ACCELERATED AGING EFFECTS ON SEED VIGOUR AND PLANT PERFORMANCES IN MUNGBEAN (*Vigna radiata* L.)

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ABSTRACT

Research on accelerated aging effects on seed vigour and plant performances in mungbean (*Vigna radiata* L.) was undertaken at Universiti Malaysia Sabah, Sandakan Campus. The research was divided into four studies: Study I: Evaluation of Initial Mungbean Seed Quality, Study II: Effect of Accelerated Aging on Mungbean Seed Quality, Study III: Effect of Seed Vigour on Mungbean Growth and Yield Traits, and Study IV: Relationship Between Quality Traits and Field Performance in Mungbean Seeds of Different Vigour. The initial standard germination and seedling vigour index of those seeds were recorded as 95 % and 19.68, respectively. This indicated that those seeds were highly viable and vigorous. The seeds were then subjected to accelerated aging treatments in order to obtain seedlots of varying vigour levels. They were exposed to high temperatures (41, 43 and 45°C), high relative humidity (≈95%) for 48 and 96 hours. The aging treatments were found to have significantly deleterious effects on mungbean seed quality. The extent of deterioration corresponded linearly with temperature and duration of aging. The higher the temperature and the longer the aging duration, the more severe was the damage. The resultant seedlots ranged in germination percentage from 95 % (for non-aged seeds) to 59.5 % (for those aged at 45°C for 96 hours) and their corresponding vigour indices dropped from 19.68 to 5.73. The different vigour seedlots obtained were evaluated for quality attributes in the laboratory as well as in the field. Quality traits evaluated in the laboratory included seed moisture content, seed leachate conductivity, germination percentage, germination index, seedling vigour index, length, fresh weight and dry weight of radicle and plumule. Laboratory evaluations revealed that all the seed quality attributes corresponded directly with their respective vigour levels, with the differences being significant. Tetrazolium test was rather hard to distinctly separate the variations in germination potential among the seedlots. Field evaluations included days to first emergence, field emergence percentage, plant height, days to first flowering, number of fruit clusters per plant, single pod length and weight, number of seeds per pod, 100-seed weight and seed yield per plant. Data revealed that all the yield components were significantly influenced by seed vigour, except days to first emergence, plant height and days to first flowering. Plants derived from the highest vigour seeds produced a seed yield of 35.37 g per plant while the lowest vigour seeds only produced 7.83 g of seed yield per plant. These findings proved that there was a relationship between quality traits and mungbean plant performances. Correlation of seed vigour and field performance become more remarkable as the differences in seed quality increase. Both laboratory and field experiments demonstrated that high vigour seeds outperformed low vigour seeds in almost all traits evaluated. Therefore, it is concluded that planting high vigour seeds can help to ensure success in crop establishment and productivity.

Keywords: accelerated aging, seed quality, seed vigour, *Vigna radiata*.

ABSTRAK

KESAN RAWATAN PENUAAN SECARA CEPAT TERHADAP KECERGASAN BIJI BENIH DAN PRESTASI PERTUMBUHAN BAGI KACANG HIJAU (Vigna radiata L.)

Kajian mengenai kesan penuaan secara cepat terhadap kecergasan dan prestasi pertumbuhan bagi kacang hijau (Vigna radiata L.) telah dijalankan di Universiti Malaysia Sabah, kampus Sandakan. Penyelidikan ini dibahagi kepada empat kajian: Kajian I: Penilaian kualiti awal biji benih kacang hijau, Kajian II: Kesan penuaan buatan ke atas kualiti biji benih, Kajian III: Kesan kecergasan biji benih terhadap tumbesaran dan hasil kacang hijau, dan Kajian IV: Hubung kait di antara sifat kualiti dan prestasi lapangan di antara biji benih kacang hijau yang berbeza kecergasannya. Peratusan percambahan dan indek kecergasan benih tersebut adalah 95% dan 19.68. Ini menunjukkan bahawa biji benih yang digunakan adalah berkualiti tinggi. Biji benih tersebut kemudian didedahkan kepada rawatan penuaan secara cepat untuk mendapatkan benih yang berbeza tahap kecergasannya. Biji benih didedahkan kepada tiga suhu tinggi (41, 43 dan 45°C), kelembapan yang tinggi (≈95%) untuk jangka masa 48 dan 96 jam. Rawatan penuaan ini didapati mempunyai kesan ketara terhadap kemerosotan kualiti benih. Tahap kemerosotan biji benih adalah secara linear dengan suhu dan tempoh penuaan. Kemerosotan tersebut semakin serius apabila suhu dan tempoh penuaan semakin tinggi dan lama. Peratusan percambahan bagi dtujuh lot benih yang terhasil adalah di antara 95.0% (bagi biji benih tanpa rawatan) hingga 59.5% (bagi biji benih yang telah dirawat 45°C/96 jam) dan indeks kecergasan merosot dari 19.68 ke 5.73. Lot benih yang mempunyai tahap kecergasan yang berbeza telah dinilai di dalam makmal serta di ladang. Parameter yang dinilai dalam makmal termasuk kandungan kelembapan biji benih; kekonduksian larut lepasan benih; peratusan percambahan; indeks percambahan; indeks kecergasan benih; panjang, berat basah dan berat kering bagi radikel dan plumul. Hasil penilaian menunjukkan terdapat interaksi yang signifikan antara tahap kecergasan benih dan semua parameter yang dinilai di dalam makmal. Penilaian tetrazolium kurang sensitif dalam menentukan perbezaan lot benih berdasarkan kecergasan biji benih. Parameter yang dinilai di ladang termasuk masa untuk mencapai percambahan yang pertama; peratusan percambahan benih di ladang; ketinggian tumbuhan; masa untuk pengeluaran bunga yang pertama; bilangan kelompok lenggai pada setiap pokok; panjang dan berat lenggai tunggal; bilangan biji benih dalam satu lenggai; berat basah bagi seratus biji benih dan hasil benih bagi setiap pokok. Hasil penilaian menunjukkan bahawa semua parameter telah dipengaruhi oleh kecergasan biji benih secara signifikan, kecuali masa untuk mencapai percambahan yang pertama, ketinggian tumbuhan dan masa untuk pengeluaran bunga yang pertama. Pokok kacang hijau yang berasal daripada benih yang bertahap kecergasan tinggi mampu menghasilkan benih yang lebih banyak (35.37 g sepokok) berbanding bertahap rendah (7.83g sepokok). Hasil kajian menunjukkan bahawa terdapat hubung kait yang nyata antara kecergasan biji benih dan prestasi tanaman kacang hijau. Hasil kajian ini membuktikan bahawa biji benih yang bertahap kecergasan tinggi mempunyai prestasi yang lebih bagus berbanding yang bertahap kecergasan rendah dalam kebanyakan sifat-sifat yang dinilai. Oleh yang demikian, dapat disimpulkan bahawa penanaman biji benih yang cergas dapat membantu untuk memastikan kejayaan dalam penanaman dan produktiviti.

Kata kunci: penuaan secara cepat, kualiti biji benih, kecergasan biji benih, Vigna radiata.

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&	And
°C	Celsius
%	Per Cent
cm	Centimetre
g	Gram
h	Hour
kg	Kilogram
m	Meter

LIST OF ABBREVIATIONS

AA	Accelerated Aging
ANOVA	Analysis of Variance
AOSA	Association of Official Seed Analyst
AVRDC	Asian Vegetable Research and Development Centre
AVGRIS	AVRDC Vegetable Genetic Resources Information System
Co. Ltd.	Limited Liability Company
CRD	Completely Randomized Design
DMRT	Duncan's Multiple Range Test
EC	Electrical Conductivity
et al.	And others
FAO	Food and Agriculture Organization
FE	Field Emergence
FSA	Faulty of Sustainable Agriculture
GI	Germination Index
GP	Germination Percentage
ISTA	International Seed Testing Association
L.	Linnaeus
MC	Moisture Content
SAS	Statistical Analysis System
SVI	Seedling Vigour Index
TZ	Tetrazolium
UK	United Kingdom
UMS	Universiti Malaysia Sabah
USA	United States of America
USDA	United States Department of Agriculture
WorldVeg	World Vegetables Centre

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CHAPTER 1

INTRODUCTION

1.1 Study Background

Mungbean (*Vigna radiata* (L.) R. Wilczek) is one of the most important pulse crops grown in South and Southeast Asia (Nair *et al.*, 2013). India, China and Thailand are responsible for about 90% of world's mungbean production (Lambrides & Godwin, 2007). Mungbean is a short annual cash crop, harvestable 75 to 90 days after sowing. It is commonly cultivated in various crop rotation systems to increase soil fertility and provide additional income to farmers. It provides essential nutrients in human and animal diets as the grains are rich in protein and micronutrients (Afzal *et al.*, 2008). Besides that, it helps the symbiotic association with *Rhizobium* species to fix the atmospheric nitrogen (Somta *et al.*, 2007). Mungbean is also used as an excellent green manure crop to improve the soil physical conditions (Algan & Celen, 2011).

Seed quality is an important agronomic, essential for a sustainable and profitable crop production. Seed quality can be determined through a series of measurable traits such as viability, purity, physical conditions, health, and also a complex traits of seed vigour (ISTA, 2015). A good seed is generally characterised by high viability and vigour levels, free from diseases and resistant to multiple growth-limiting stresses (AOSA, 2002). High quality seed could ensure the uniform crop establishment within a short period, with sufficient crop stand developed, under a wide range of field conditions. This could directly contribute to the enhancement of resource input and yield productivity. Characterization of seed quality enables the selection of robust seeds as regenerative materials in seed

production to protect the quality of genetic materials. Besides that, it also enhances the seed technology knowledge by providing a better consideration for selection of high quality seeds.

Seed vigour is a sum of seed properties which determine the potential for rapid, uniform emergence and development of normal seedlings under a wide range of field conditions (AOSA, 1983). It was rather hard to precisely define seed vigour. Instead of a single measurable trait, this concept was associated with different aspects of seed performances, including rate and uniformity of seed germination and seedling growth; emergence ability of seeds under unfavourable environmental conditions; and performance after storage, particularly the retention of the ability to germinate (ISTA, 2015). Seed vigour can be influenced by several factors such as genetic make-up, environment during seed development, subsequent harvesting and handling, and seed storage environment (Copeland & McDonald, 2001). Heterogeneity characteristics in seeds allow them to perform differently even though they shared common genotype.

All seeds undergo deterioration. Even within a short period, seed quality can decrease and eventually the seeds die (Delouche & Baskin, 1973). However, seed death does not occur instantly. Seeds progressively gain germination ability on their mother plants during seed development (Bewley *et al.*, 2013). Seed vigour gradually increases and reaches the maximum at physiological maturity stage (Savage & Bassel, 2016). Beyond that, seeds start to age and the process of aging occurs progressively. Seed aging manifests a series of unfavourable physiological, biochemical, molecular, and metabolic changes in seed cells, such as cellular membrane degradation, lipid peroxidation and DNA degradation (Kurek *et al.*, 2019). Seed aging gradually limits seed vigour, causes the loss of viability and ultimately seed death. The rate and extent of seed aging and deterioration mainly depend on the initial vigour of the particular seed lot (Bewley *et al.*, 2013).

Crop cultivation in the field exposed sown seeds to complex seedbed stresses such as soil temperature, soil strength, water availability and oxygen stress (Savage & Bassel, 2016). The situation was worsened by the unavoidable ongoing climate change in the sub-optimal field environment. Variation in seed vigour is

believed to be negatively affecting the crop field performance. Low vigour seeds may not be able to withstand these growth-limiting factors and restrict seedling emergence. Insufficient crop stand within a unit area could directly contribute to the less uniform crop establishment, which limit the potential of bountiful harvest. The resource inputs cannot be compensated by the lack of seedlings and thus increase the input cost. Reduced stand can reduce the amount of harvestable and marketable yield, thus limiting the profit gain.

Seed vigour is an influential quality component in agricultural practices. It provides the complementary information of planting value and storage potential for a wide range of crops (Delouche & Baskin, 1973). Since then, many seed vigour tests had been developed to assess the seed quality and predict their crop performance under suboptimal field conditions. The *accelerated aging* test is presently recognized as one of the most widely adopted vigour tests (Delouche & Baskin, 1973; Savage & Bassel, 2016). Exposure of seeds to adverse environmental conditions of high temperature and relative humidity within a certain period was believed to be able to reveal the seed vigour status and predict their crop performance under the suboptimal field conditions (Delouche & Baskin, 1973; Woltz & TeKrony, 2001; Basra *et al.*, 2003; Farhadi *et al.*, 2012; Gordin *et al.*, 2015; Deuner *et al.*, 2018). An efficient vigour test could satisfy the need for a quick and precise decision making in seed programs, reduce the risks and losses, and hence improve the profitability.

1.2 Problem Statement

Seed is an important input in agriculture. It is rather common for most farmers to keep harvested seeds for months or even years before selling or sowing them. Rapid seed deterioration during storage is one of the most critical dilemmas faced by the farming community and the seed industry. Ongoing climate change and suboptimal seedbed conditions worsen the situation by exerting more growth-limiting stresses during the seed development. The impact of this phenomena is seen in the lack of supply of high vigour seeds for agricultural activities and seed production.

Traditionally, seed quality is measured by standard germination test which usually is conducted under ideal growth conditions for a particular crop. However, the field conditions are not always optimized. Hence, the suboptimal environment defeats the ability of germination test as it often overestimates the crop performance in the field. Thus, seed vigour tests had been proposed to determine the potential of a seed lot to achieve rapid uniform emergence and development of normal seedlings under a wide range of field conditions (AOSA, 1983).

An efficient vigour test should be able to differentiate a particular seed lot into distinct vigour levels, in order to evaluate their effects on seed quality, thus enabling prediction of crop emergence performance. Many studies had demonstrated the reliability of the accelerated aging test as a seed vigour test to predict the field emergence. This correlation was emphasized in most of the seed vigour definitions (Kumar *et al.*, 1989; Egli & TeKrony, 1996; Torres & Julio, 2003; Lovato *et al.*, 2005; Noli *et al.*, 2008; Gordin *et al.*, 2015; Deuner *et al.*, 2018; Jitender *et al.*, 2018). However, there is still lack of information reported on the effects of accelerated aging on seed vigour and plant performances in mungbean.

1.3 Objectives of Study

The present investigation comprising four research experiments and their respective objectives were as follows:

Study I	:	Evaluation of initial mungbean seed quality
Objective I	:	To benchmark the quality standard of initial seed lot received from the supplier.
Study II	:	Effect of accelerated aging on mungbean seed quality
Objective II	:	To evaluate the effect of accelerated aging on mungbean seeds.
Study III	:	Effect of seed vigour on mungbean growth and yield
Objective III	:	To evaluate the effect of seed vigour on mungbean growth

and yield performance.

Study IV : Relationship between quality traits and field performance of mungbean seeds of different vigour

Objective IV : To determine the relationship between quality traits and field performance of mungbean seeds of different vigour.

CHAPTER 2

LITERATURE REVIEW

2.1 Mungbean Story

Mungbean, *Vigna radiata* (L.) Wilczek belongs to the Fabaceae family. It is widely grown as a short duration cash crop between two principal crops. It serves as an important crop in various intercropping and crop rotation systems (Rahman *et al.*, 2012; Singh & Kaur, 2012). Mungbean is an economically important legume crop in the subtropical zones of the world. It has been widely cultivated in India since 3500 years ago, evidenced by a series of genetic diversity data and archaeological documentation (Fuller, 2007). This cultivation then spread rapidly to Thailand, China, Myanmar and several South and Southeast Asia regions. Now India is currently the world's largest mungbean producer contributing more than 50% of the global production of 6 million tons annually (Nair *et al.*, 2013). Recently, the National Crop Gene Bank of China reported that they hold more than 5000 mungbean accessions (Liu *et al.*, 2006). Even more recently, Pataczek *et al.* (2018) reported that more than 7000 accessions had been documented by the World Vegetable Centre (WorldVeg) in Taiwan.

Mungbean is highly nutritive. It is composed of 55 to 65 % carbohydrates, 20 to 25 % protein and a high content of micronutrients (Afzal *et al.*, 2008). The carbohydrates in mungbean are easily digestible by human hence it reduces the flatulence as compared to other legumes (Nair *et al.*, 2013). Besides, it is a significant source of dietary protein (240 g/kg) as it contains great amount of essential amino acids likes arginine, isoleucine, leucine, methionine, phenylalanine,