; pH; Pesticides; Temperature

1. Introduction

The non-living elements of the environment are referred to as abiotic factors. These chemical and physical factors impact living things. Abiotic elements are non-biological and inorganic. They have an impact on living things and the ecology. We separated the records into groups for independent analysis to examine the impact of abiotic factors on male function and how these impacts changed based on the component that was altered. Aboveground and belowground factors were the two subcategories into which we separated the abiotic manipulations for the first set of analyses. Research that directly altered water or nutrients, such as nitrogen, phosphorus, and salts, was included in below-ground records, whereas aboveground records included research that directly altered light (UV), temperature, or carbon dioxide (CO2). (Schaeffer *et al.*, 2013.). One crucial indicator of resistance to abiotic stressors is pollen viability. These abiotic stressors cause significant production losses by interfering with plants' normal growth and development (Razzaq *et al.*, 2019.).

A significant secretion of membrane and cell wall components at the tip of pollen tubes facilitates their rapid development. Among these, pectins such as the homogalacturonan (HG) motif are deposited in a highly methyl-esterified form and are dimethyl esterified in the sub-apical region by pectin methylesterases (PMEs). This interaction

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with calcium of the negative charges of galacturonic acids allows the cell wall to stiffen. The investigation of pollen-specific PME mutants in Arabidopsis brought attention to the significance of PMEs (Laggoun *et al*., 2021.). In the stylar canal, carbohydrates enhance pollen germination and pollen tube growth by acting as an osmotic regulator and a primary energy source substrate (Sharma *et al*., 2022.). The pollen tube wall shows a secondary callose wall and a distinctive main wall i.e primarily made of cellulose, hemicellulose and pectin (Barral et al., 2005).

In the tropics, watermelon production is fraught with diseases including downy mildew, powdery mildew, anthracnose, gummy stem blight, and numerous pests like whiteflies, aphids, and others. Moreover, rainy seasons are ideal for disease incidence, which encourages farmers to use a wide variety of pesticides, fungicides, and combinations. In sub-Saharan Africa, the application of pesticides always begins when disease signs appear on the leaves of watermelon plants and continues until the fruit is harvested. However, pollen viability and germination are severely inhibited by a large number of commercial pesticide formulations (Tonfack *et al*., 2019.). Incorporating soil facilitates transfer to nectar and the absorption of systemic insecticides. Foliar spraying encourages the transfer of pollen and the uptake of non-systemic insecticides (Li., 2022.).

The process of creating pollen tubes from pollen grains in a controlled environment and nutrient-rich media outside of a plant is known as “in vitro pollen germination”. The anatomy of pollen is simpler than that of other highly specialized plant organs and tissues. The pollen grain, which is essential to the breeding program and helps ensure a healthy fruit set, is what moves the male gamete to the female portion of a flower. Viable pollen grains are typically necessary for high crop yields. The viability and fertility of pollen are crucial to the hybridization process. Numerous pollens have been successfully grown on comparatively simple substrates in a lab setting (Patel and Mankad., 2014.). Tube initiation and pollen germination were observed within the first half hour of incubation on the media. Whenever pollen germination started, a single pollen tube emerged from the pollen grain (Burke *et al*., 2004). In vitro, pollen germination is a dependable technique for assessing pollen viability. To artificially germinate pollen, a wide range of pollen germination media have been developed, ranging from basic sugars to complicated ones that contain vitamins, growth regulators, and other minerals (Jayprakash., 2018.).

2. Review literature

2.1 Effects of abiotic factors on pollen germination

Many previous studies had shown the biotic and abiotic factors play major role in sexual reproduction of plant. Pollen germination is crucial part of this process. Herein table 1 listed major impact of abiotic factors on pollen germination.

Table 1 List of Abiotic factors and their impact on pollen germination

Sr no.	Abiotic factors	Plant species	Effect	Reference
1.	UV-B radiation	*Glycine max* (L.) Merr.	Reductions in lengths of flower, petal, and staminal column along with reduced pollen production, germination and tube growth were observed in all genotypes with increasing UV-B radiation	Koti *et al*., 2004.
		Salix matsudana f. tortosa (Vilm.) Rehd	Increase germination rates under the highest UV-B dose.	Feng *et al*., 2000.
		Juglans regia L.	High pollen tube growth.	
		Capsella bursa-pastoris (L.) Medic	Low pollen germination & pollen tube growth.	
		Philadelphus incanus Koehne	Low pollen germination under exposure to UV-B light.	
		Chaenomeles speciosa (Sweet.) Nakai	Low pollen tube growth.	
		Kerria japonica (L.) DC	Increase in germination percentage under elevated UV-B.	
		Pyrus bretschneideri Rehd.	Low rate of pollen germination & pollen tube growth.	
		Wisteria sinensis (Sims.) Sweet.	Low rate of pollen germination & pollen tube growth.	
		Forsythia giraldiana Lingelsh.	Low rate of pollen germination.	
		Forsythia suspensa (Thunb.) Vahl	High inhibitory effect on germination.	
		Fraxinus chinensis Roxb.	Low rate of pollen tube growth.	
		Syringa pinnatifolia Hemsl.	Low rate of pollen germination.	
		Lonicera maackii (Rupr.) Maxim.	UV-B inhibited germination & pollen tube growth.	
		Carex heterostachya Bge.	Inhibitory effect on germination.	

		Brassica rapa L.	Reduced pollen viability.	Demchik & Day, 1996.
		Paulownia tomentosa (Thunb.) Steud.	Low rate of pollen germination & pollen tube growth.	He *et al*., 2006.
		Zea mays L.	Pollen germination rate & tube length decreased as time of exposure increased of UV-B radiation.	Singh *et al*., 2014.
2.	Temperature	*Lycopersicon esculntum* L.	Significant reduction in the pollen viability	Sato *et al*., 2002.
		Glycine max (L.) Merr.	Produced smaller flowers with shorter standard petal and staminal column lengths. Flowers produced had less pollen with poor germination and shorter tube lengths.	Thuzar, 2010.
		Arachis hypogea L.	Genotypes were discriminated against based on pollen viability & pollen tube growth.	Kakani *et al*., 2002.
		Sorghum bicolor L.	Pollen viability & seed setting were significantly reduced. Pollen viability ranged from 17-63%.	Nguyen *et al*., 2012.
		Helianthus annuus L.	Pollen sterility was used to discriminate heat tolerant & susceptible genotypes.	Kalyar *et al*., 2013.
		Oryza sativa L.	The decrease in pollen viability & germination, pollen per anther, and tube length.	Das *et al*., 2014.
		Triticum aestivum L.	Floral fertility was also decreased by pollen abnormalities.	Prasad and Djanaguiraman, 2014.
		Pistacia atlantica Desf.	Maximum germination at 20°C.	Acar & Kakani, 2010.
		Malus sylvestris (L.) Mill.	Maximum germination (46%) at 15°C.	Wickham, 2016.
		Prunus avium L.	Maximum germination at 20°C.	Houghton, 2024.
		Prunus persica (L.) Batsch.	High temperature accelerated both pollen germination in vitro & pollen tube growth in the style.	Herrero & Arbeloa, 1989.
		Gossypium hirsutum L.	Higher pollen germination percentage & longer pollen tubes under optimum conditions & with optimum temperature above 32°C for pollen germination would indicate tolerance to high temp.	Farooq *et al*., 2015.

		Pisum sativum L.	In vitro, pollen germination decreased significantly from 81.6 % to 30.8% after incubation.	Petkova *et al*., 2009.
		Olea europaea L.	Extreme temperature for a short period reduces pollen germination.	Koubouris *et al*., 2009.
		Chenopodium quinoa Willd.	Pollen viability was significantly reduced in both genotypes as a consequence of the high-temperature treatment.	Bhargava *et al*., 2006.
		Phoenix dactylifera L.	Different treatments with temperature were effective on pollen germination & tube elongation of date palm. The best results for both were observed between 15°C & 30°C.	Dehghan *et al*., 2010.
		Capsicum annum L.	A high percentage of pollen germination was observed at the optimum temperature (30.8°C).	Aloni *et al*., 2001.
		Cocos nucifera L.	At warmer sites, the temperature optima for pollen germination & pollen tube growth were higher compared to cooler sites.	Ranasinghe *et al*., 2018.
		Juglans regia L.	Pollen germination rates increased significantly with increasing temperature.	Mert, 2009.
		Anacardium occidentale L.	The high reducing sugars mainly glucose & fructose in pollen of early varieties may be correlated to high pollen germination in response to temperature.	Mong *et al*., 2023.
3.	Carbon dioxide	*Lilium longiflorum* Thunb.	The germination of lily pollen in hanging drop culture increased rapidly when the CO2 concentration was increased from from 0.03% (in air) to 1.3%, with very little further effect at concentrations up to 5%.	Diciraso, 1965.
		Glycine max L.	High germination rate.	Musil *et al*., 1999.
		Capsicum annuum L.	Pollen viability & germination are known to be sensitive to CO2.	Abdul-Baki & Stommel, 1995.
		Arachis hypogea L.	Pollen germination decreased from about 90% at anthesis to 75 %.	Prasad *et al*., 2003.
		Sorghum bicolor (L.) Moench.	Low-rate pollen germination.	Lansac *et al*., 1994.
		Acer negundo L.	A decrease in the pollen fructose content with increasing CO2 concentration.	Silva *et al*., 2015.
		Phaseolus vulgaris L.	Decreased pollen production & pollen viability.	Prasad *et al*., 2002.

		Vicia faba L.	Increases in carbon dioxide were associated with an increase in pollination	Ainsworth *et al.*, 2020.
		Ambrosia artemisiifolia L.	Increased production of allergenic pollen.	Bazzaz, 1990.
		Brassica campestris Linn.	The CO2 effect must occur after pollen germination, modifying the interaction between pollen tubes & stigma cells.	O'Neill *et al.*, 1988.
4.	Humidity	*Olea europaea* L.	Drastic loss of pollen viability was found under high temperatures and humidity conditions.	Ozdemir, 2016.
		Nicotiana tabacum L.	The prolonged exposure of pollen to high humidity at both room temperature & 38 °C did not affect membrane integrity.	Shivanna & Cresti, 1989.
		Oryza sativa L.	Increased spikelet sterility was due to increased pollen grain sterility which reduced the deposition of viable pollen grains on stigma.	Cho, 1956.
		Zea mays L.	Relative humidity tends to reduce the negative effects of high temperature on the seed set, probably to pollen viability.	Alam *et al.*, 2017.
		Carya illinoensis (Wangenh.) K.Koch.	Maximum germination percentage occurred as relative humidity increased & temperature decreased.	Adams & Rinne., 1980.
5.	Light	*Peltophorum pterocarpum* (DC.) Baker ex.	The highest rate of pollen germination and tube growth was observed in normal light as compared to other light conditions. The rate of pollen germination was fast up to 40 min., but as the period proceeded it slowed down.	Singh, 1976.
		Cyrtanthus mackenii Hook.f.	Pollen tubes elongated less in the direction toward light under LED & elongated with up directional trend in darkness.	Hoyo *et al.*, 2014.
6.	pH	*Ambrosia artemisiifolia* L.	The germination rate of *Ambrosia artemisiifolia* was higher at pH5 to pH7 than at lower or higher pH values. These results are by those of those who found the optimum pH of germination between pH5 and pH8.	Sang *et al.*, 2011.
		Pistacia palsestina Boiss.	It was found that pollen germination & pollen tube growth were greatly reduced when grown in the pH 3.0 medium.	Acar *et al.*, 2010.
		Lilium formosanum (Baker)Wallace.	Optimum germination is supported by a rather wide range of Ph.	Bordenave., 1996.
		Crotolaria retusa L.	In unbuffered media, satisfactory pollen germination & tube growth occurred over a wide range of pH values of 4.0-9.0.	Sharma & Shivanna., 1983.
7.	Water availability	*Cicer arietinum* L.	Pollen viability was reduced by 50%, and pollen germination decreased by 89% in vitro. Pollen germination decreased by 80%in vivo.	Fang *et al.*, 2010.

		Lytharus sativus L.	Pollen viability, germination, and number of pollen tubes reaching the ovary reduced by 13%, 25%, & 31%.	Gusmao *et al*., 2012.
		Zea mays L.	Strong association between pollen availability & grains per cob.	Hall *et al*., 1982.
		Oryza sativa L.	Pollen viability & seed setting had a strong association under stress.	Nguyen *et al*., 2009.
		Sorghum bicolor L.	Pollen fertility was reduced by drought & germplasm was discriminated over drought.	Sakhi *et al*., 2014.
		Clivia miniata (Lindl.) Verschaff.	Pollen sizes of plants grown in drought & flooded conditions were a little larger than those of the control group.	Barnabas *et al*., 2008.
		Triticum aestivum L.	A large proportion of the anthers on water-stressed plants was small & shriveled and did not dehisce normally.	Saini & Aspinall., 1981.
8.	Oxygen level and ROS	*Picea pungens* Engelm.	Endogenous ROS play a crucial role during the early stages of pollen germination in gymnosperms while the sensitivity to exogenous H2O2 is acquired. Later during the growth process.	Potocky *et al*., 2007.
		Nicotiana tabacum L.	Sensitivity to exogenous H2O2 is acquired Later during the growth process.	Gemes *et al*., 2017.
		Lycopersicon esculentum L.	Inhibition of pollen tube growth	Muhlemann *et al*., 2018.
		Actinidia deliciosa (A.Chev.) C.F.Liang & A.R.Ferguson	Endogenous ROS were detected immediately following pollen rehydration & during the lag phase preceding pollen tube emergence.	Speranza *et al*., 2011.
		Zea mays L.	The increased ROS production & impaired antioxidant ability resulted in lipid peroxidation & may be responsible for inhibition effect on pollen germination.	Wang *et al*., 2009.
9.	Nutrients availability	*Juniperus communis* L.	The effect of nutrient availability on the quantity and quality of pollen grains produced.	Verheyen *et al*., 2009.
10.	Calcium ion	*Lilium longiflorum* Thumb.	It impacts on growth direction and alteration of its focal point leads to reorientation of the growth axis toward the site of the higher Ca2+ concentration.	Brewbaker & Kwack., 1963.
		Acacia auriculiformis A.Cunn. ex Benth.	The higher of Ca2+ concentration, the lower the pollen germination percentage.	Kwack., 1963.
		Acacia mangium Willd.	The pollen germination percentage and pollen tube length increased with the rise of Ca2+ concentration.	Zhan & Huang., 2016.
		Acacia crassicarpa A.Cunn. ex Benth.	Pollen germination percentage and pollen tube length increased with the rise of Ca2+ concentration.	

		Zea mays L.	The addition of calcium nitrate decreased the germination percentage and pollen tube length.	
		Lilium formosanum Wallace.	Germination rate is optimal when Ca2+ is in the range of 0.1±1.0 mM, and it falls off only moderately either below 0.1 mM or above 1.0 mM. However, even the extremes of 0.01 mM and 10 mM support better than 50% germination.	Holdaway-Clarke *et al*., 2003.
		Juglans regia L.	Pollen germination was significantly improved on the media containing 50 ppm calcium chloride than on those containing 100 ppm or no addition of calcium chloride. The significantly lowest average pollen germination was obtained on the media without calcium chloride.	Jankovic *et al*., 2014.
		Agapanthus umbellatus (L.) Hoffmans.	Weak EFs also elevated [Ca2+]c, reduced growth rates and resulted in the reorientation of pollen tubes towards the cathode.	Malho *et al*., 1994.
		Arabidopsis thaliana (L.) Heynh.	In the pollen grain, [Ca2+] cyt increased at the potential germination site soon after hydration and remained augmented until germination.	Iwano *et al*., 2004.
		Nicotiana tabacum L.	Germination relatively higher amounts of Ca2+ and CaM were found to regionalize towards the aperture through which the pollen tube would emerge Both short and long-growing pollen tubes manifest tip-to-base Ca2+ and CaM gradients which are disturbed in non-growing tubes.	Tirlapur *et al*., 1992.

2.2 Effect of carbohydrate on pollen germination

The proper growth and development of plants depends on their cell walls, which are made up of protein, carbohydrates and aromatic chemicals. About 90% of the primary wall is composed of carbohydrates, which are essential to wall function (Caffall and Mohnen., 2009). The main way that photoassimilates are transported in higher plants is by sucrose, which creates the interface between heterotrophic sink tissue and photosynthetically active source tissue. Here, it provides building blocks for storage metabolism and acts as an energy source for growth. The manufacture of sucrose involves seven enzymatic stages and stars with triose-P during the light period (Bornke and Sonnewald, 2011.).

For plants to reproduce malely, sugar metabolism is crucial. Genetic male sterility (GMS) is frequently caused by abnormalities in sugar metabolism during anther and pollen formation. For the purpose of promoting callose wall and primexine formation, intine development, pollen maturation and starch accumulation, pollen germination and tube growth, and other processes, sugars are primarily produced in the resource organs and transported into the sink organs (Liu *et al*., 2021).

Table 2 Effects of different sugar on pollen germination

Carbohydrates	**Plant Species**	**Effects**	**References**
Sugars (2-deoxyglucose, 3-O-methylglucose, 6-deoxyglucose, cellobiose, fructose, galactose, D-glucose, L-glucose, mannitol, mannose, sorbitol, L-sorbose, lactose, lactulose, leucrose, maltitol, maltose, mannoheptulose, melezitose, melibiose, raffinose, stachyose, sucralose, sucrose, trehalose and turanose)	*Arabidopsis thaliana* (L.) Heynh	Highest percentage of pollen germination (55.4%) was observed in stachyose.	Hirsche *et al*., 2017.
Homogalacturonan (HG) & pectin methylesterases (PMEs)	*Solanum lycopersicum* L.	Germination was observed in any treatments after 16h of growth at 4°C.	Laggoun *et al*., 2021.
Fructose	*Pyrus pyrifolia* Nakai	Inhibitory effect of fructose was dose-dependent. Sucrose enhanced pollen tube growth much more effectively than glucose. Addition of 5% fructose to 5% or 10% sucrose or glucose media suppressed germination completely.	Okusaka *et al*., 2009
Invertases and hexose	*Nicotiana tabacum* L.	Tobacco Pollen Germination and Tube Growth Are Inhibited by the Chemical Invertase Inhibitor Miglitol.	Goetz *et al*., 2017.
Raffinose & Cellobiose	*Setaria sphacelata* (Schumach.) Stapf & C.E.Hubb ex M.B.Moss	Good germination and growth were obtained with raffinose and cellobiose, alone or in combination with sucrose	Bruyn, 1966.
Sucrose level	*Spathiphyllum floribundum* (Linden & Andre) N. E. Br & *Vriesea malzinei* (E.Morren) Baker	*S. floribundum*, cv. Mauna Loa, pollen germinated well in a medium containing 5-10% sucrose, whereas *V. malzinei*, pollen germinated in a medium containing 5-30% sucrose.	Henney, 1977.
Sucrose + starch	*Capsicum annuum* L. cv. Mazurka	In pollen from HT plants, sucrose and starch concentrations were	Aloni *et al*., 2001.

		significantly higher at A−1 pollen than in that of NT plants.	
Glucose + phosphoglucose isomerase + fructose + sucrose	*Gossypium hirsutum* L.	The lower stored starch content in drought-stressed pistils, at the beginning of pollen tube germination (12:00 h), was one of the main reasons for the decreased pollen tube growth rates	Hu *et al*., 2021.
Sucrose + boric acid	*Psidium guajava* L.	various concentrations of sucrose solution viz. 10%, 15%, 20% and 25% were used for pollen germination and it was found that the maximum percentage of pollen grain germinated at 10% sucrose solution for most of the cultivars.	Sarkar *et al*., 2018.

2.3 Effect of pesticides on pollen germination

Pesticides can come from a variety of sources. The majority comes from artificial random synthesis, and scientists must conduct numerous tests to demonstrate the effectiveness of their products (Saladin and Clement, 2005.). The term “pesticide” refers to a broad category of chemicals, such as insecticides, fungicides, herbicides, plant growth regulators, etc., whose purpose is to control pest. The first recorded intentional use of it in antiquity dates back to 2500 BC, when Sumerians rubbed their bodies with foul-smelling sulfur compounds as pesticides to control insects, ticks, and mites. It has been used since farmers began using technical approaches for sustainable agricultural practices (Shahid *et al*., 2021.).

Pesticides are extremely harmful chemicals. Their toxicity can negatively impact several processes in the non-target host plants, even if it may not be entirely specific to the target organisms. The impact of excessive usage of four widely used pesticides- emamectin benzoate, alpha -cypermethrin, lambda-cyhalothrin, and imidacloprid on germination, seedling vigor, and photosynthetic pigments was assessed in this study. The result showed that the pesticides reduced seed germination, with this effect being particularly noticeable in the early stage of exposure (Shakir *et al*., 2016.).

Table 3 Effects of pesticides and insecticide on pollen germination

Pesticides	**Plant species**	**Effects**	**References**
Insecticide – Profex super (Profenofos 40% + Cypermethrin 4% EC)	*Lycopersicon esculentum* Mill.	Germination decreased as the dosage increased as compared to control.	Meshram & Chaturvedi., 2017.
Group 1(chemical fungicides) + Group 2 (organic fungicides) + Group 3 (biological insecticides)	*Rubus glaucus* Benth.	The highest % pollen germination in blackberry was observed against the treatment of biological pesticides & control; group.	Pallida *et al*., 2017.
	Solanum betaceum Cav.	Chemical pesticides inhibit tree tomato pollen grain germination.	
Fungicides (sumi eight + cupravit + karatane + topsin m + vitavax thiram + beam + benlate + tecto)	*Prunus persica* (L.) Batsch.	The best pollen germination rates were obtained in basic or control related to all fungicides.	kargar and Imani., 2011.

Imidacloprid + 15% Sucrose solution + Mancozeb + Azadirachtin + Agroplus (tulsi)	*Abelmoschus esculentus* L.	Germination occurred faster in 10% and 15% of sucrose solutions when compared to 5%, 20% and 25% of solutions.	Etna, 2022.
Fungicides (sumi eight + cupravit + karatane + topsin m + vitavax thiram + beam + benlate + tecto)	*Prunus dulcis* (Miller) D.A.Webb.	All fungicides reduced the percentage of pollen germination, length of germ-tube elongation and morphological features of almond pollen.	Zarrabi & Imani, 2011.
Insecticides- methomyl (ME) and imidacloprid (IM)	*Pisum sativum* L.	In the control group, after 1 h, 80.33% of the seeds germinated, which increased to 87% and 95% at 48 and 72 h, respectively.	Siddiqui *et al.*, 2022.
Insecticides: diazinon, dicofol, endosulfan, malathion, and Pyrenone (6% pyrethrins and 60% piperonyl butoxide); 2 fungicides: captan and Manzate (zinc and manganese ethylene bisdithiocarbamate)	*Cucumis sativus* L.	Reduced germination of cucumber pollen on an artificial medium.	Gentile *et al.*, 1978.
Insecticides- Phosphamidon (0.1%), endrin (0.02%), fenitrothion (0.1%), formothion (0.025%), malathion (0.05%), endosulfan (0.05%), chlorfenvinphos (0.025%) and quinalphos (0.05%) inhibited germination. Parathion (0.025%), methyl-demeton (0.025%) and dimethoate (0.03%)	*Solanum melongena* L.	Little effect on germination but significantly reduced tube length.	Raghunath *et al.*, 1973.
Fungicide- Propiconazole	*Tradescantia virginiana* L.	Propiconazole inhibited pollen germination, cytoplasmic streaming, and tube elongation.	Yi He *et al.*, 1995.
Glyphosate- based herbicides (GBH)	*Rosa acicularis* Lindl.	Pollen grains treated with GBH were significantly smaller than controls.	Golt & Wood., 2021
Herbicides – biotype WLR1 & biotype WLR96	*Lolium rigidum* Gaudin.	Pollen produced by resistant biotype grew uninhibited when challenged with herbicide, whereas that form a susceptible biotype was inhibited	Richter & Powles., 1993.

When pollen is administered to a flower or ovule's stigma in a controlled environment, a process known as "in vitro pollination" takes place outside of the plant in a laboratory (Bhojwani and Razdan, 1996).

They both sucrose and boric acid had positive effects when used separately, but when combined, they enhanced pollen germination and tube development because boron forms a complex with sugar that is known to have superior translocation capabilities over non-borate, non-ionized sugar molecules (Patel and Mankad, 2012). The grass pollen is discharged at a high moisture level (30-40%), whereas conventional plants release it at a moisture concentration of 1-5%. It has been noted that monocots need less salt in the pollen germination media than dicots. Additionally, wild species need fewer mediums than domesticated ones (Jayprakash, 2018).

3. Conclusion

Plant reproduction and agricultural productivity depends heavily on pollen viability and germination, which are impacted by a number of abiotic and nutritional variables. Pollen performance can be greatly impacted by environmental stressors such as temperature extreme, humidity fluctuations, UV-B radiation, which can result in decreased fertility and crop yield. In addition, pollen tube development and total reproductive performance are significantly influenced by soil minerals, especially calcium and carbohydrates.

Concerns regarding the detrimental impact of chemical pollutants and pesticides on pollen viability have been raised by their growing use. According to numerous studies, these compounds can decrease pollen tube elongation, interfere with enzymatic processes and prevent germination. In the meanwhile, methods for pollen germination in vitro have been useful for evaluating pollen health and enhancing breeding initiative.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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